Networking Concepts

CME 451

Fundamental Layers

- Communication networks consist of network elements connected by communications paths.
- Organized into:
  - Transmission facilities
  - Protocol engines
  - Switching & queuing components

Transmission Media

- Physical media used to transmit information.
- Four main options:
  1. Copper wire
  2. Coaxial cable
  3. Optical fiber
  4. Wireless communication (e.g., air).

Copper Wire

- One of the earliest used.
- Known as unshielded twisted pair (UTP)
  - Category 5 (Cat-5) in networking applications (with 100 Ω characteristic impedance at 100 MHz)
- Absence of shielding: high-frequency leaks
- Load coils: high-frequency blocking (LP filter)
- Problems:
  - Low bandwidth (for voice communications)
  - Signal attenuation (a few km transmission only)
- DSL (digital subscriber loop) technology.

Coaxial Cable

- Insulator (dielectric) and conductive shield
- Transmission of high frequencies possible
  - Cable TV in N. America: 20 TV channels (each 6MHz bandwidth) on a single coaxial cable.
- Suitable for high-speed data transfer
- Not available universally
- Not suitable for long distances.
- High-speed cable modem technology
  - Broadcast video & high-speed Internet access on same cable.
  - Hybridization of coaxial cable and optical fibers.

Optical Fiber

- Transmission medium of choice
- Suitable for long-haul and last-mile networks
- Terahertz frequencies allowing terabytes per second (TB/s) of bandwidth.
- Low signal attenuation (transmission over km's without losing strength)
- Optical signal processing robust against noise.

Wireless Communication

- Signal transmission in air
  - Microwave, low-Earth-orbit satellites, cellular, wireless LANs
- Flexible infrastructure, no need for cables.
- Significant mobility and ubiquitous access.
- Problems:
  - Low resources available: bandwidth and power.
  - Harsh propagation environments (wireless fading channel, interferences, mobile user activities).

Network Classes

- Due to historical developments, a variety of network topologies and protocols are in use.
- Based on geographical span and functionality, networks classified as:
  - Access networks
  - Local area networks (LANs)
  - Storage area networks (SANs)
  - Metropolitan area networks (MANs)
  - Wide area networks (WANs).

Network Classes

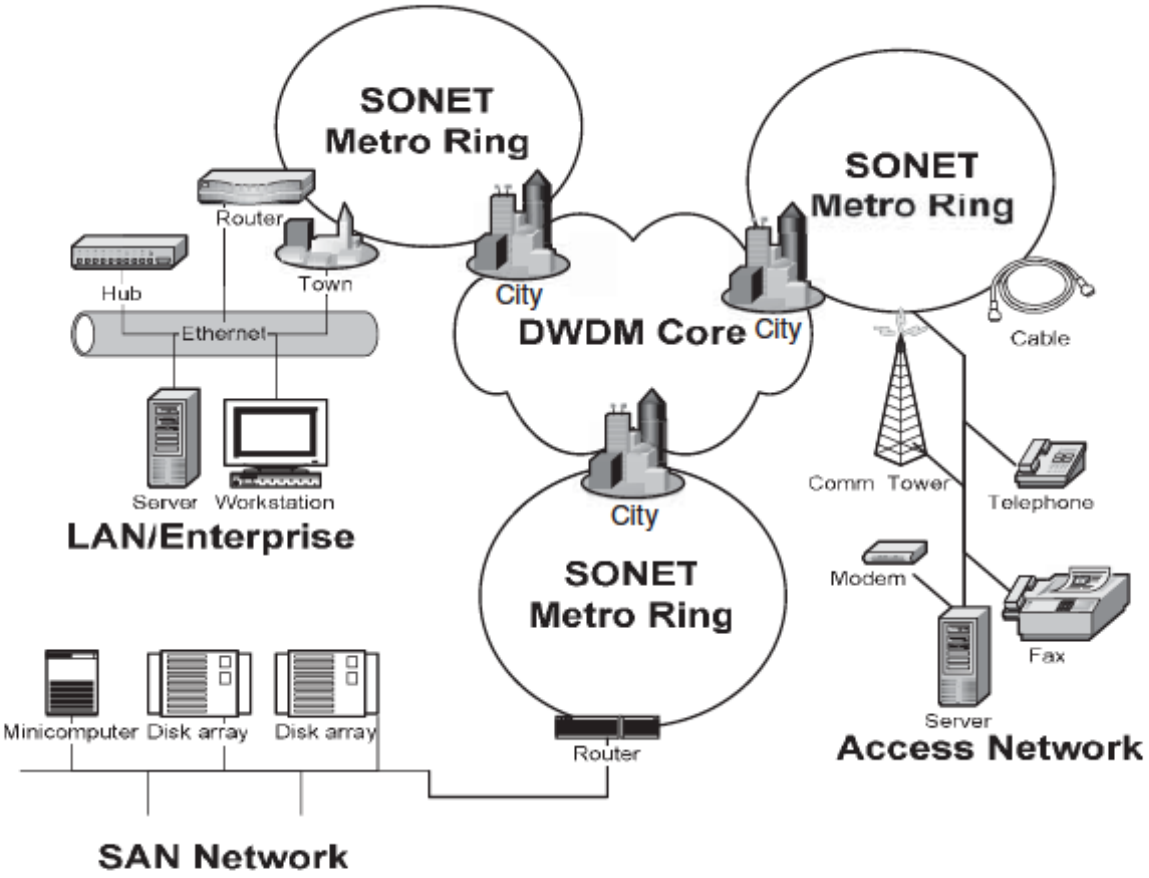

FIGURE 1.1 Broadband network elements consisting of a network core, synchronous optical network (SONET) rings, a local area network, storage, and access networks.

