Computer Networks Vs. Distributed Systems

- **Computer Networks:**
  - **A computer network is an interconnected collection of autonomous computers able to exchange information.**
  - **A computer network usually require users to explicitly login onto one machine, explicitly submit jobs remotely, explicitly move files/data around the network.**

- **Distributed Systems:**
  - **The existence of multiple autonomous computers in a computer network is transparent to the user.**
  - **The operating system automatically allocates jobs to processors, moves files among various computers without explicit user intervention.**

Motivation for Computer Network Applications

- **Motivation for business network applications:**
  - **Resource sharing: Data, programs, equipment are available to users regardless of their physical location.**
  - **High reliability: Files and databases could be duplicated on multiple machines. Multiple CPUs prevent total system loss.**
  - **Economically sound: Networked micro computers using the client-server model offer better price/performance ratio than mainframes.**
- **Motivation for personal network applications:**
  - **Access to remote information: Financial information, database access, the Web, newsgroups.**
  - **Person to person communication: Email, voice, videoconferencing.**
  - **Interactive entertainment: Video on demand, interactive TV, networked games.**

The Client-Server Model

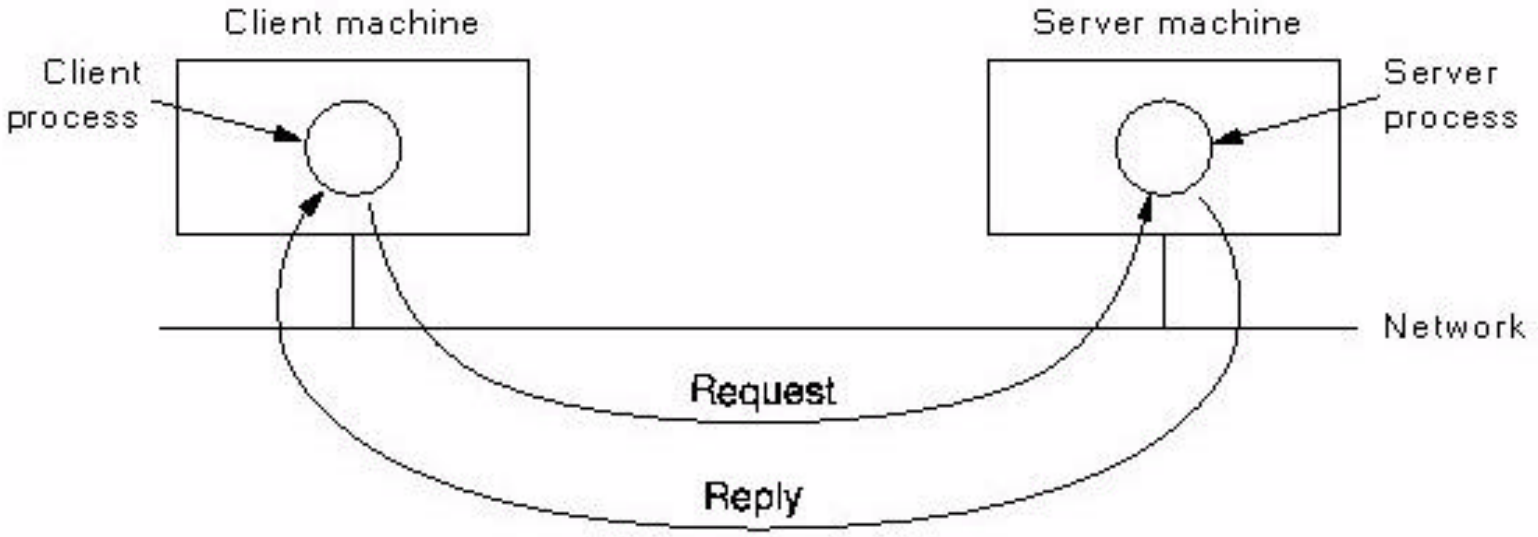


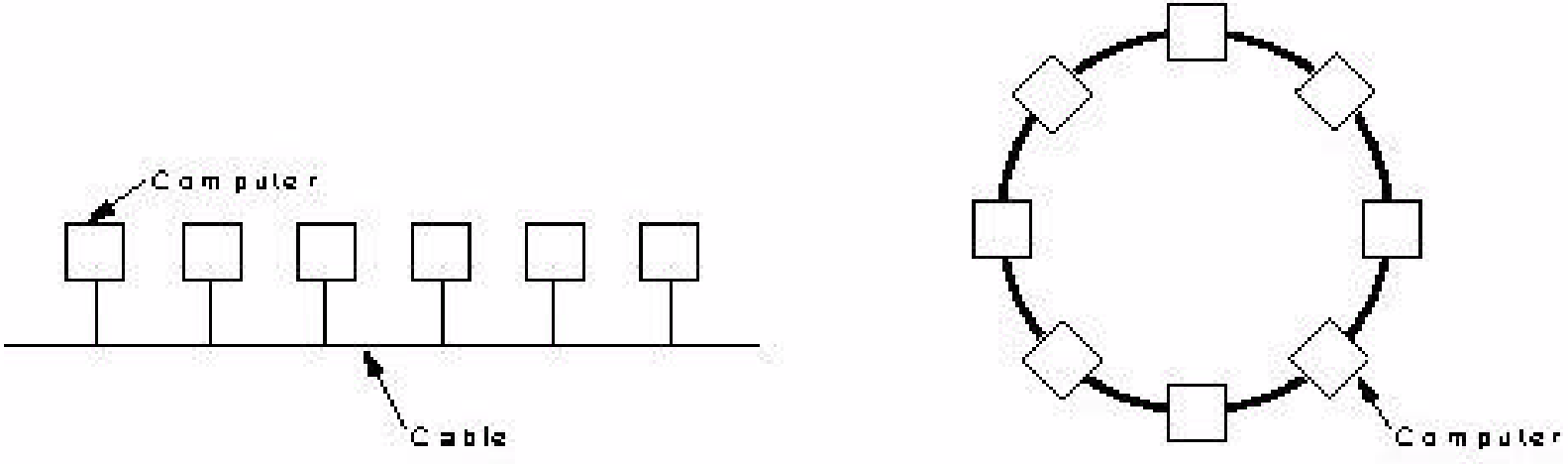
Fig. 1-1. The client-server model.

Classification of Computer Networks

- **Based on transmission mode:**
  - **Broadcast networks:**
    - **Use a single communication channel shared by all computers in the network**
    - **Short messages (packets) are sent by any machine and received by all other computers on the network**
    - **An address is used in the message to select the target machine.**
    - **Most localized networks are broadcast networks**
  - **Point-to-point-networks:**
    - **Consist of many connections between individual pairs of machines.**
    - **A message packet may have to visit one or more intermediate machines before reaching its intended target.**
    - **Routing algorithms play an important role.**
    - **Most large area networks are point-to-point networks.**

