INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

CSN-101 (Introduction to Computer Science and Engineering)

Lecture 13: Computer Networking and Web Technology

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Piazza Class Room: https://piazza.com/iitr.ac.in/fall2019/csn101

[Access Code: csn101@2019]

Moodle Submission Site: https://moodle.iitr.ac.in/course/view.php?id=45

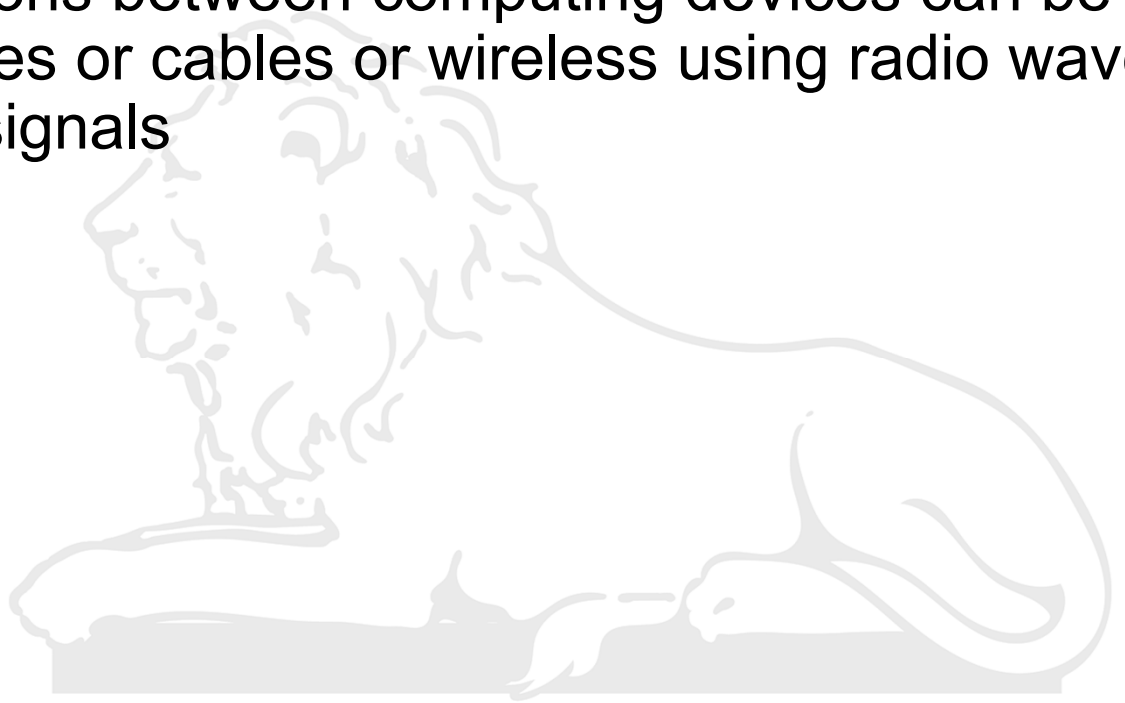
[Enrollment Key: csn101@2019]

Plan for Lecture Classes in CSN-101 (Autumn, 2019-2020)

Week	Lecture 1 (Monday 4-5 PM)	Lecture 2 (Friday 5-6 PM)	
1	Evolution of Computer Hardware and Moore's Law, Software and Hardware in a Computer	Computer Structure and Components, Operating Systems	MTE
2	Computer Hardware: Block Diagrams, List of Components	Computer Hardware: List of Components, Working Principles in Brief, Organization of a Computer System	
3	Linux OS	Linux OS	
4	Writing Pseudo-codes for Algorithms to Solve Computational Problems	Writing Pseudo-codes for Algorithms to Solve Computational Problems	
5	Sorting Algorithms – Bubble sort, selection sort, and Search Algorithms	Sorting Algorithms – Bubble sort, selection sort, and Search Algorithms	
6	C Programming	C Programming	
7	Number Systems: Binary, Octal, Hexadecimal, Conversions among them	Number Systems: Binary, Octal, Hexadecimal, Conversions among them	
8	Number Systems: Negative number representation, Fractional (Real) number representation	Boolean Logic: Boolean Logic Basics, De Morgan's Theorem, Logic Gates: AND, OR, NOT, NOR, NAND, XOR, XNOR, Truth-tables	
9	Computer Networking and Web Technologies: Basic concepts of networking, bandwidth, throughput	Computer Networking and Web Technologies: Basic concepts of networking, bandwidth, throughput	MTE
10	Different layers of networking, Network components, Type of networks	Network topologies, MAC, IP Addresses, DNS, URL	
11	Different fields of CSE: Computer Architecture and Chip Design	Different fields of CSE: Data Structures, Algorithms and Programming Languages	
12	Different fields of CSE: Database management	Different fields of CSE: Operating systems and System softwares	
13	Different fields of CSE: Computer Networking, HPCs, Web technologies	Different Applications of CSE: Image Processing, CV, ML, DL	
14	Different Applications of CSE: Data mining, Computaional Geometry, Cryptography, Information Security	Different Applications of CSE: Cyber-physical systems and IoTs	

Computer network

- A collection of computing devices connected in order to communicate and share resources
- Connections between computing devices can be physical using wires or cables or wireless using radio waves or infrared signals



Networking

Node (host)

Any device on a network

Data transfer rate (bandwidth)

The speed with which data is moved from one place to another on a network

Network Topologies:

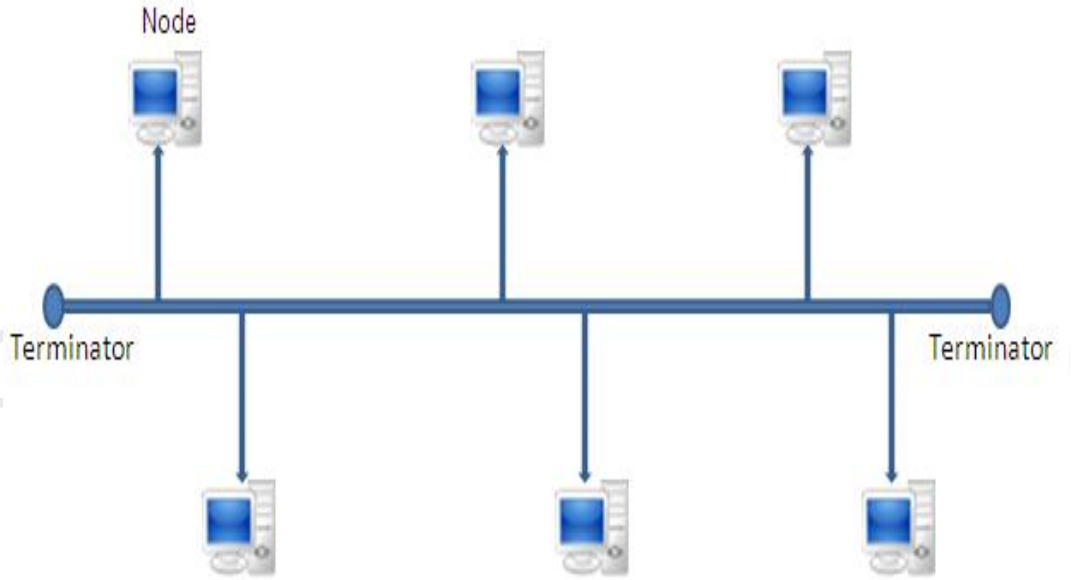
- LAN topologies
- WAN topologies

LAN Topologies (Physical)

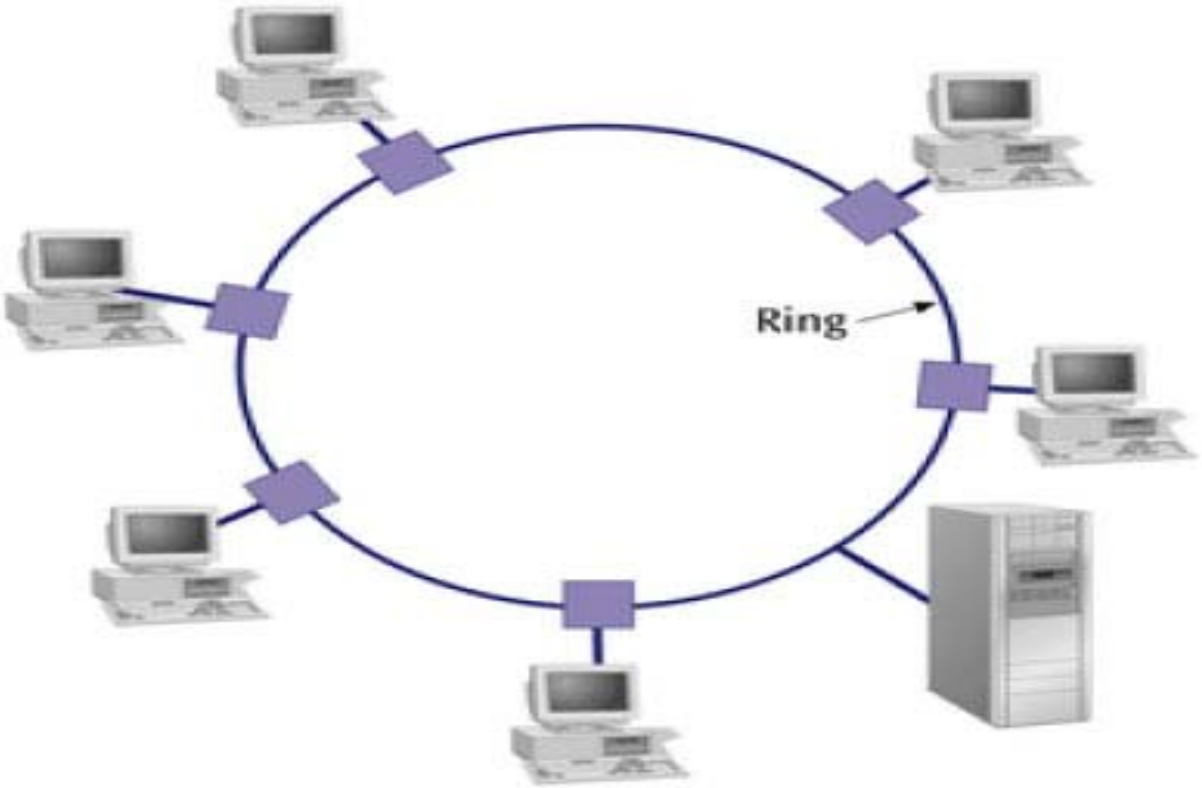
1) Bus
2) Star
3) Ring
4) Switched
5) Daisy chains
6) Hierarchies

Bus topology

- All networked nodes are interconnected, peer to peer, using a single, open-ended cable
- Both ends of the bus must be terminated with a terminating resistor to prevent signal bounce

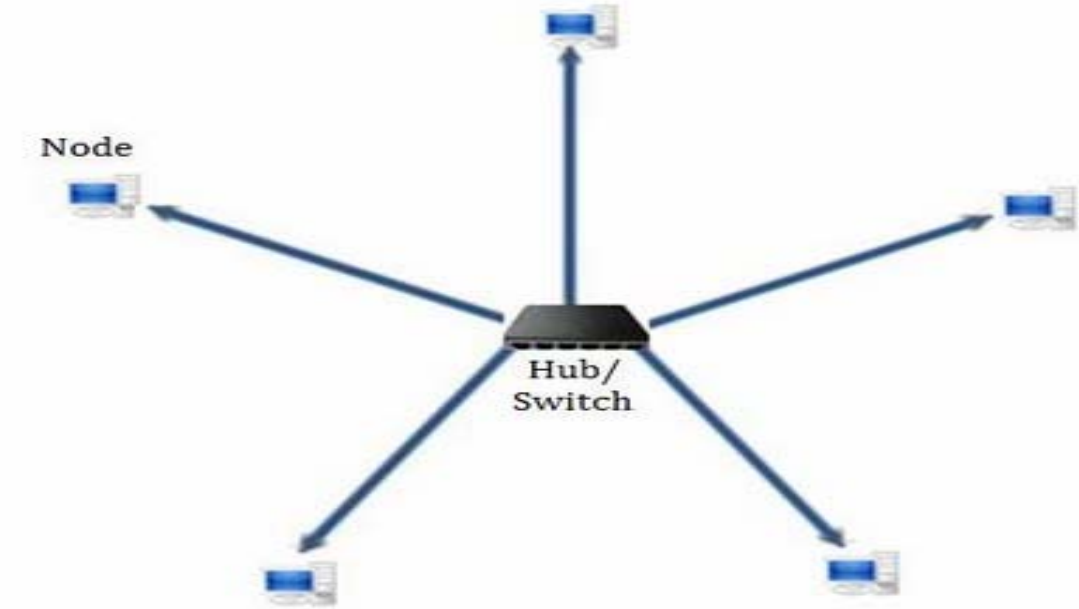


Ring topology



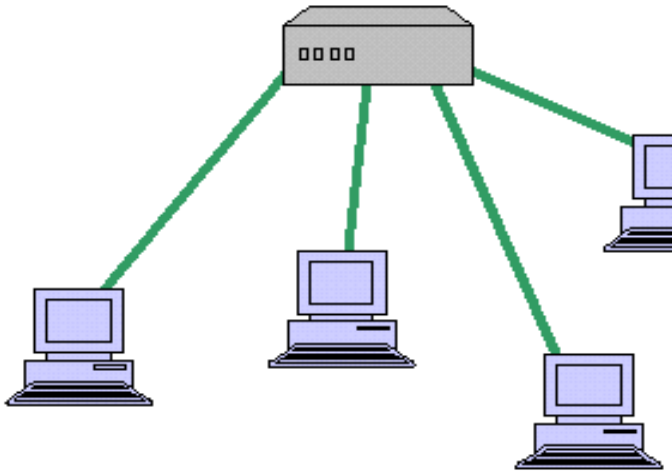
Star topology

- Have connections to networked devices that “radiate” out form a common point
- Each networked device in star topology can access the media independently
- Have become the dominant topology type in contemporary LANs
- Stars have made buses and rings obsolete in LAN topologies