Network Classes

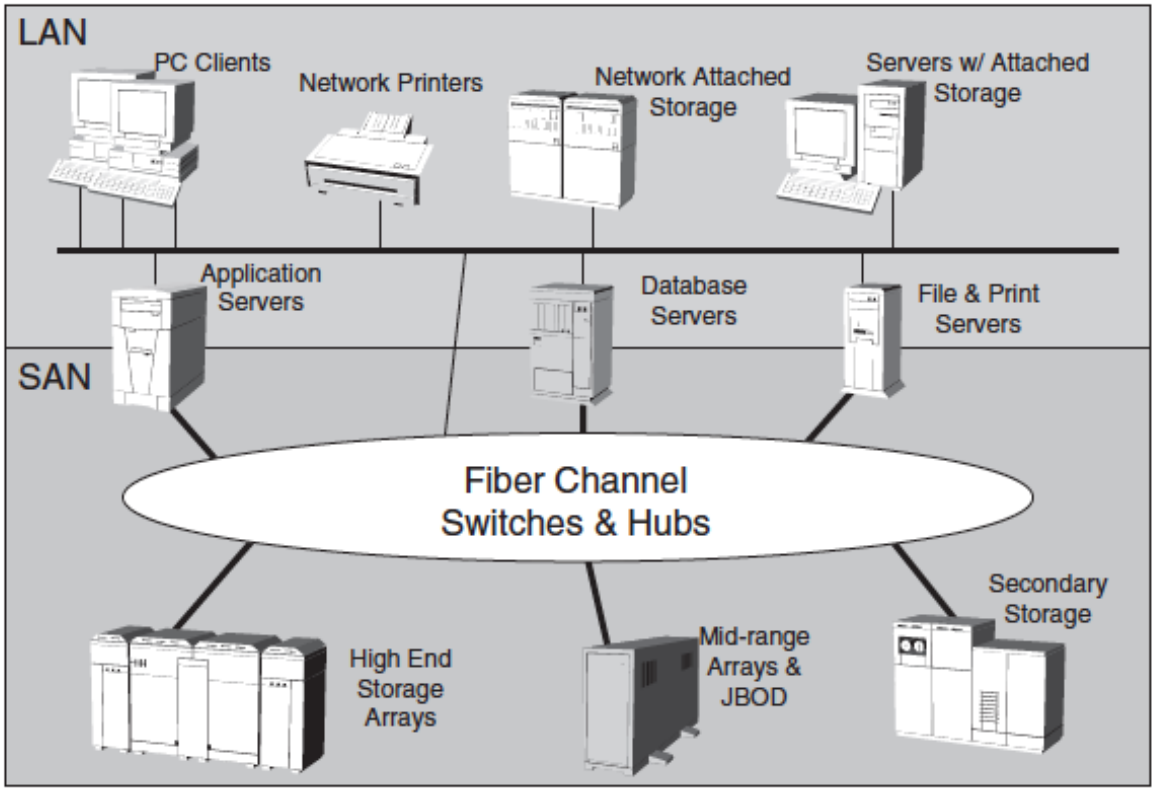

FIGURE 1.2 LAN and SAN networks.

Network Topologies

- Main topologies:
  - Point-to-point
  - Hub
  - Ring
  - Mesh.
- Other related or intermediate forms also exist:
  - Star, bus (similar to hub)
  - Tree (combination of hub & point-to-point)
  - Partially meshed
  - etc.

Network Topologies

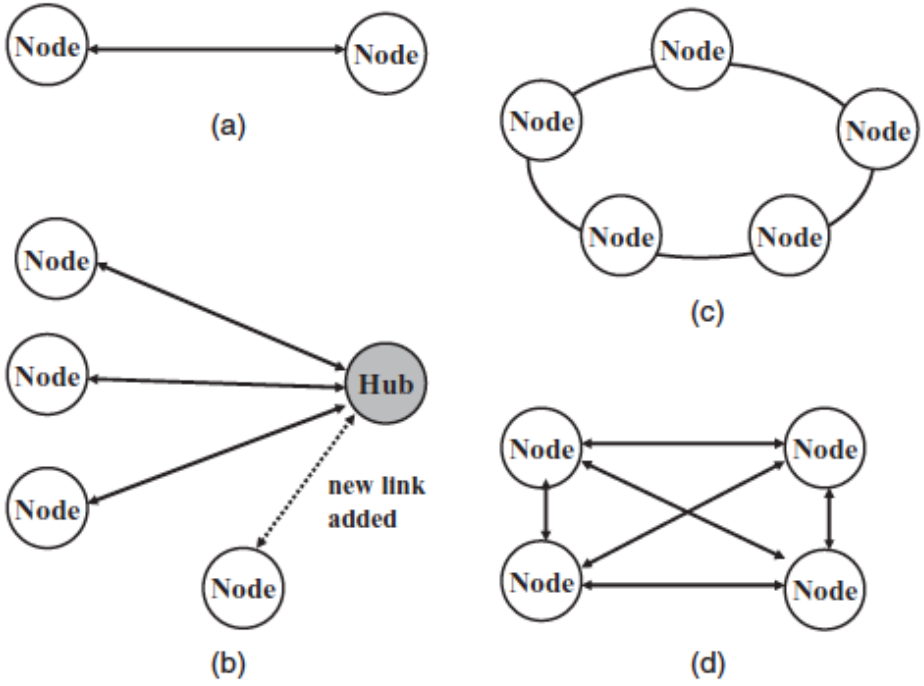

FIGURE 1.3 (a) Point-to-point, (b) hub (star), (c) ring, and (d) mesh network topologies.