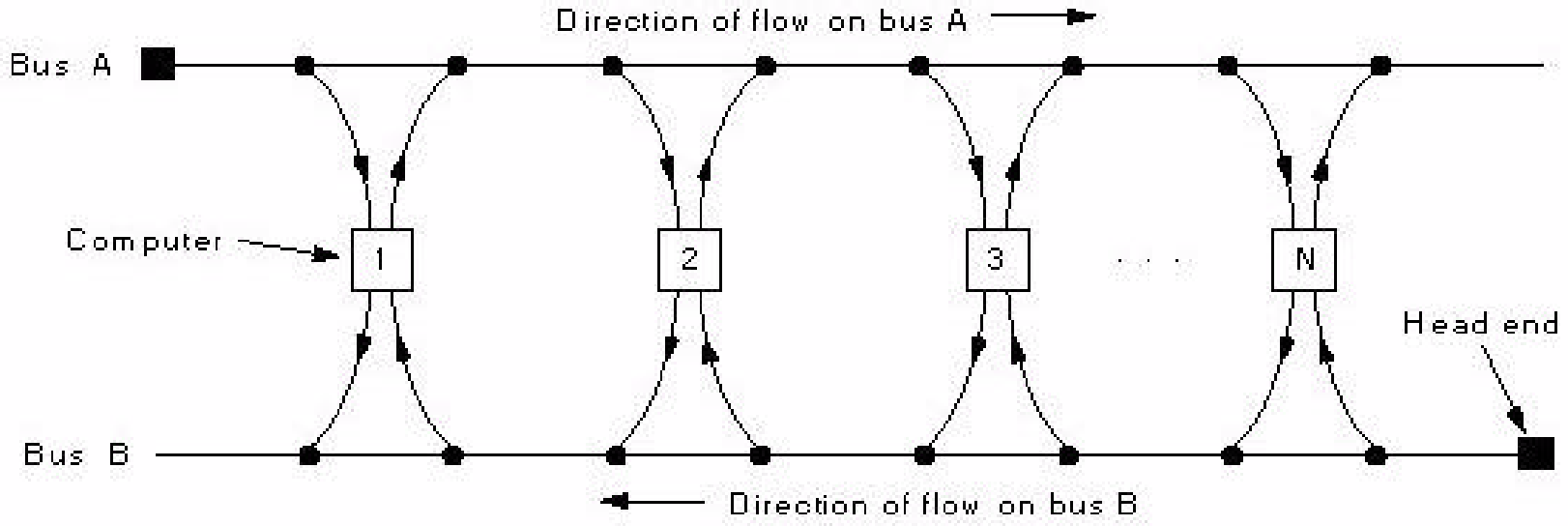
Classification of Computer Networks

- **Based on network scale:**
  1. **Local area networks (LANS): room, building, campus**
     - **Broadcast-based using a bus (Ethernet) or ring topology (Token Ring).**
     - **At any instant only one machine can transmit successfully (unless switches are used to segment the network).**
     - **Conflict arbitration is usually used (Ethernet)**
     - **Operate at 10 Mbps (Ethernet), 100 Mbps (Fast Ethernet), 1000 Mbps (Gigabit Ethernet).**



Classification of Computer Networks

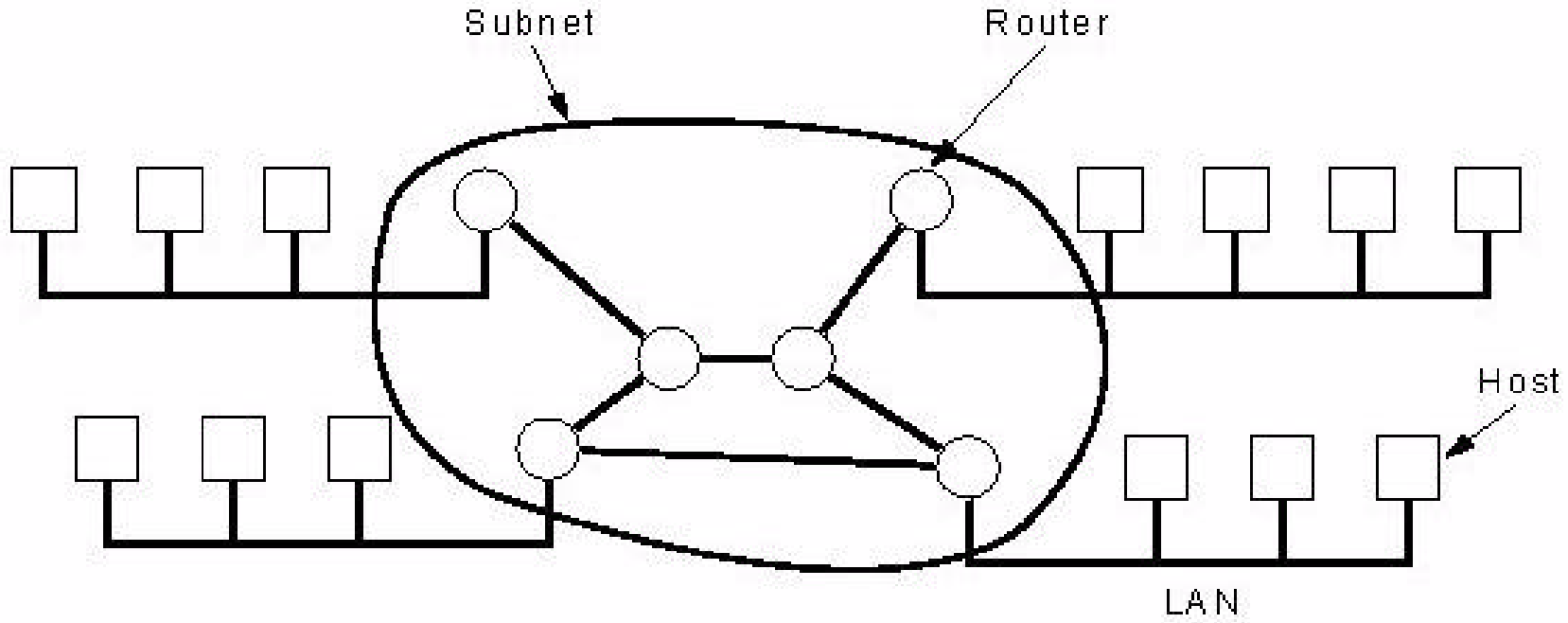
- **Based on network scale:**
  2 **Metropolitan area networks (MANS): city**
  - **Uses Distributed Queue Dual Bus (DQDB)**
  - **Traffic destined to the right of the computer uses the upper bus while traffic destined to the left uses the lower bus.**