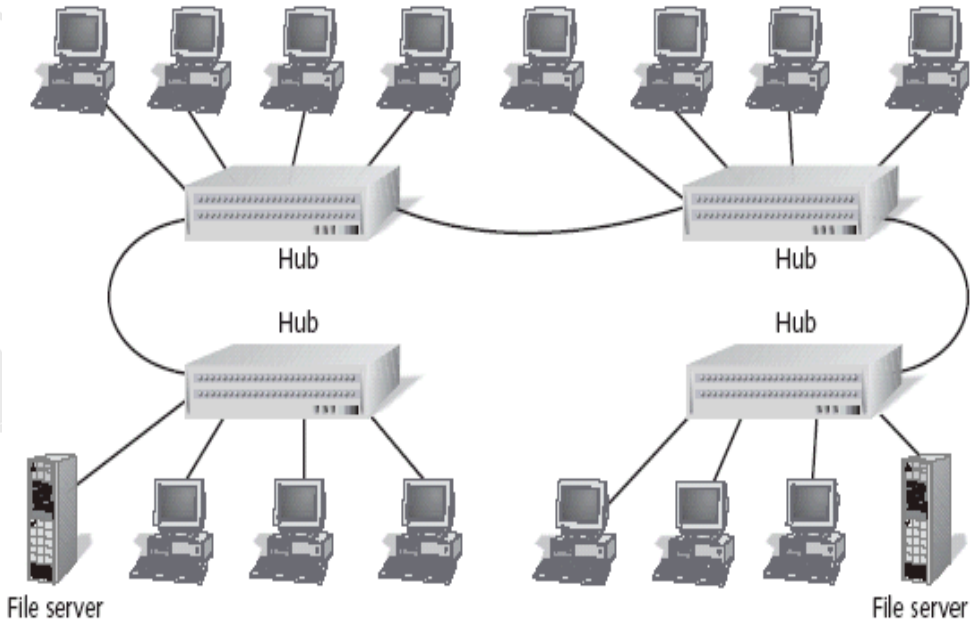
Switched topology

- A switch is a multiport, Data Link Layer device
- A switch “learns” Media Access Control addresses and stores them in an internal lookup table
- Temporary, switched paths are created between the frame’s originator and its intended recipient, and the frames are forwarded along the temporary path
- Switched topology features multiple connections to a switching hub/Switch
- Each port, and the device to which it connects, has its own dedicated bandwidth

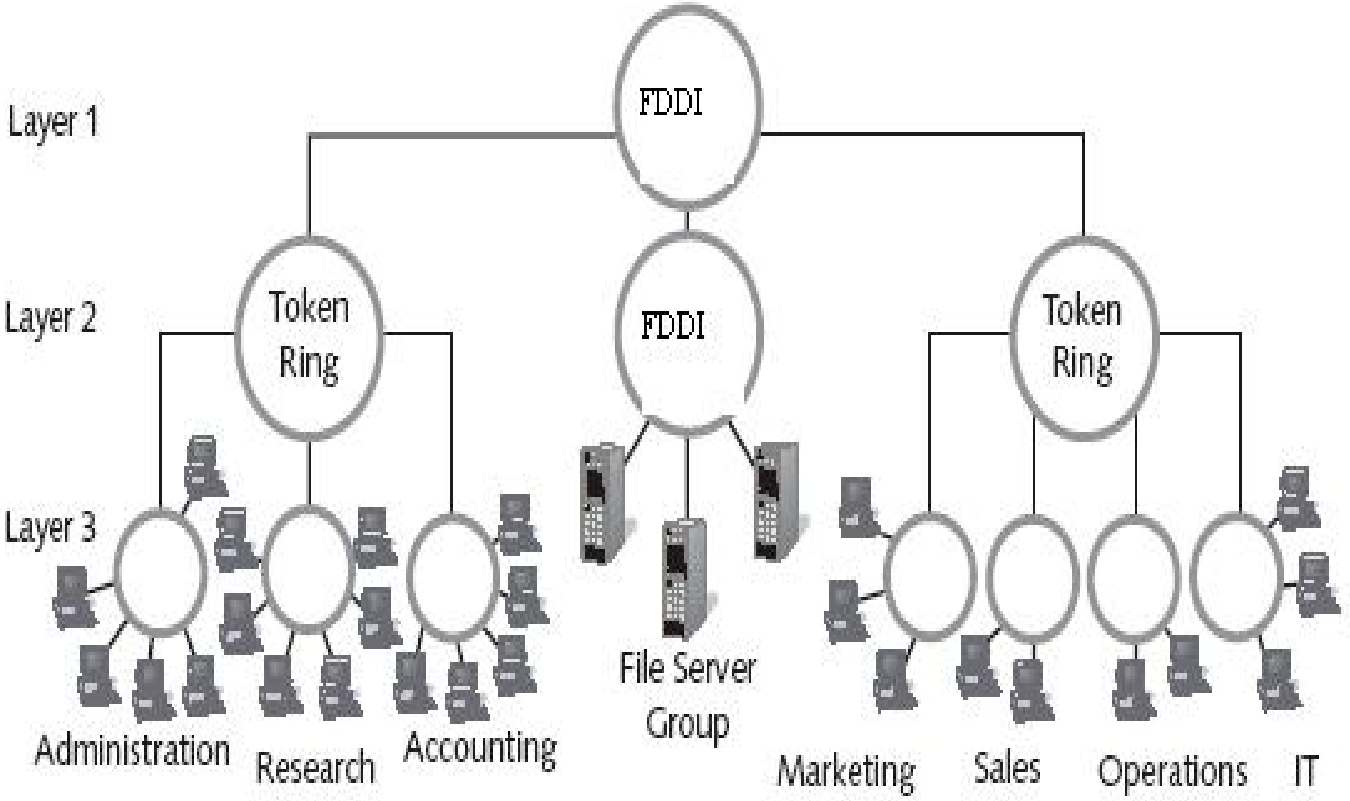


Daisy chains

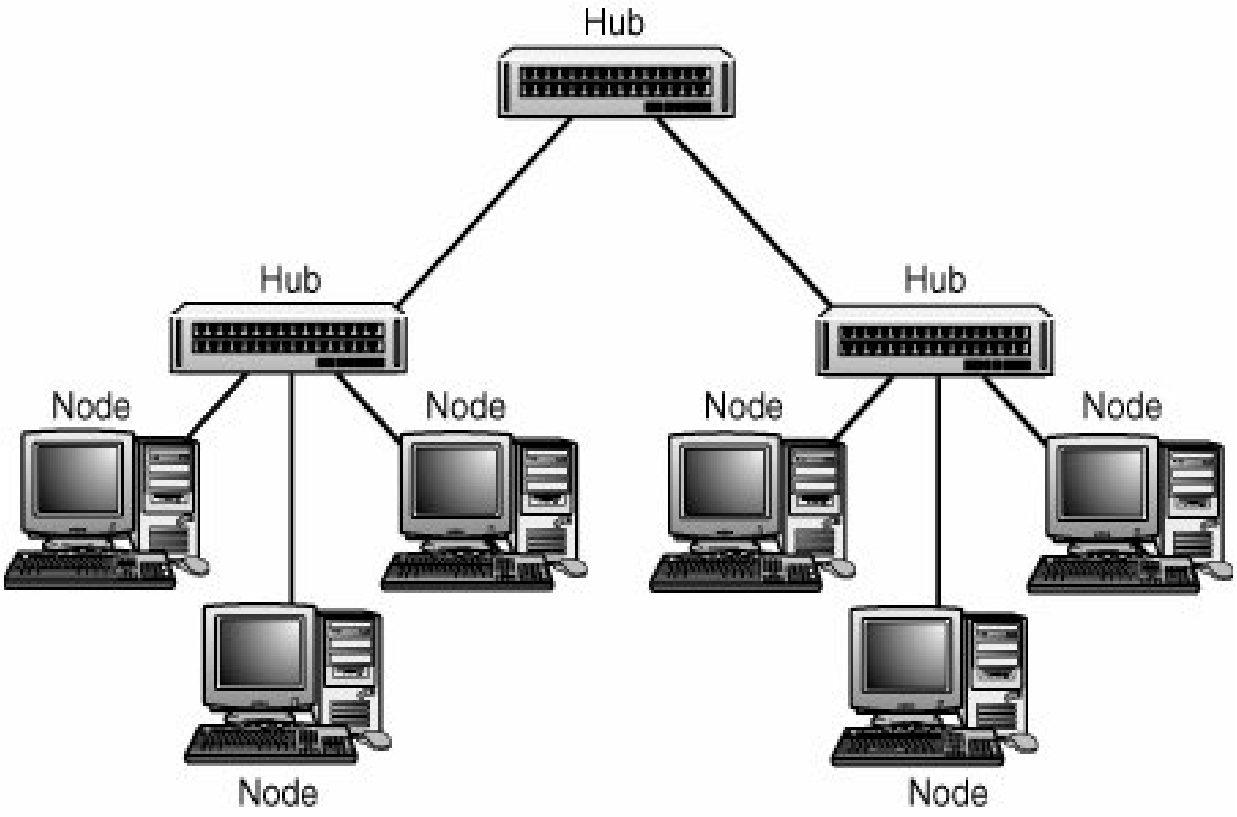
- Developed by serially interconnecting all the hubs of a network
- This simple approach uses ports on existing hubs for interconnecting the hubs
- Daisy chains are easily built and don't require any special administrative skills
- Daisy chains were, historically, the interconnection method of choice for emerging, first-generation LANs