Network Topologies

TABLE 1.1 Network Topology Comparison

Topology	Benefits	Shortcomings	Example
Point-to-point	Very simple	Single point of failure	Long-haul links
Hub	Simple	Single point of failure	Ethernet LAN
Ring	Some redundancy	Scalability problems	Metropolitan SONET/SDH
Mesh	Full redundancy	Complex, hardware intensive	WDM core

Network Connection

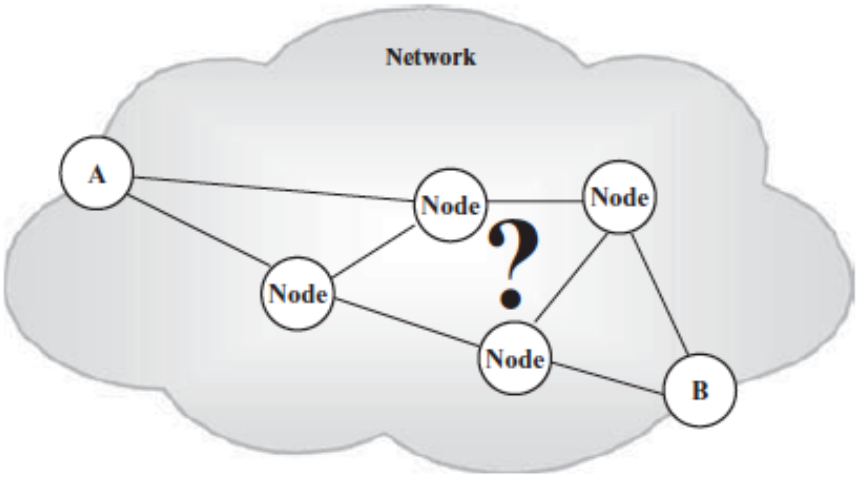

FIGURE 1.4 Network connection problem between points A and B.

- How to establish network connection?
  - Circuit vs. Packet switching

Circuit Switching

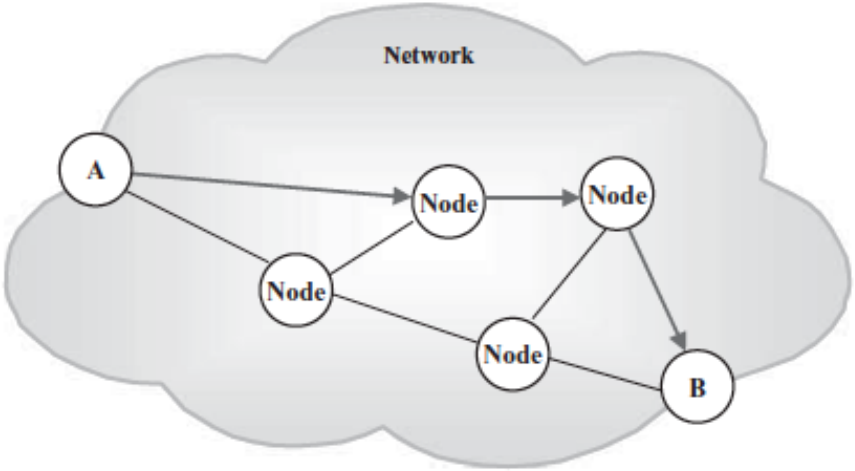

FIGURE 1.5 Circuit-switching principle. A permanent connection is established between points A and B.

Packet Switching

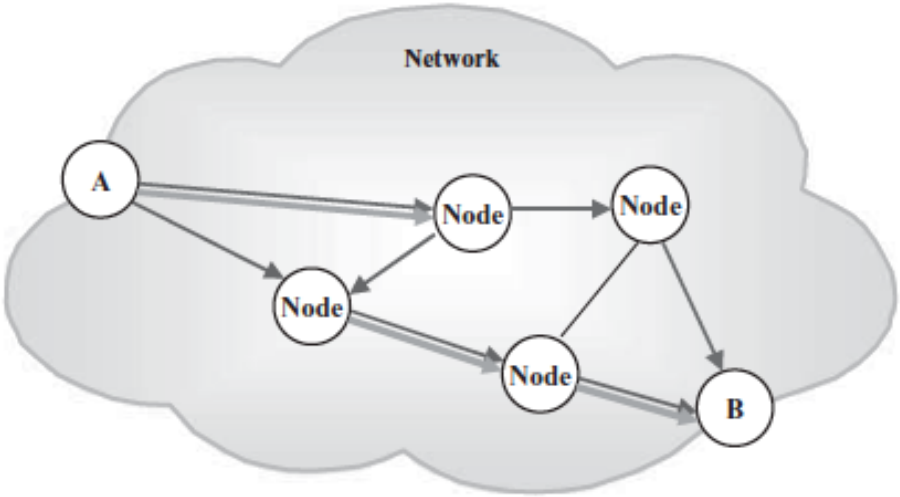

FIGURE 1.6 Packet-switching principle. Each packet travels using a different route from paint A to paint B, as indicated by arrows.