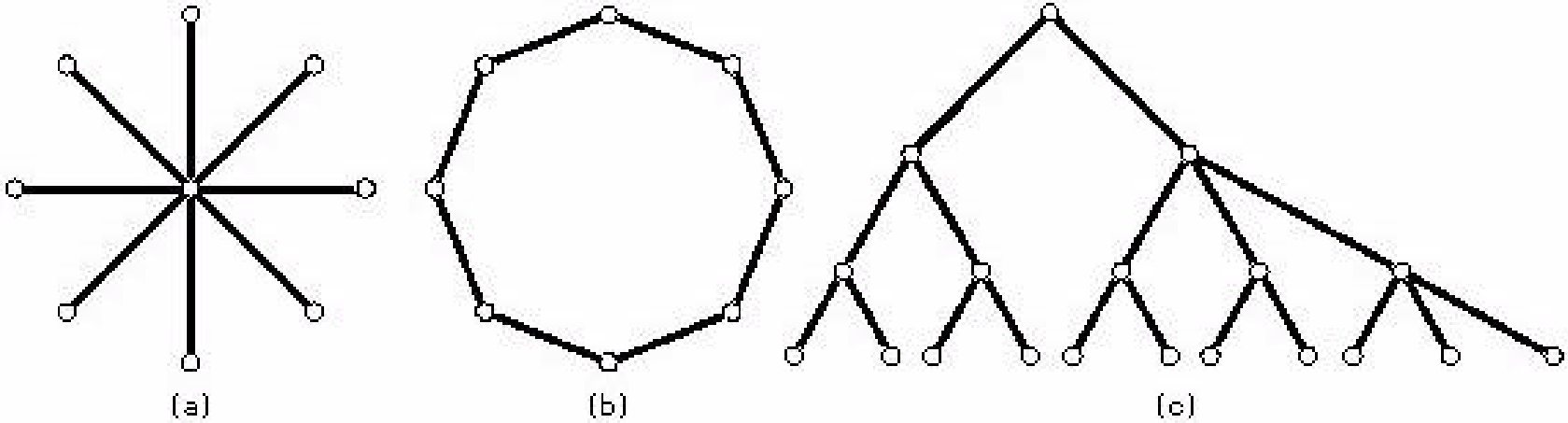
Classification of Computer Networks

- **Based on network scale:**
  - 3 **Wide area networks (WANS): Large geographical areas**
    - **Consists of hosts (machines intended to run applications).**
    - **Hosts and their LANS are connected by a communication subnet which carries messages from host to host.**
    - **Subnets consist of:**
      - **Transmission lines (circuits, channels, trunks).**
      - **Switching elements: Specialized computers used to connect two or more transmission lines. These elements are also called routers.**
    - **Subnets are usually packet-switched (use point-to-point communication and routing algorithms).**
    - **Each host and its associated LAN are connected to the subnet using one or more routers.**
    - **The router interconnection topology is an important issue in WAN design.**