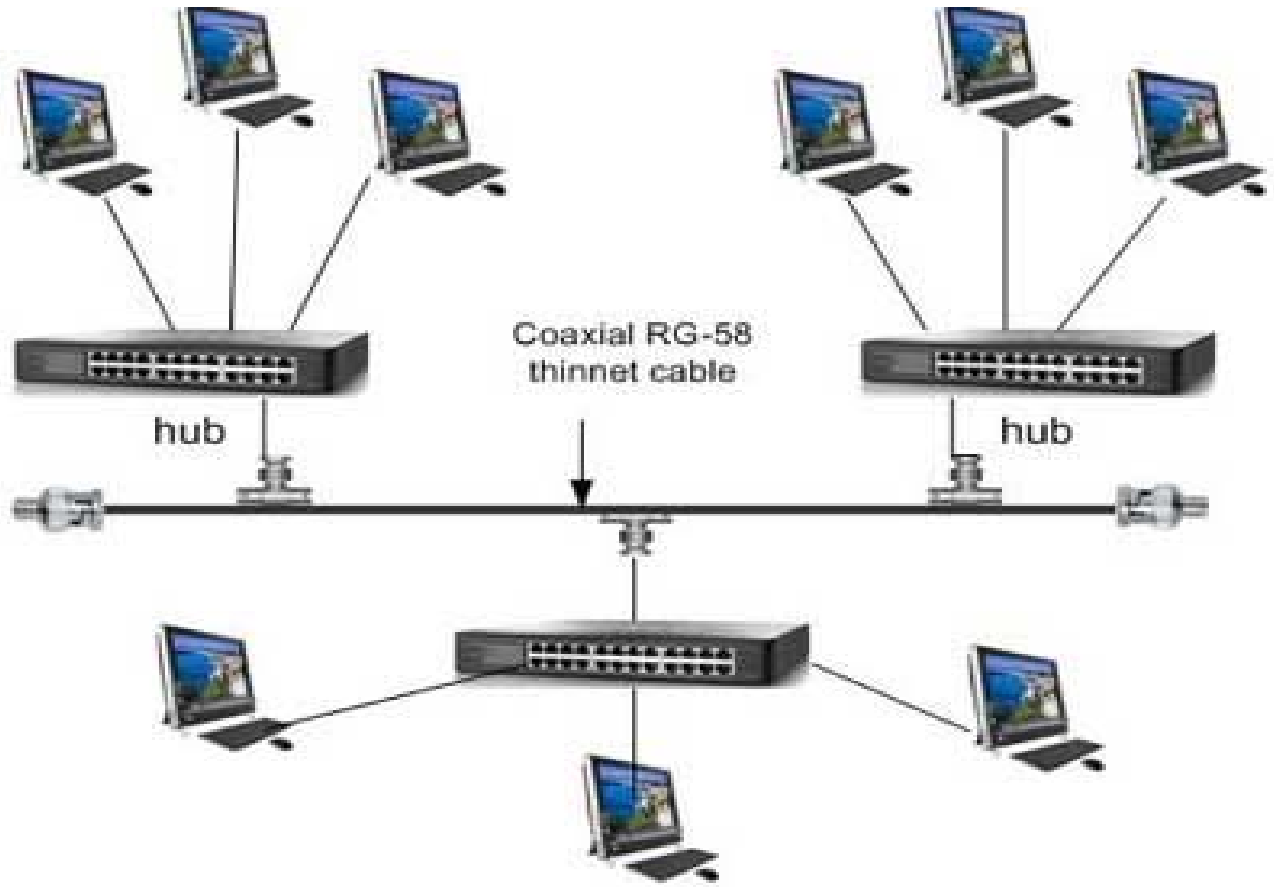
Hierarchical rings



Hierarchical stars



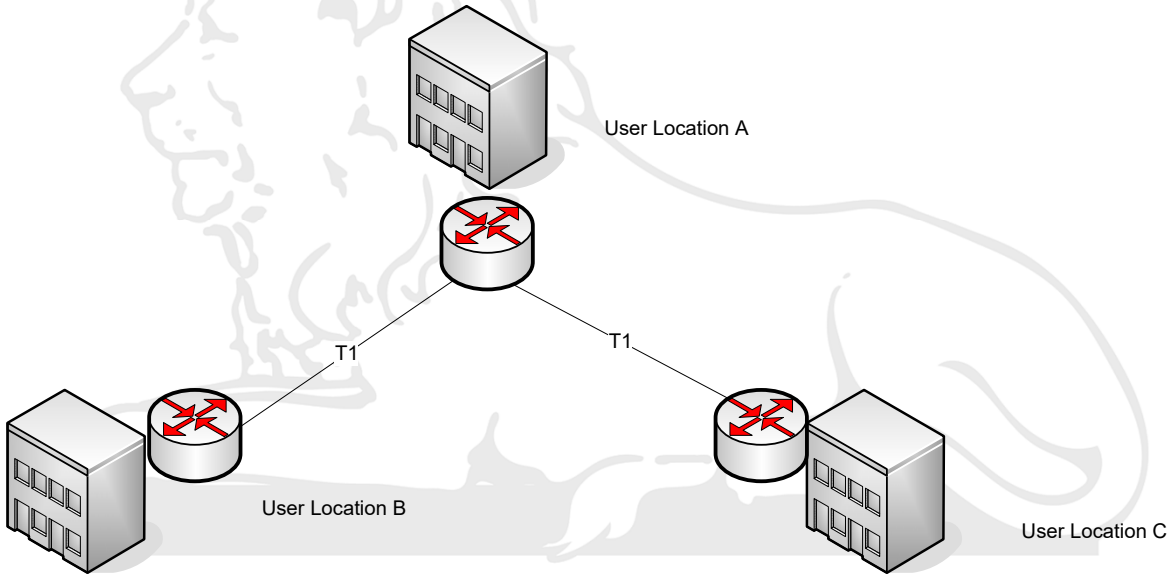
Hierarchical combinations



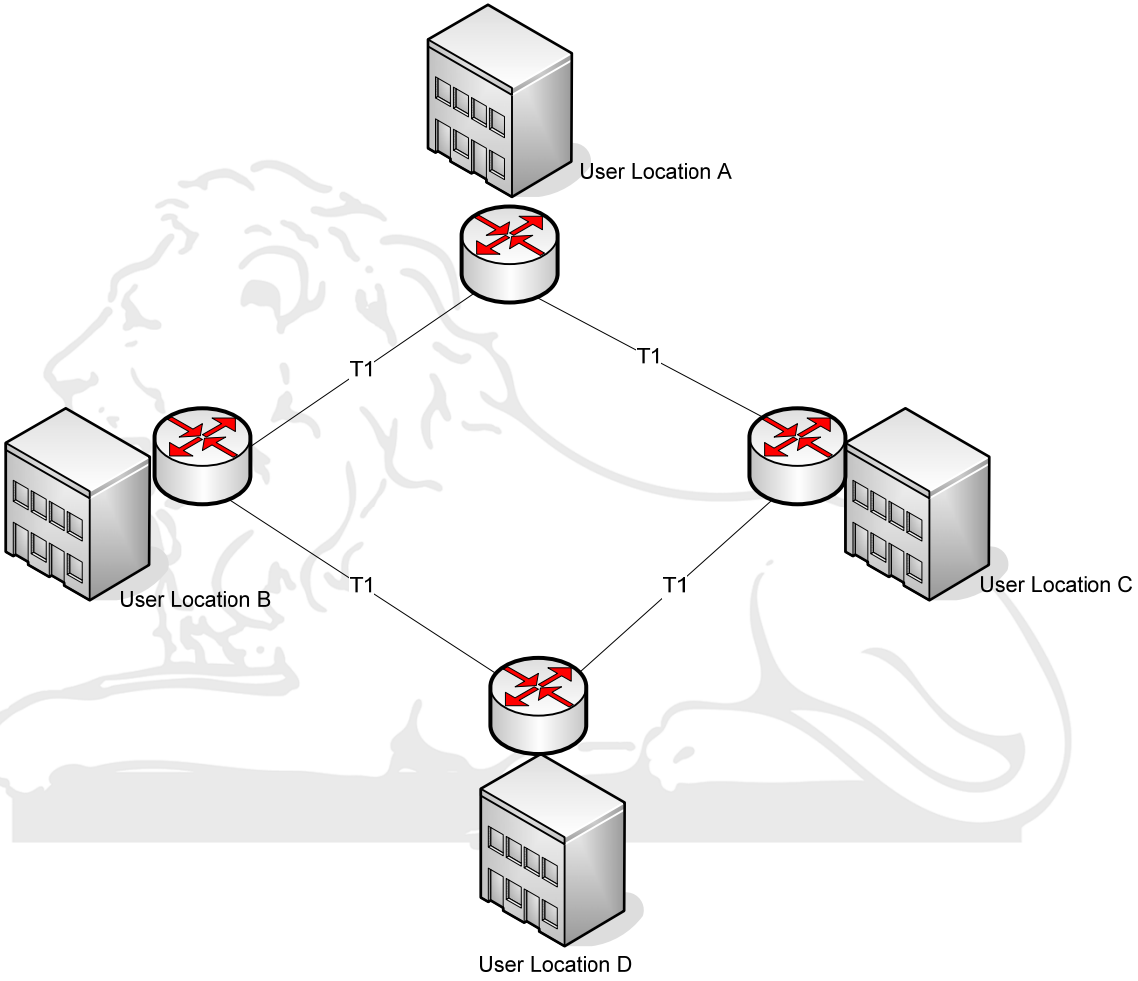
WAN Topologies

1) Peer-to-peer WANs
2) Ring WANs
3) Star WANs
4) Full-mesh WANs
5) Partial-mesh WANs
6) Two-tiered
7) Three-tiered
8) Hybrids