Signal Multiplexing

- Methods for multiplexing communication signals
  - Wavelength-Division Multiplexing (WDM)
  - Time-Division Multiplexing (TDM)
    - Synchronous
    - Asynchronous (aka statistical multiplexing)

WDM

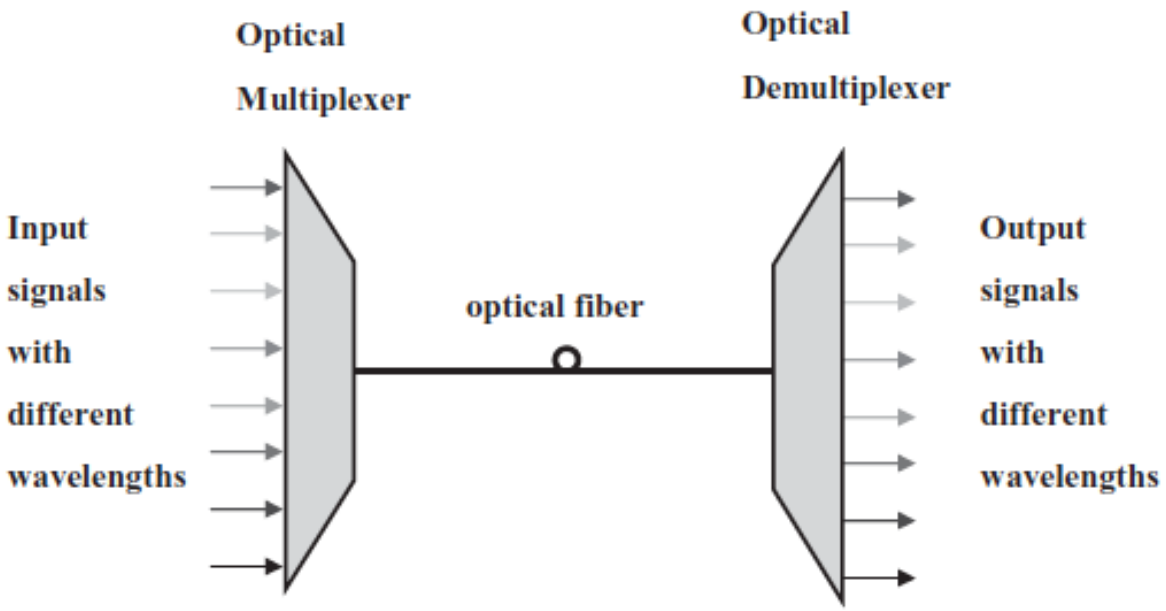

FIGURE 1.7 Principle of wavelength-division multiplexing.

Synchronous TDM

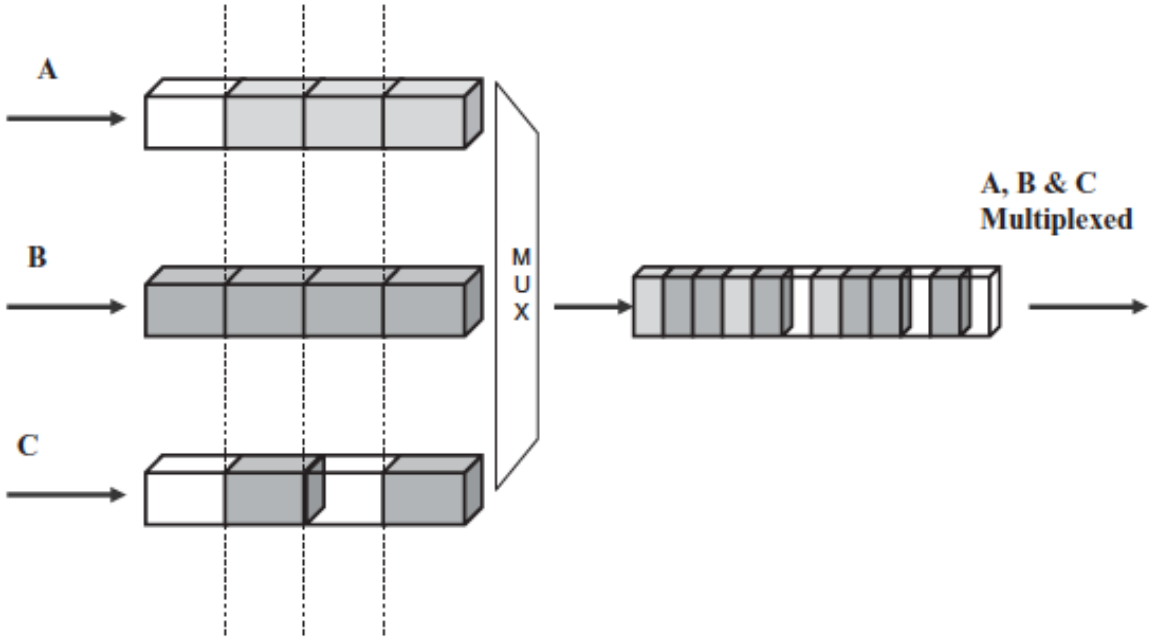

FIGURE 1.8 Principle of synchronous time-division multiplexing.