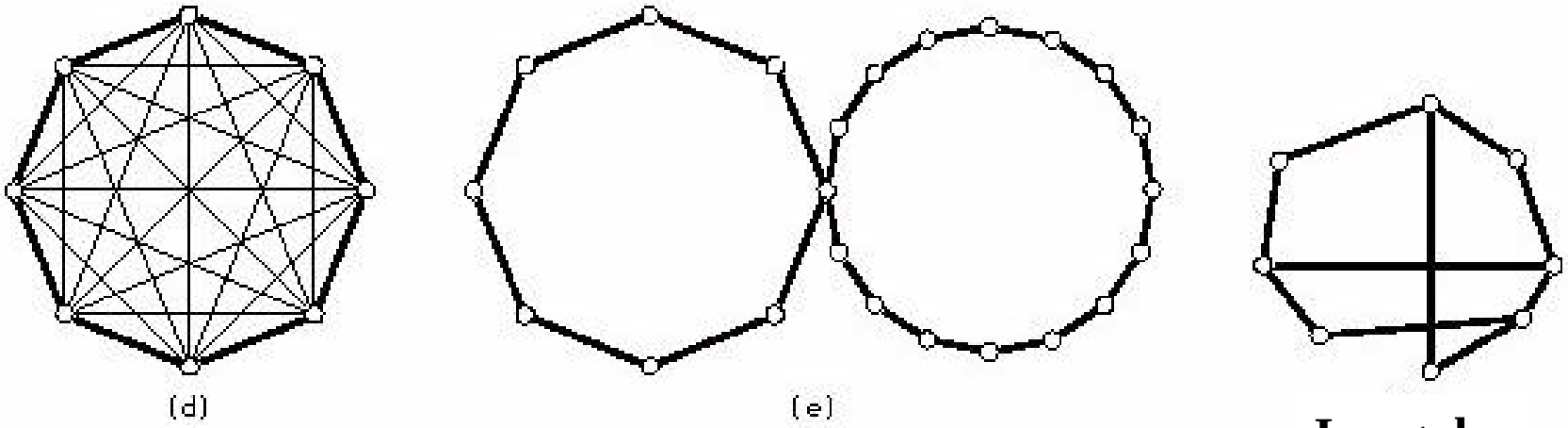
Relation Between Hosts And The Subnet



Possible Router Topologies for Point-to-Point Subnets



Star **Ring** **Tree**



Irregular

Complete **Intersecting Rings**

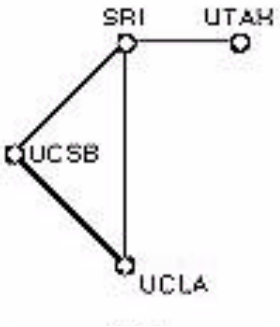
Interprocessor distance	Processors located in same	Example
0.1 m	Circuit board	Data flow machine
1 m	System	Multicomputer
10 m	Room	Local area network
100 m	Building	
1 km	Campus	
10 km	City	Metropolitan area network
100 km	Country	Wide area network
1,000 km	Continent	
10,000 km	Planet	The internet

Fig. 1-2. Classification of interconnected processors by scale.