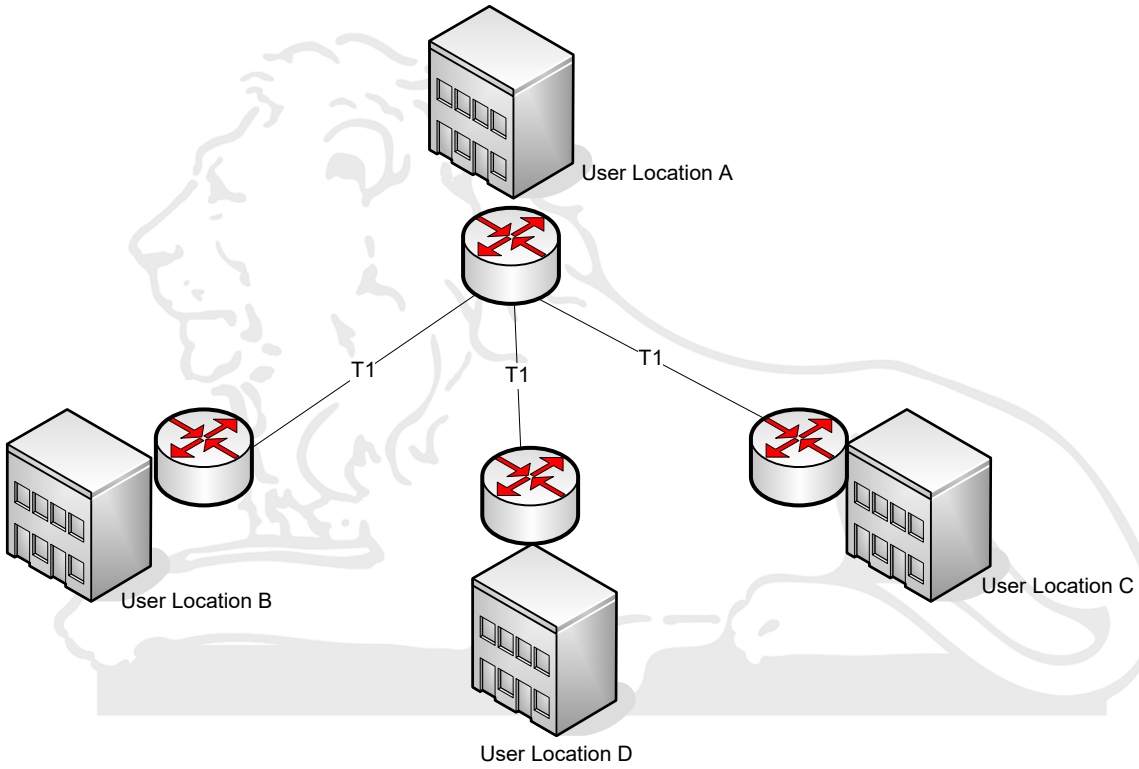
Peer-to-peer



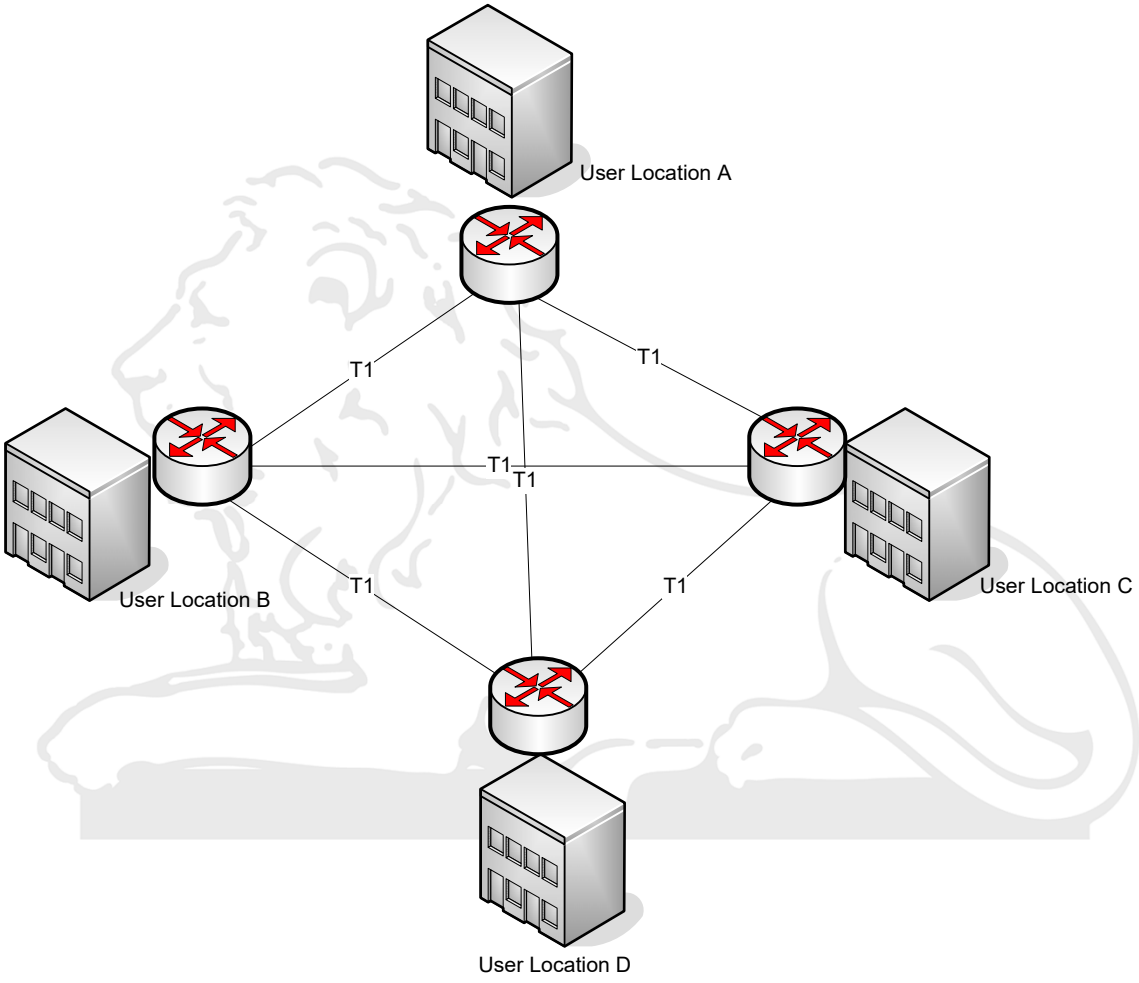
Ring topology



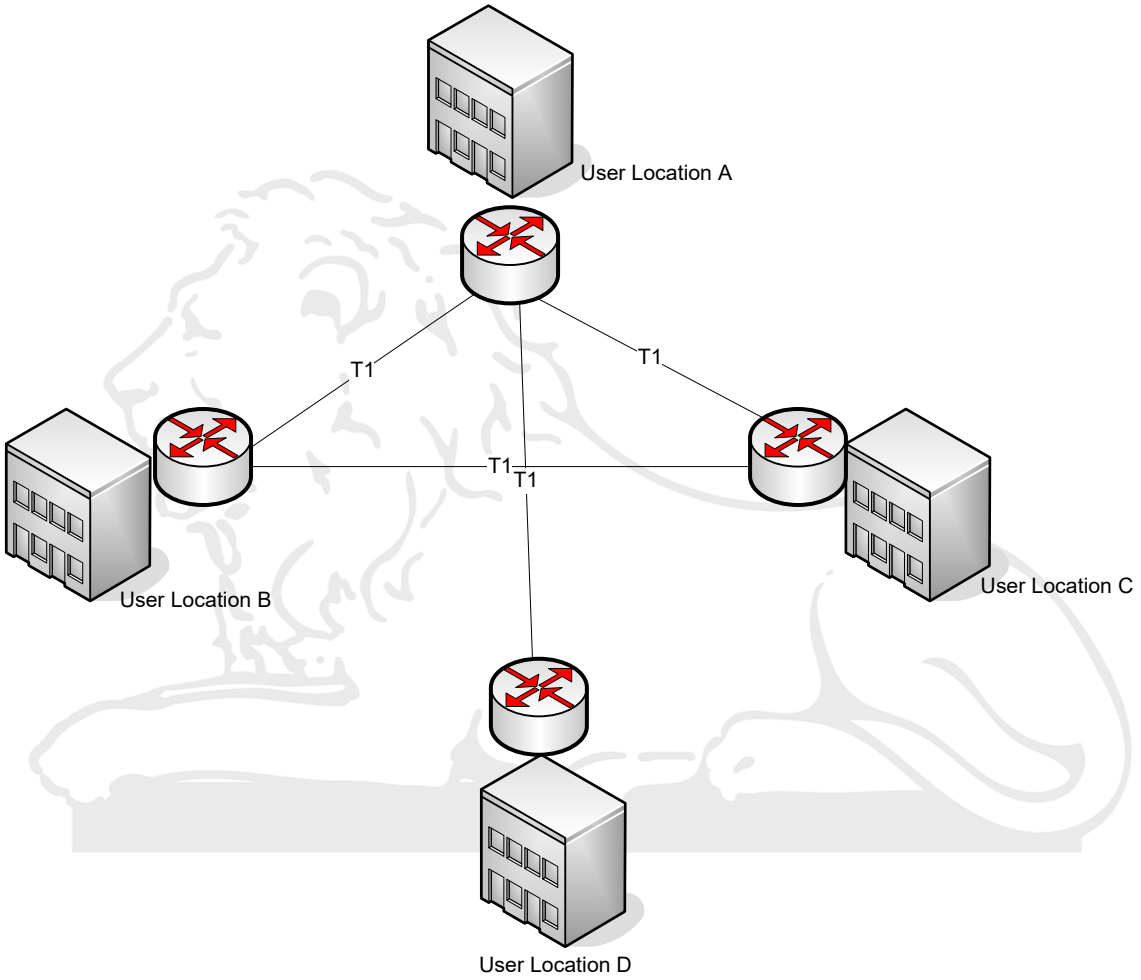
Star topology



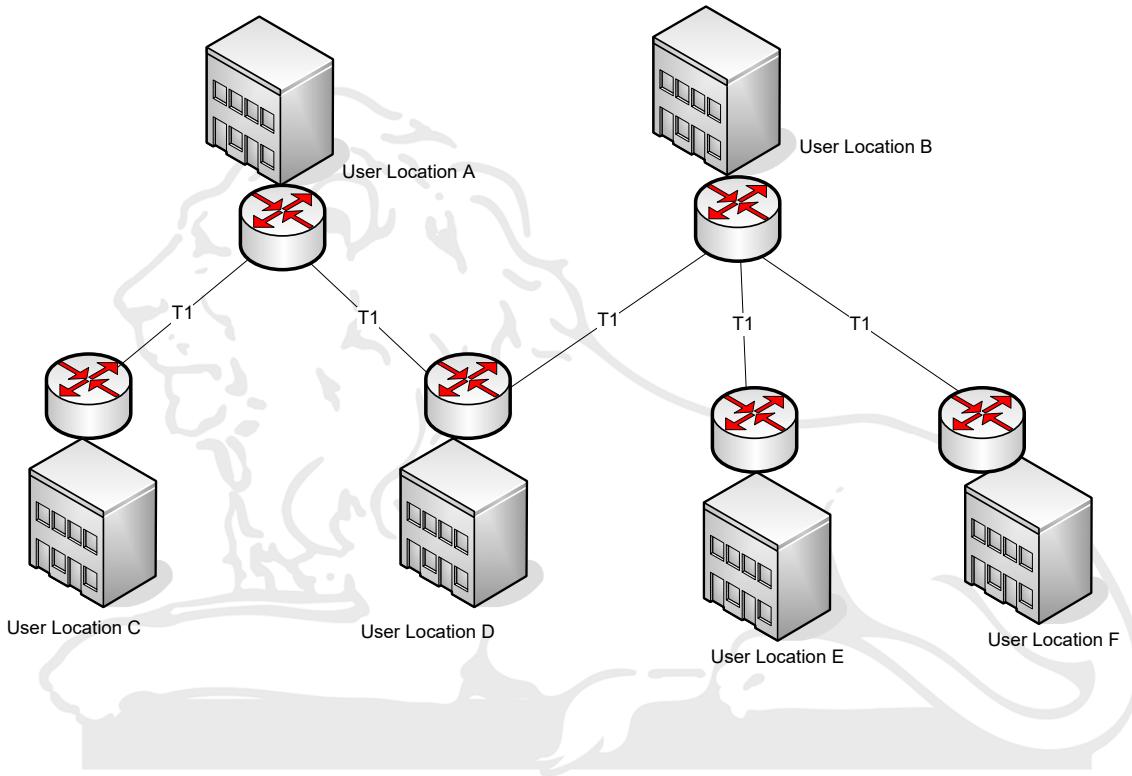
Full-mesh topology



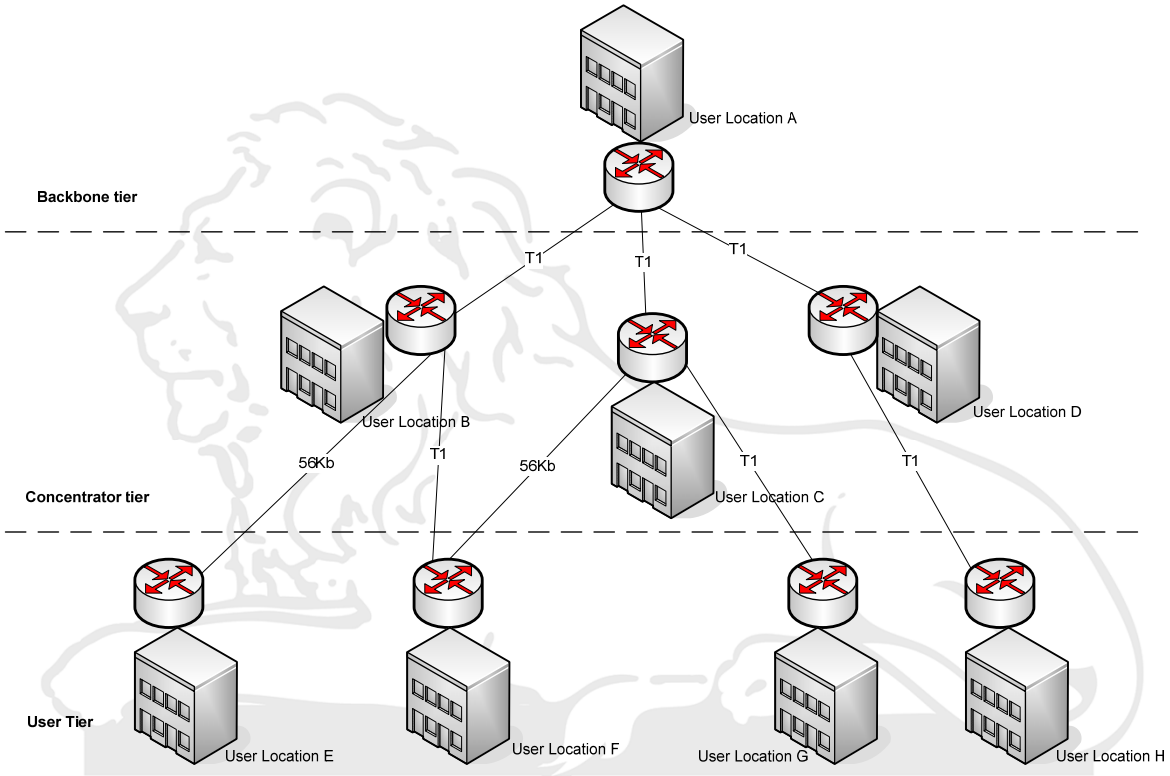
Partial-mesh



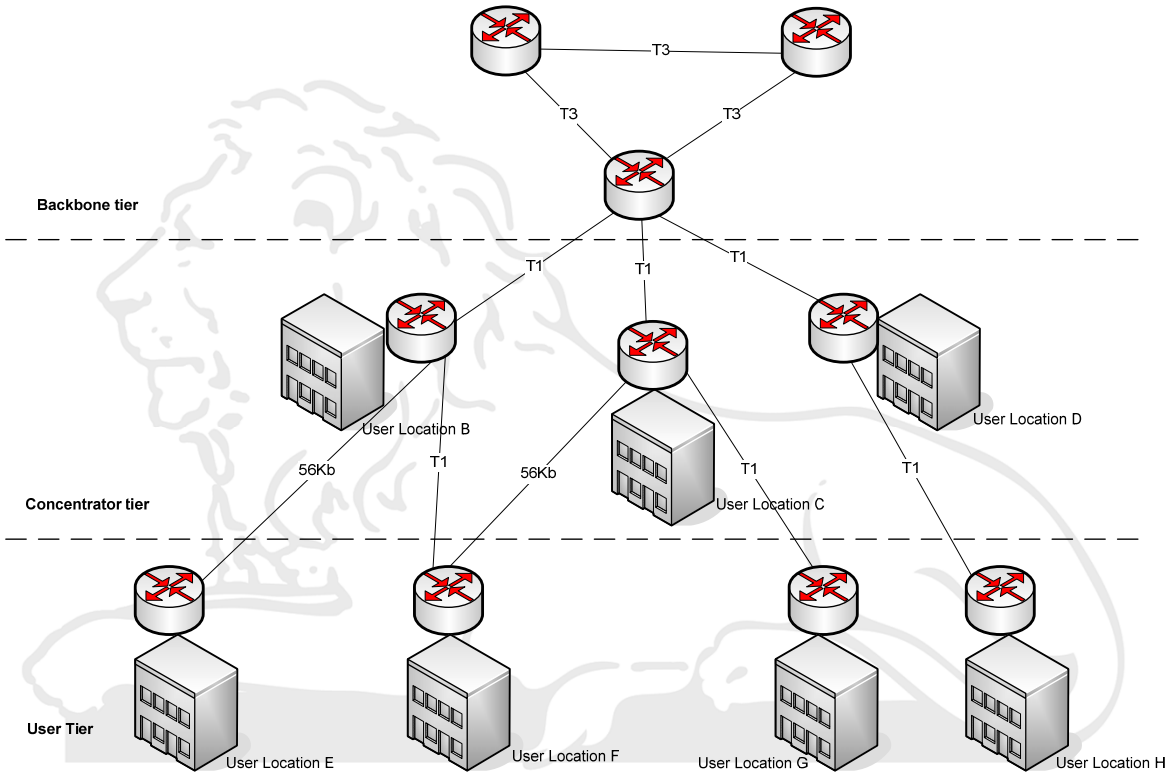
Two-tiered topology



Three-tiered



Hybrid topology



Networking

Protocol

A set of rules that defines how data is formatted and processed on a network

File server

A computer dedicated to storing and managing files for network users

Web server

A computer dedicated to responding to requests for web pages

P2P model

A decentralized approach that shares resources and responsibilities among many “peer” computers