Asynchronous TDM

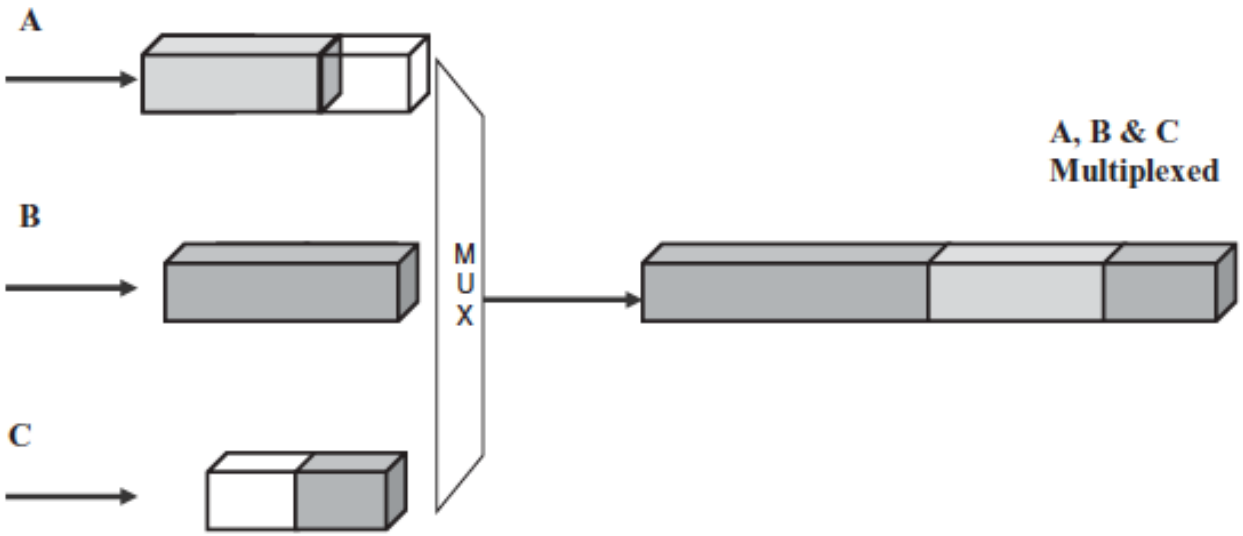

FIGURE 1.9 Principle of statistical multiplexing.

OSI Model

- Open System Interconnect (OSI), by ISO (International Organization for Standardization): a useful conceptual model for classifying network functions.
- Seven layers defined. Three are hardware layers: network (3), data link (2), transport (1)
  - Also consider media layer (layer 0).

OSI Model

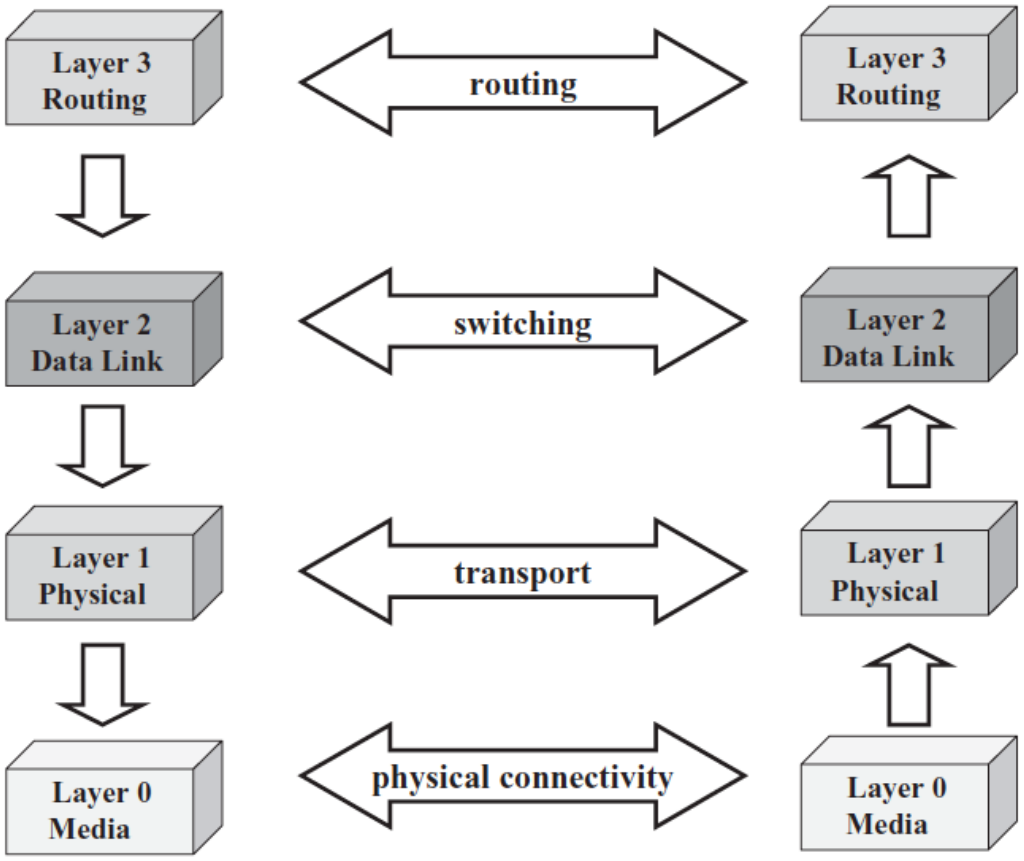

FIGURE 1.10 OSI model for hardware layers.

Data Encapsulation

- Similar structures consisting of data (payload) and additional overhead (header & trailer)
  - Layer 0: optical pulses or electrical currents
  - Layer 1: frame
  - Layer 2: frame or cell (constant length)
  - Layer 3: packet
- Lower layers append additional overhead to payload.

Data Encapsulation

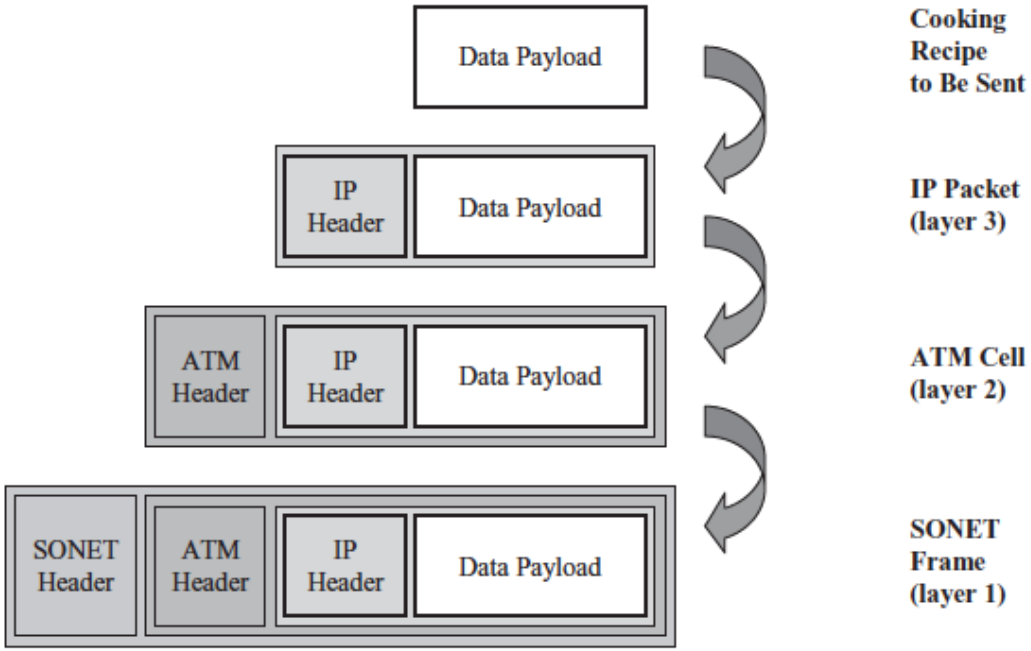

FIGURE 1.11 Process of data encapsulation.

Network Overlay Hierarchy

- Typical stack: IP over ATM over SONET over WDM

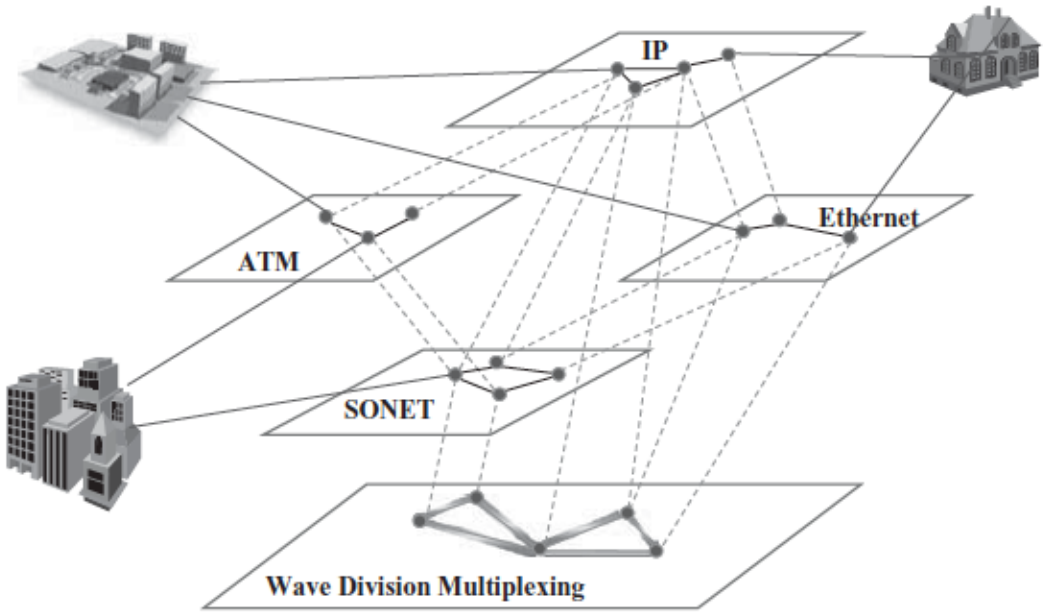

FIGURE 1.12 Overlay network hierarchy.

Network Equipment

- Classify network elements according to operations in OSI model:
  - Layer 3: IP routers
  - Layer 2: switches
  - Layer 1: regenerators, modems, hubs, add/drop multiplexers (ADM)
  - Layer 0: WDM terminals

Network equipment

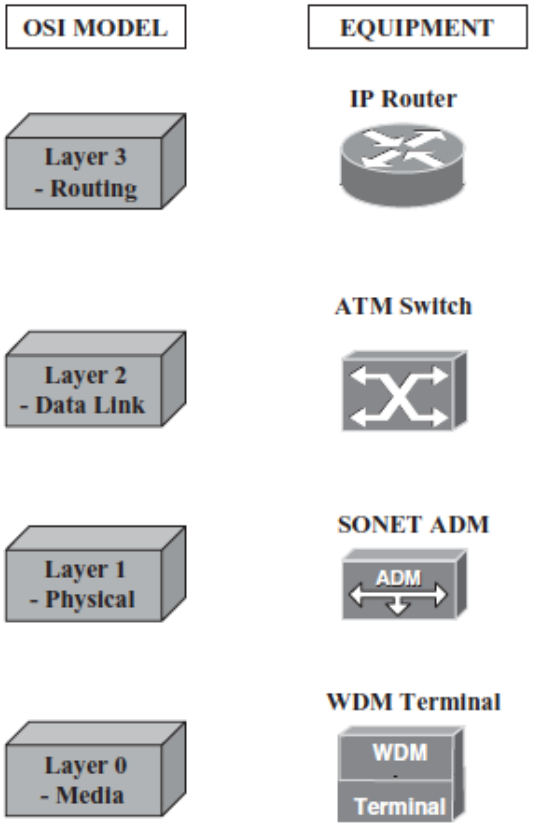

FIGURE 1.14 Networking elements and corresponding OSI layer hierarchy.