Open Systems

Number	Layer
7	Application layer
6	Presentation layer
5	Session layer
4	Transport layer
3	Network layer
2	Data Link layer
1	Physical layer

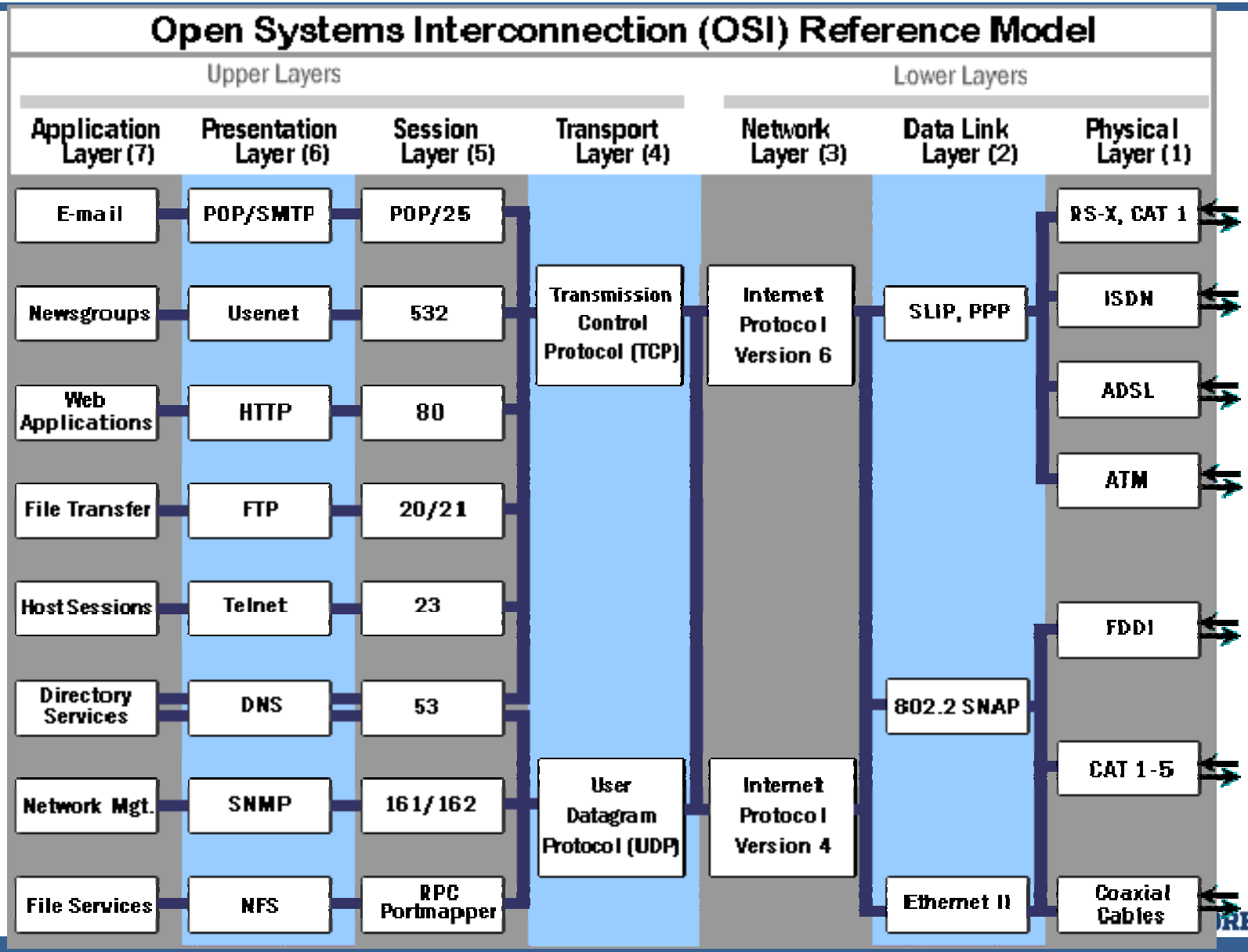
FIGURE 15.5 The layers of the OSI Reference Model

Open Systems Interconnection Reference Model

A seven-layer logical break down of network interaction to facilitate communication standards

Each layer deals with a particular aspect of network communication

OSI


Open Systems Interconnection (OSI) Reference Model
Upper Layers
Lower Layers
Application Layer (7)
Presentation Layer (6)
Session Layer (5)
Transport Layer (4)
Network Layer (3)
Data Link Layer (2)
Physical Layer (1)
E-mail
POP/SMTP
POP/25
Newsgroups
Usenet
532
Web Applications
HTTP
80
File Transfer
FTP
20/21
Host Sessions
Telnet
23
Directory Services
DNS
53
Network Mgt.
SNMP
161/162
File Services
NFS
RPC Portmapper
Transmission Control Protocol (TCP)
User Datagram Protocol (UDP)
Internet Protocol Version 6
Internet Protocol Version 4
SLIP, PPP
802.2 SNAP
Ethernet II
RS-X, CAT 1
ISDN
ADSL
ATM
FDDI
CAT 1-5
Coaxial Cables

Network Protocols

- Network protocols are layered such that each one relies on the protocols that underlie it
- Sometimes referred to as a **protocol stack**

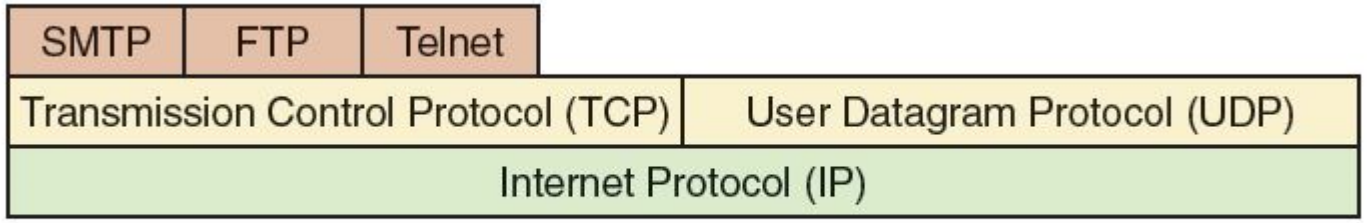


FIGURE 15.6 Layering of key network protocols

TCP/IP

Transmission Control Protocol (TCP)

Software that breaks messages into packets, hands them off to the IP software for delivery, and then orders and reassembles the packets at their destination

Internet Protocol (IP)

Software that deals with the routing of packets through the maze of interconnected networks to their final destination

TCP/IP

User Datagram Protocol (UDP)

An alternative to TCP that is faster but less reliable

Ping

A program used to test whether a particular network computer is active and reachable

Traceroute

A program that shows the route a packet takes across the Internet

Traceroute in Action

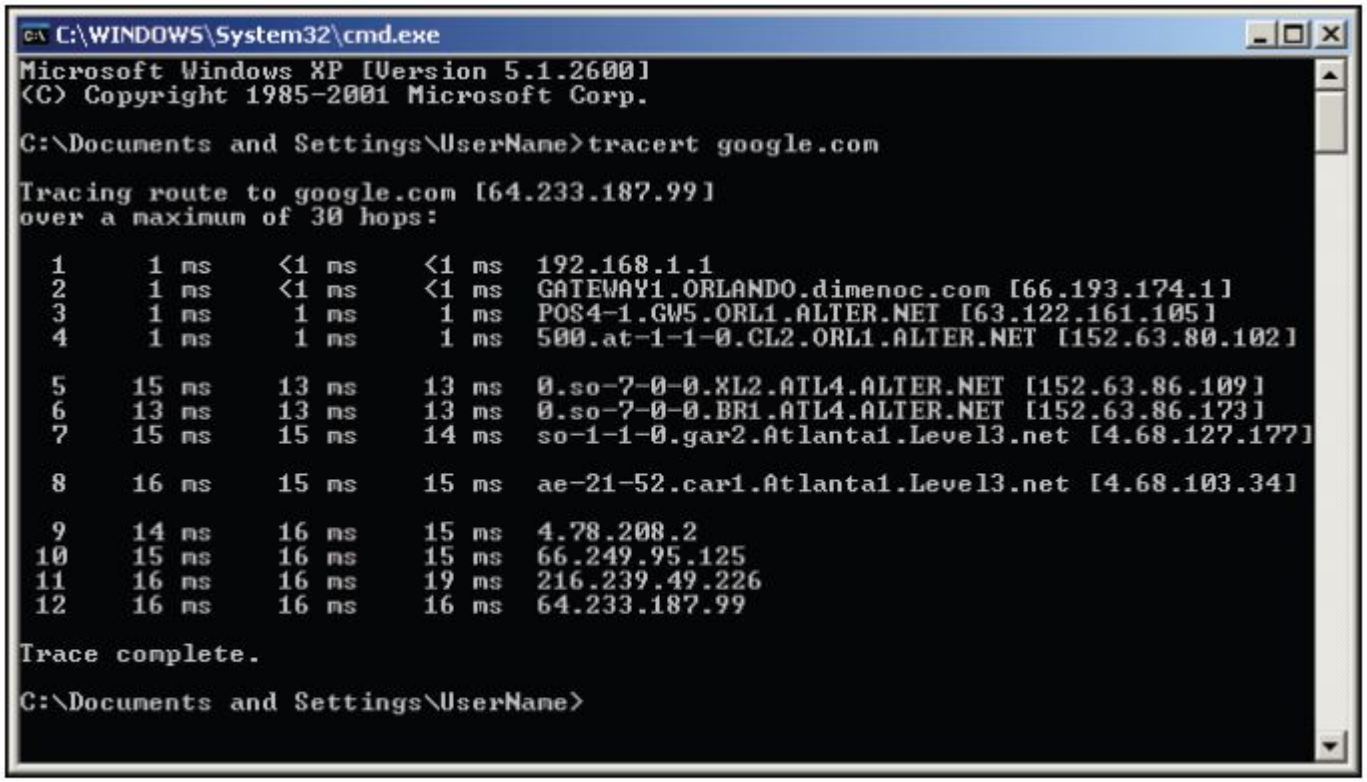


FIGURE 15.7 The traceroute utility

Used with permission from Microsoft

High-Level Protocols

Other protocols build on TCP/IP protocol suite

Simple Mail Transfer Protocol (SMTP) used to specify transfer of electronic mail

File Transfer Protocol (FTP) allows a user to transfer files to and from another computer

Telnet used to log onto one computer from another

Hyper Text Transfer Protocol (http) allows exchange of Web documents

High-Level Protocols

Protocol	Port
Echo	7
File Transfer Protocol (FTP)	21
Telnet	23
Simple Mail Transfer Protocol (SMTP)	25
Domain Name Service (DNS)	53
Gopher	70
Finger	79
Hypertext Transfer Protocol (HTTP)	80
Post Office Protocol (POP3)	110
Network News Transfer Protocol (NNTP)	119
Internet Relay Chat (IRC)	6667

FIGURE 15.8 Some protocols and the ports they use

Port
A numeric designation that corresponds to a particular high-level protocol

Network Addresses

Hostname

A name made up of words separated by dots that uniquely identifies a computer on the Internet