Network equipment

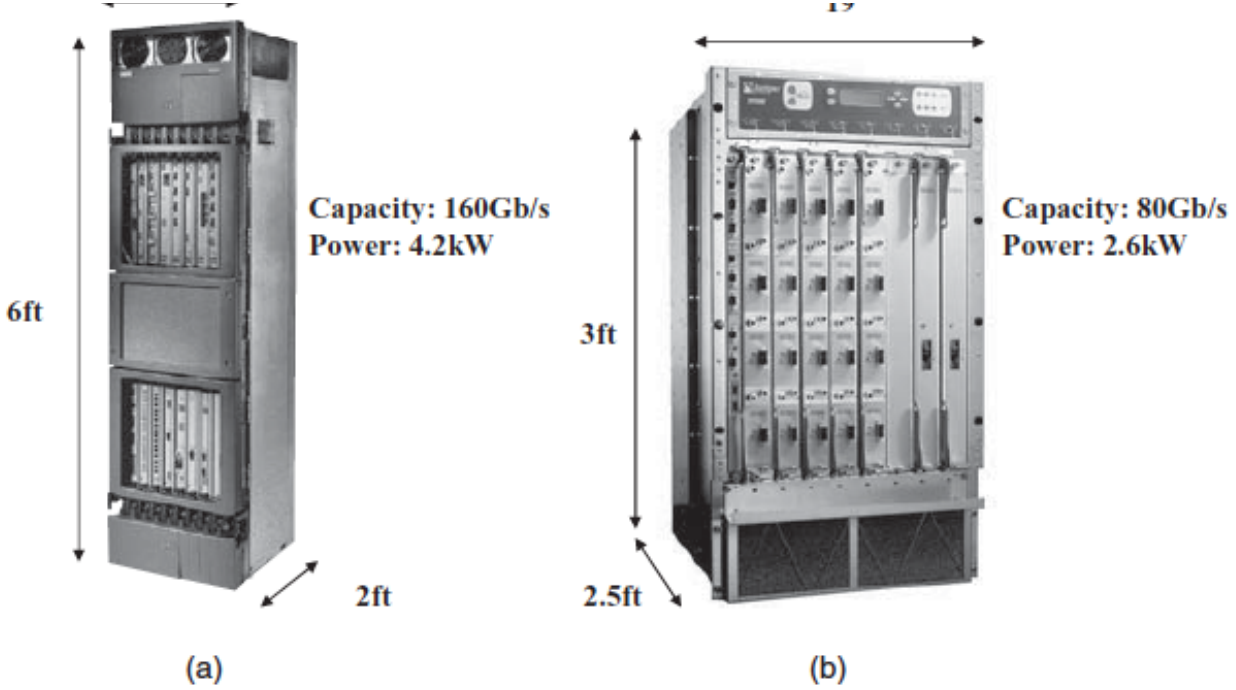

FIGURE 1.13 Examples of core routers: (a) Cisco GSR 12416; (b) Juniper M160.

Network Equipment

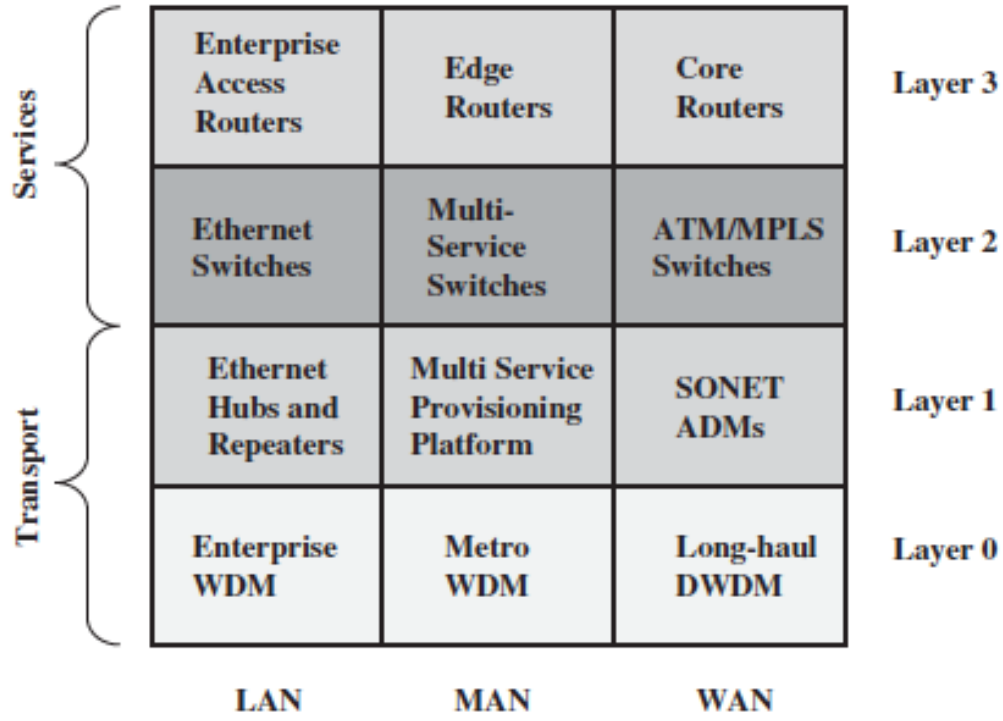

FIGURE 1.20 Various examples of networking equipment.