IP address

An address made up of four one-byte numeric values separated by dots that uniquely identifies a computer on the Internet

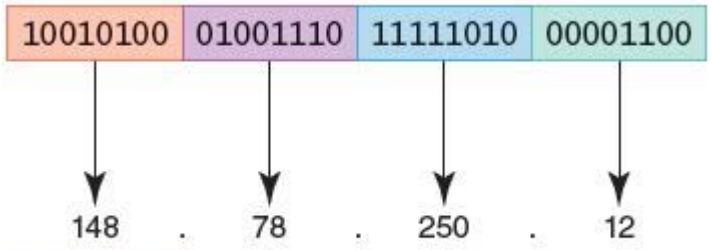


FIGURE 15.10 An IP address stored in four bytes

Network Addresses

IPv4

The last block was assigned in 2011

IPv6

32 bits organized into 4 groups of 8

`FE80:0000:0000:0000:0202:B3FF:FE1E:8329`

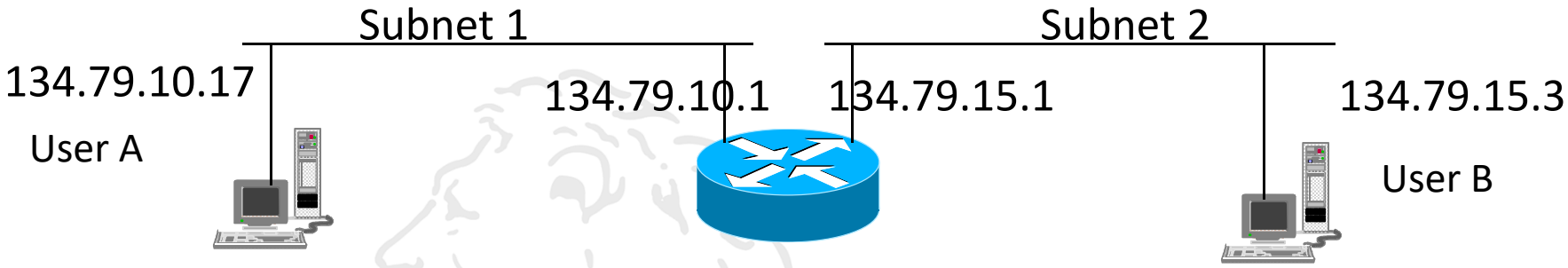
They work in parallel

Address Recognition Protocol (ARP)

- IP address is at network layer, need to map it to the MAC (medium address control) (Ethernet address) link layer address
- Use ARP to map 48 bit Ethernet address to 32 bit IP
  - IP requests MAC address for IP address from local ARP table
  - If not there, then an ARP request packet for IP address is sent using physical broadcast address (all FFFs)
  - Host with requested IP address responds with its MAC address as a unicast packet
  - On return, host updates ARP table and returns MAC address
  - ARP cache times out
  - ARP packets are on top of Ethernet

Address Recognition Protocol (ARP)

- ARP requests are local only, do not cross routers



- Compare local IP and subnet mask => local subnet
- Compare local subnet to destination IP
  - if local, ARP for MAC address
  - else remote so
    - if ROUTE entry, ARP for router to subnet
    - if default route, ARP for default gateway
    - otherwise, drop packet & return error

Setting static IP addresses

- Open Control Panel and select Network Connections
- Under LAN or High-Speed Internet select local area connection,
- right-click and select properties
- select Internet Protocol (TCP/IP) and click on properties
- fill in IP number, Subnet Mask, Default Gateway and DNS server
- click OK, close.
- Use ping to test your setup.

Domain Name System

Domain name system (DNS)

A distributed system for managing hostname resolution

Domain name server

A computer that attempts to translate a hostname into an IP address

Domain Squatting

Ransoming domain names

Domain Name System

Top-Level Domain	General Purpose
.aero	Aerospace industry
.biz	Business
.com*	U.S. commercial (unrestricted)
.coop	Cooperative
.edu*	U.S. educational
.gov*	U.S. government
.info	Information (unrestricted)
.int*	International organizations
.jobs	Employment
.mil*	U.S. military
.museum	Museums
.name	Individuals and families
.net*	Network (unrestricted)
.org*	Nonprofit organization (unrestricted)
.pro	Certain professions

FIGURE 15.11 Some top-level domains and their general purpose (* indicates an original TLD)

Distinctions between Client-Server and Peer-to-Peer

- Client-server
  - Asymmetric relationship
  - Client predominately makes requests, server makes replies
- Peer-to-peer
  - Symmetric relationship

Networking

- Computer networks have opened up an entire frontier in the world of computing called the **client/server model**

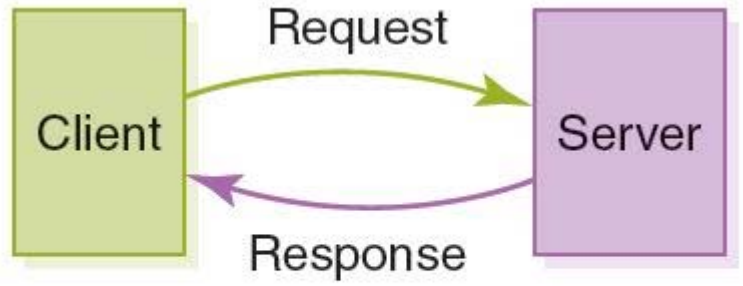
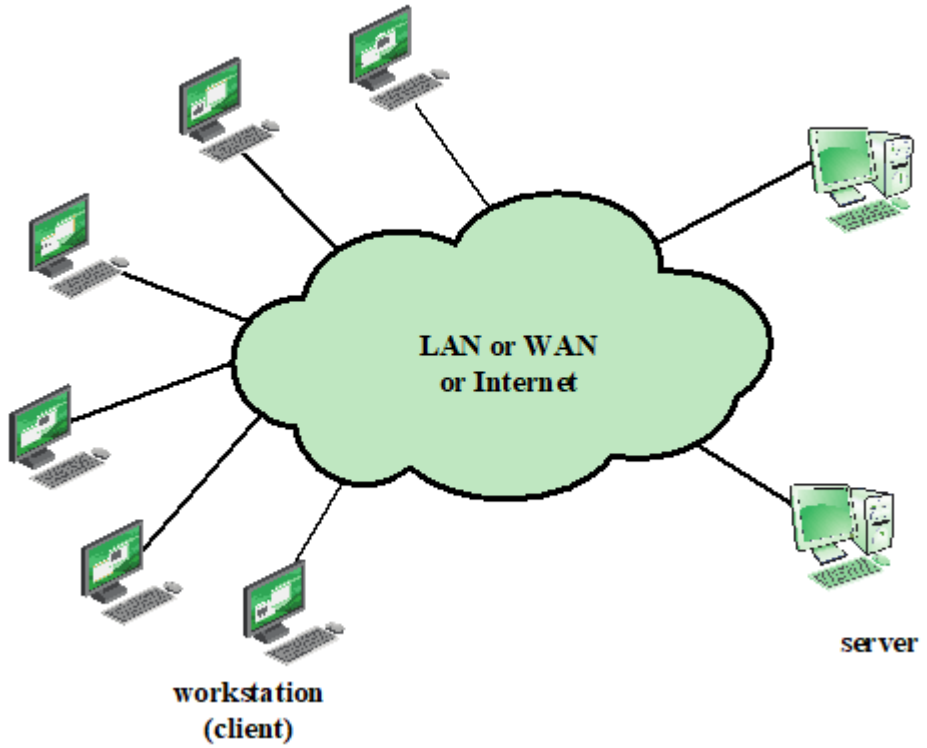


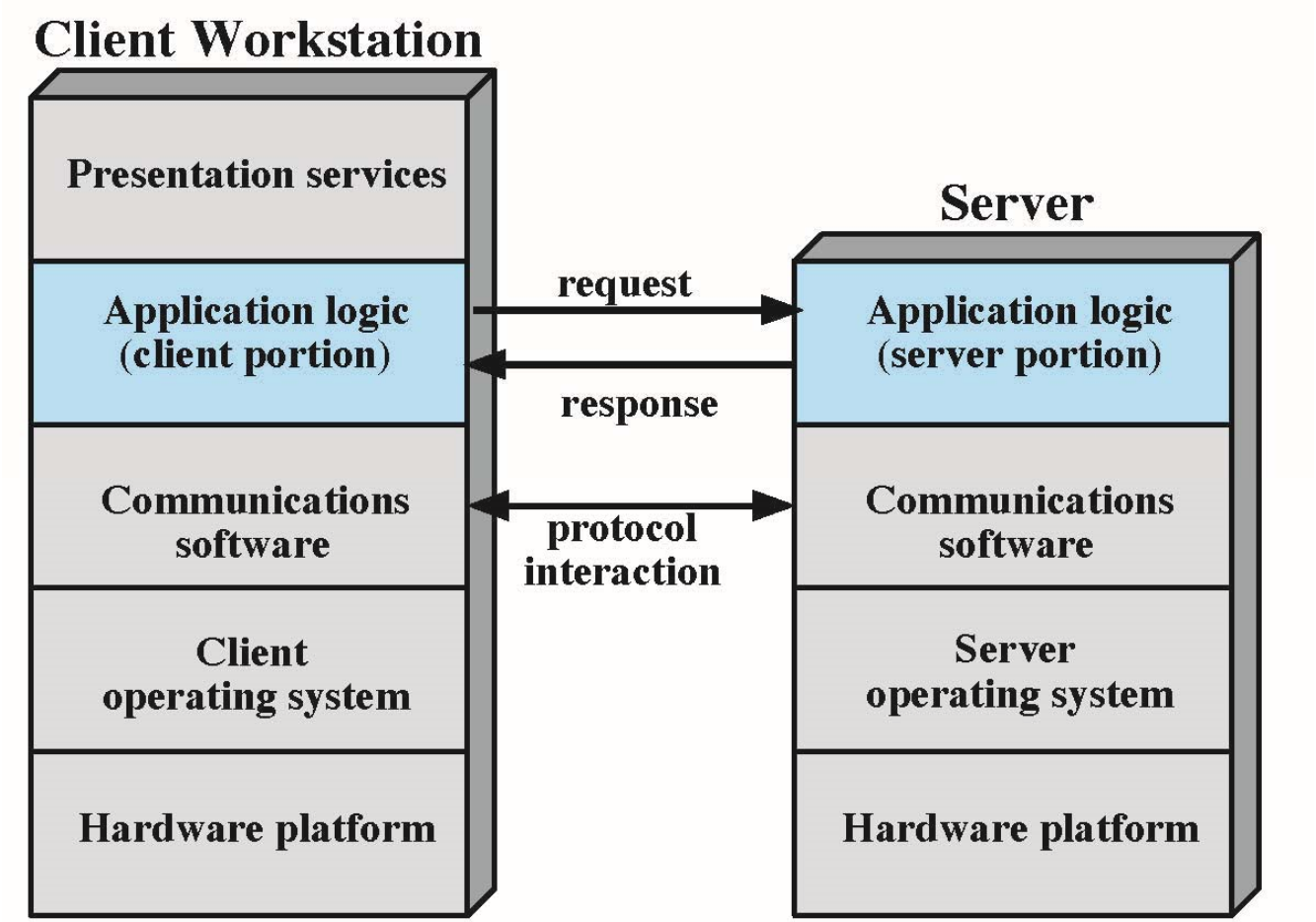
FIGURE 15.1 Client/server interaction

Client/Server Computing

- **Client** machines:
  single-user PCs or workstations that provide a highly *user-friendly interface* to the end user
- The **server** provides a set of shared user services to the clients
- The server enables **many clients** to access shared resources (e.g. a large database).
- The **server** typically runs on a cloud or a high-performance computer system.



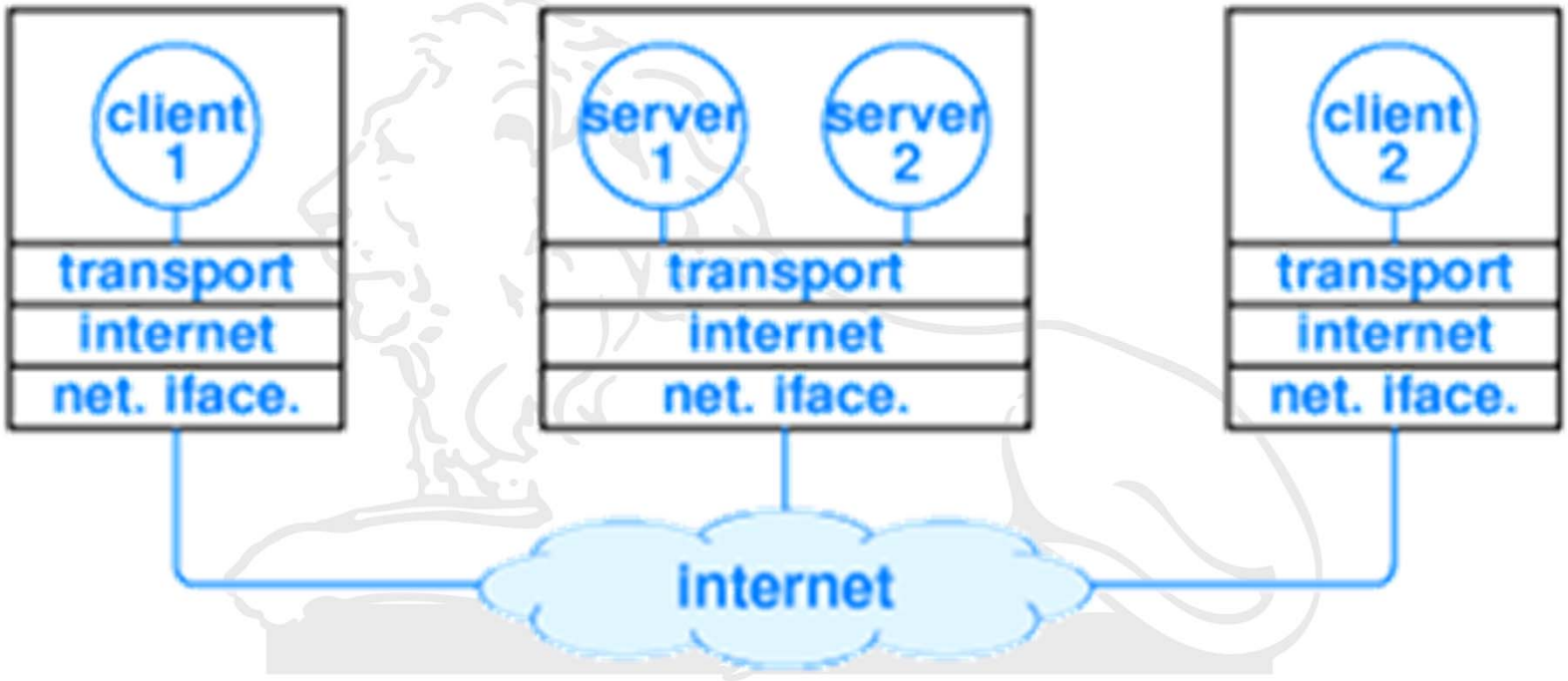
Generic Client/Server Architecture



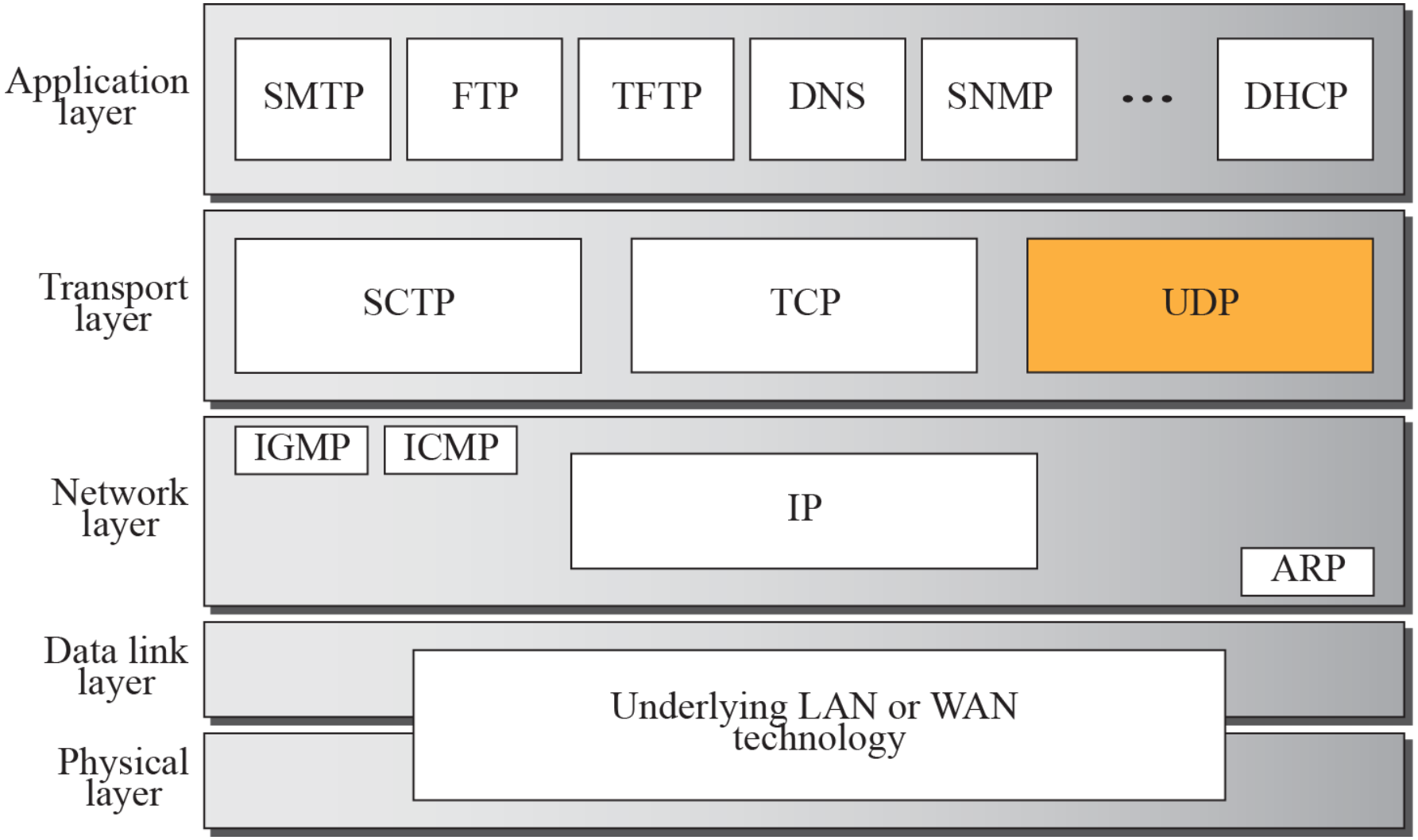
Some Server Types

- A **file server** is a computer and storage device dedicated to storing files. Any user on the network can store files on the server.
- A **print server** is a computer that manages one or more printers.
- A **network server** is a computer that manages network traffic.
- A **database server** is a computer system that processes database queries.

Multiple services



Position of UDP in the TCP/IP protocol suite



UDP vs TCP

- UDP
  - Low-level, connectionless
  - No reliability guarantee
- TCP
  - Connection-oriented
  - Not as efficient as UDP

- Why use UDP?
  - TCP connection is impossible
  - TCP connection is too expensive
  - TCP connection expense is wasteful
  - Communication pattern isn't point-to-point

UDP: User Datagram Protocol

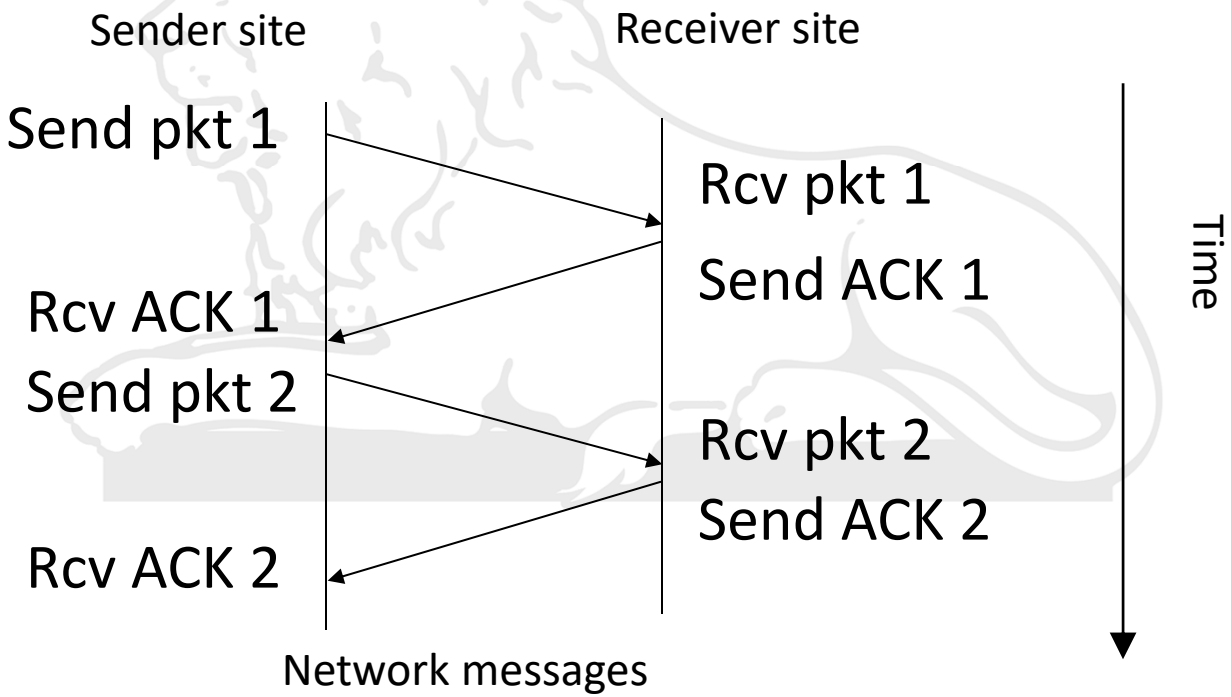
- In TCP/IP protocol suite, using IP to transport datagram (similar to IP datagram).
- Allows a application to send datagram to other application on the remote machine.
- Delivery and duplicate detection are not guaranteed.
- Low overhead: faster than TCP
- UDP (User Datagram Protocol) creates a transport layer connection between two processes.
- The port number identifies the process, or running application program. So using the port number, UDP directs the packet to the correct location.
- UDP does little else. No flow control. No ack of received packets. Only error control is if a checksum error is detected, it quietly drops the packet.

Transmission Control Protocol -TCP

- Reliable stream transport
  - Connection oriented (full duplex virtual circuit)
    - Conceptually place call, two ends communicate to agree on details
    - After agreeing application notified of connection
    - During transfer, ends communicate continuously to verify data received correctly
    - When done, ends tear down the connection
    - If UDP is like regular mail, TCP is like phone call
  - Provides buffering and flow control
  - Takes care of lost packets, out of order, duplicates, long delays
  - Isolates application program from network details
  - Jargon
    - Segment = TCP packet
    - Socket= source (address + port) + destination (address + port)

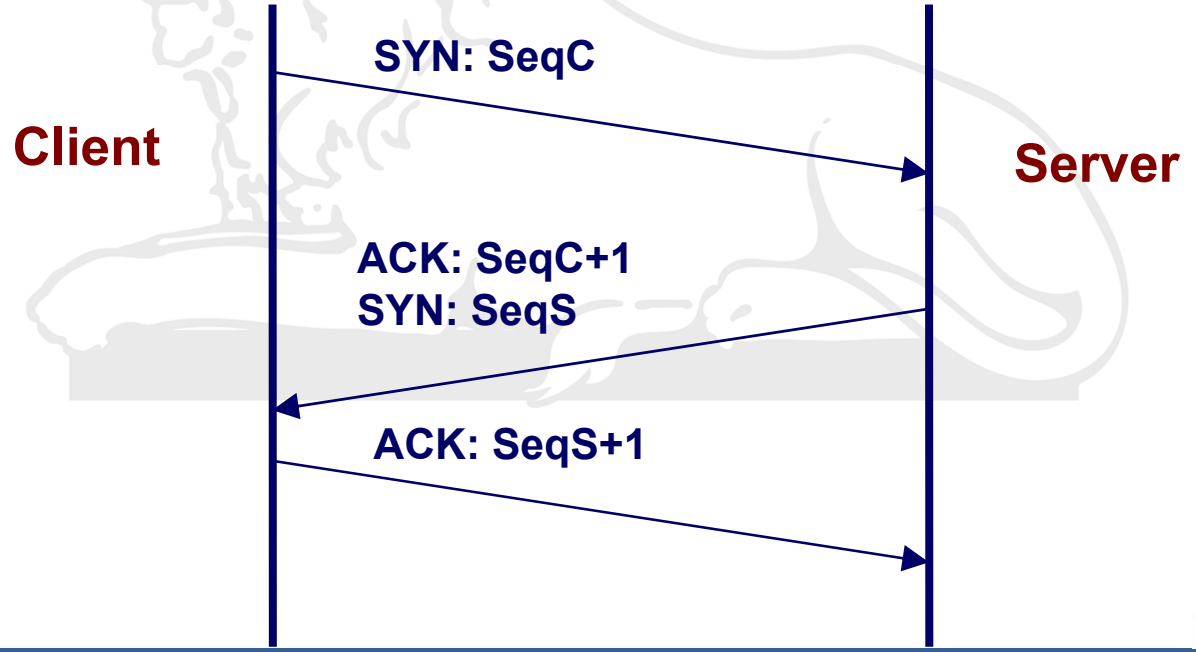
TCP – providing reliability

- Positive acknowledgement (ACK) with retransmission
  - Sender keeps record of each packet sent
  - Sender awaits an ACK
  - Sender starts timer when sends packet