Network Service Example: Leased Line

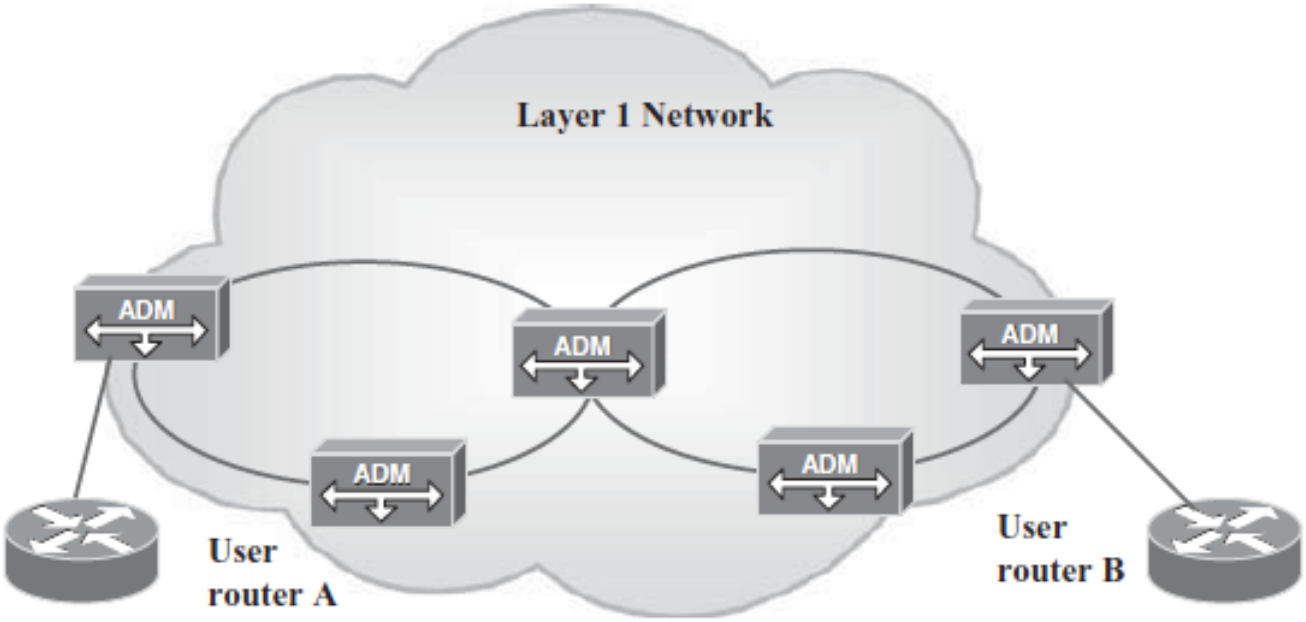

FIGURE 1.18 Leased line layer 1 transport network.

Network Service Example: VPN

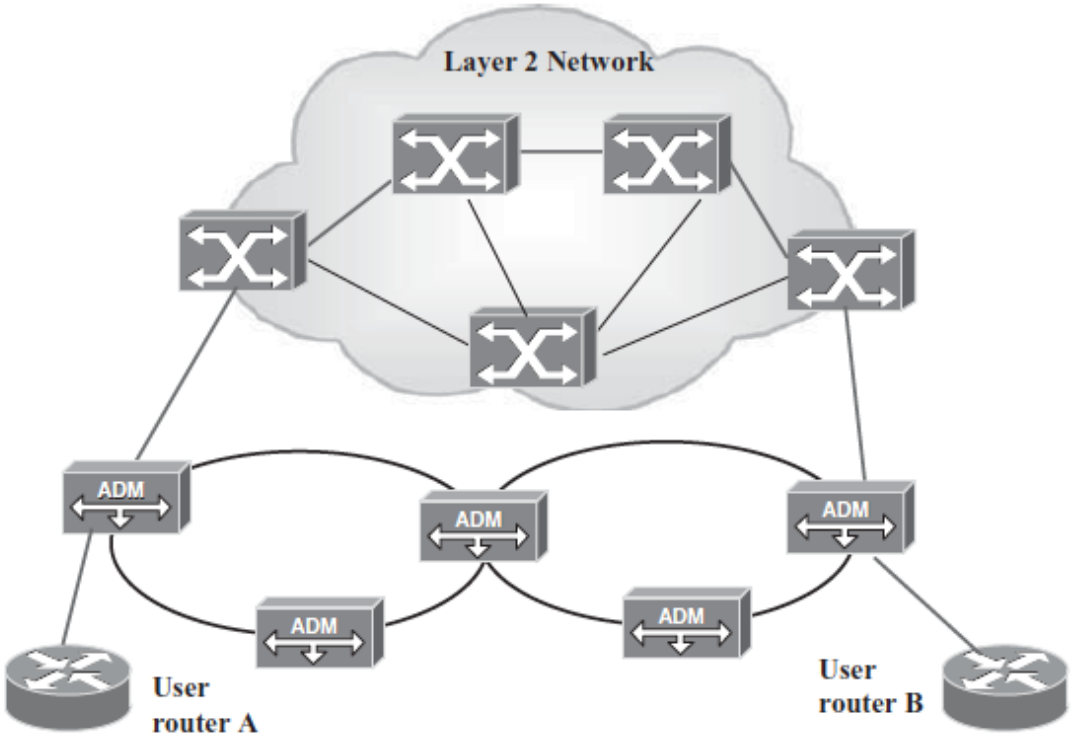

FIGURE 1.19 Virtual private network.