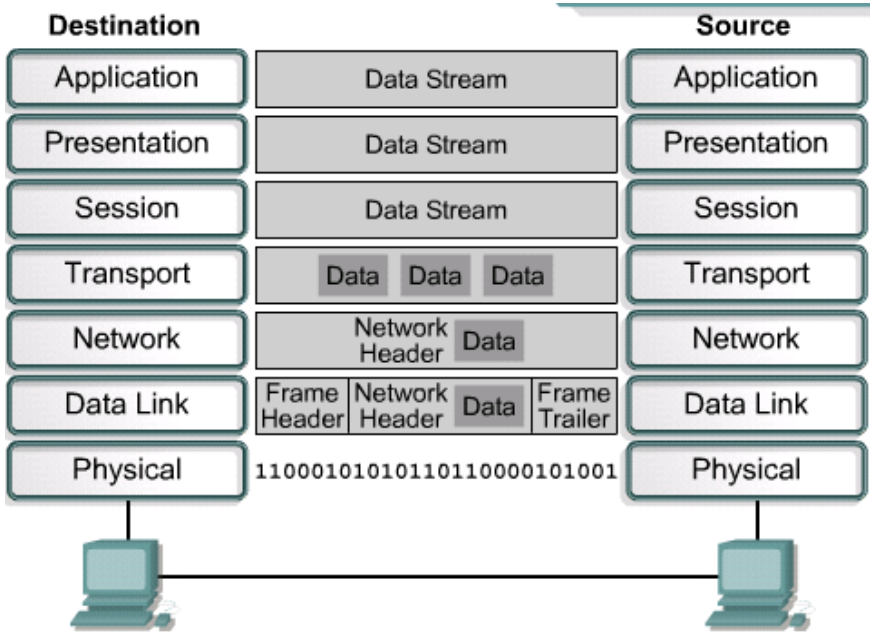
TCP: Establishing Connection

- TCP connection defined by 4-tuple
  - (IP1, Port1, IP2, Port2) --- (google.com, 4093, iitr.ac.in, 22)
- **Three-Way Handshake**
  - Each side notifies other of starting sequence number it will use for sending
  - Each side acknowledges other's sequence number
    - SYN-ACK: Acknowledge sequence number + 1
  - Can “piggy-back” second SYN with first ACK

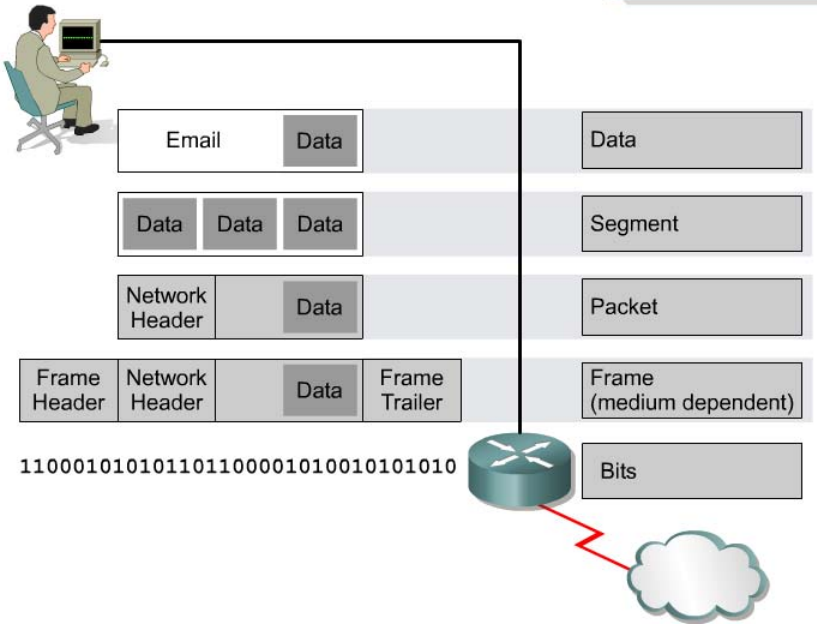


Detailed encapsulation process

- If one computer (host A) wants to send data to another computer (host B), the data is packaged through a process called *encapsulation*
- As the data packet moves down through the layers of the OSI model, it receives headers, trailers, and other information.



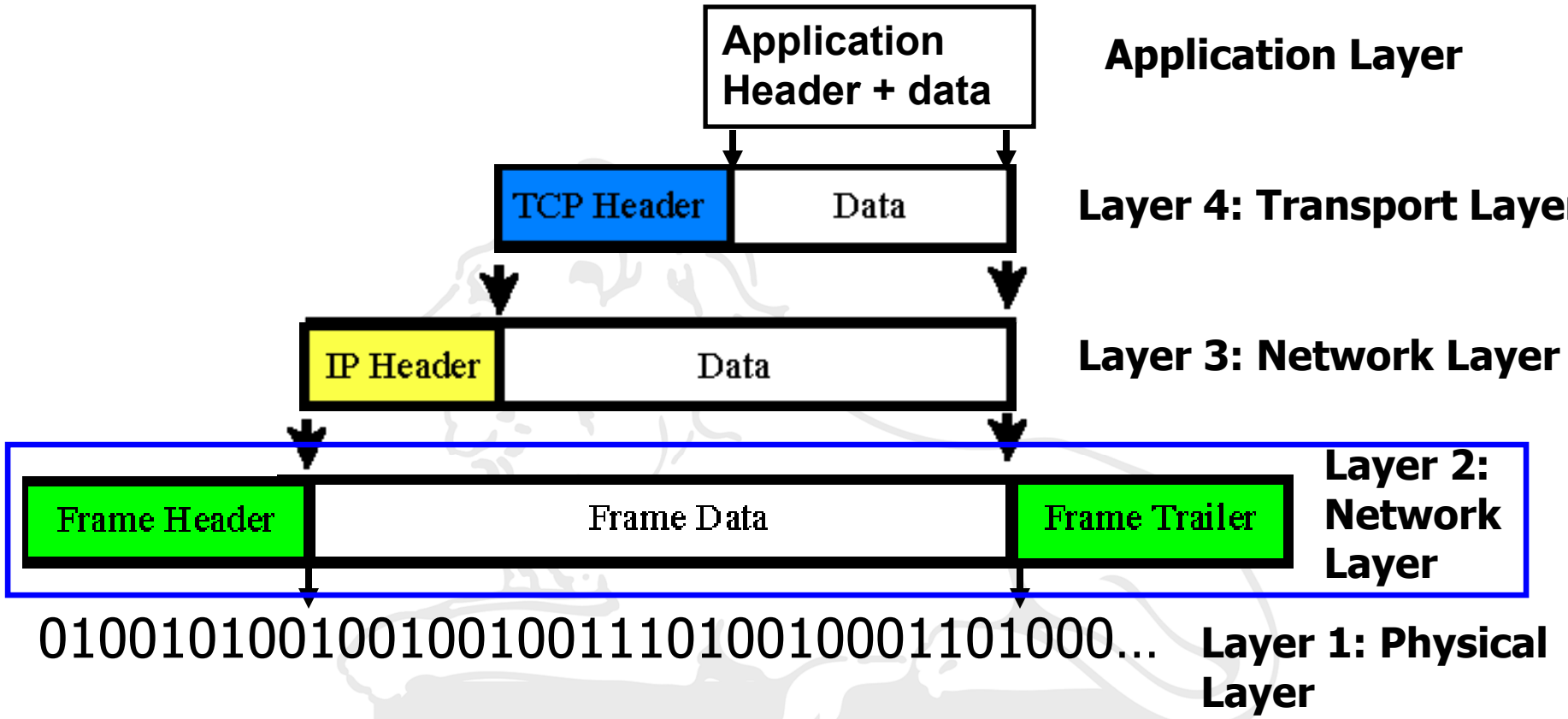
Detailed encapsulation process



Networks must perform the following five conversion steps in order to encapsulate data:

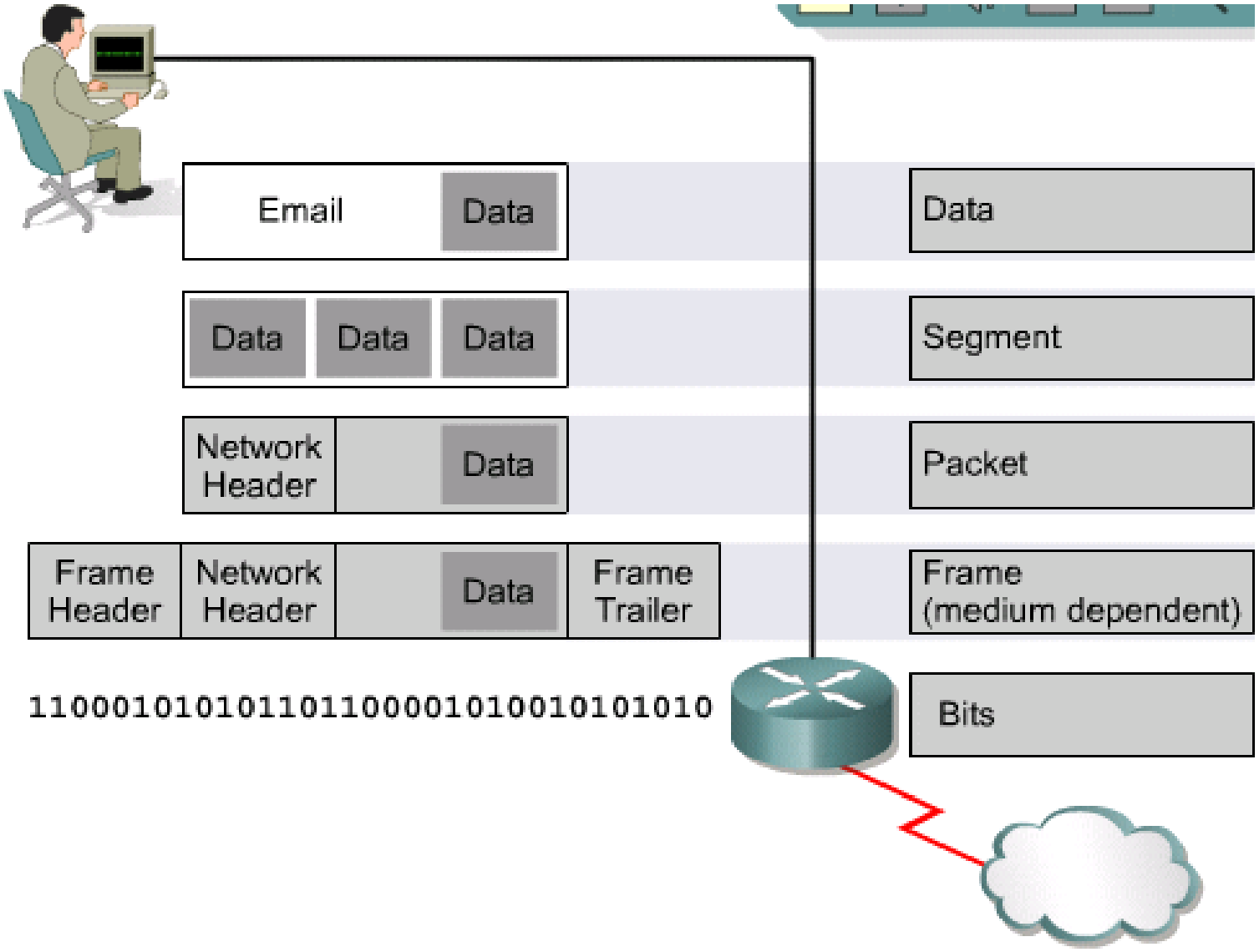
1. **Build the data.**
2. **Package the data for end-to-end transport.**
3. **Add the network IP address to the header.**
4. **Add the data link layer header and trailer.**
5. **Convert to bits for transmission.**

Data Encapsulation Example



Let us focus on the Layer 2, Data Link, Ethernet Frame for now.

Encapsulation



Encapsulation and decapsulation