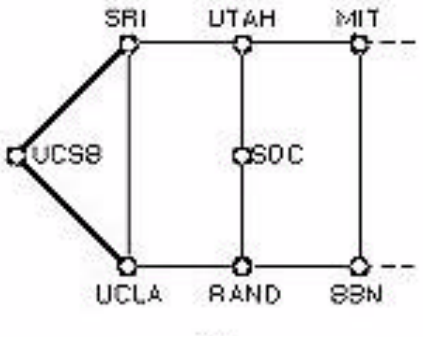
Classification of Computer Networks

- **Based on network scale:**
  - **Global networks: Covers the planet (The Internet)**
    - **Internetworks are networks with different software and hardware interconnected as one network.**
    - **Gateways are computers used to translate between the different hardware and software components of the internetwork.**
    - **The Internet is the largest example of internetworks.**
    - **The Internet started in the late sixties as ARPANET, a government-sponsored network between a small number of universities and government centers.**
    - **The National Science Foundation expanded ARPANET into NSFNET (several thousand hosts in 1988).**
    - **TCP/IP emerged as its standard network software.**
    - **The number of hosts on The Internet is more than 50 million hosts today.**

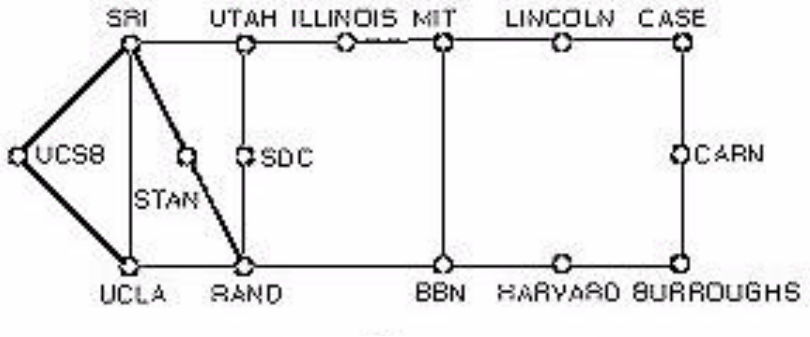
Origin of the Internet: Growth of ARPANET



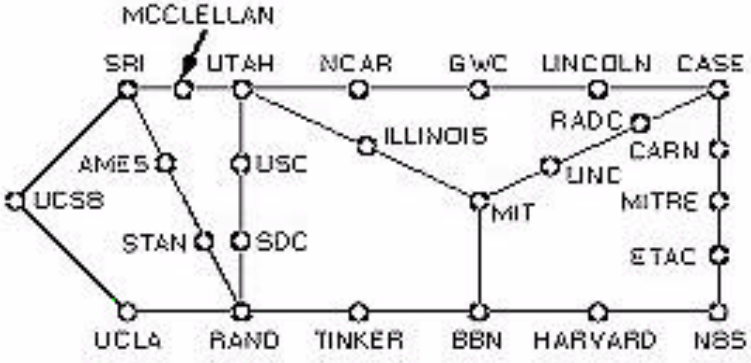
Dec. 1969



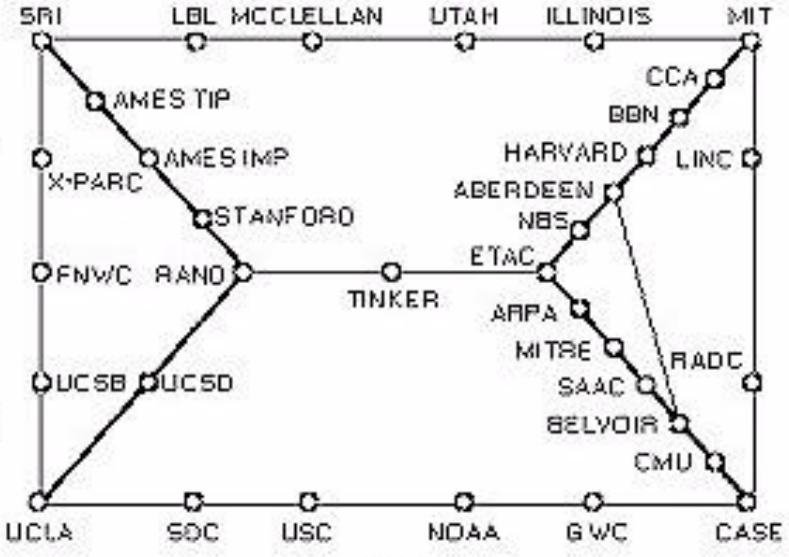
July 1970



March 1971



April 1972



Sept. 1972

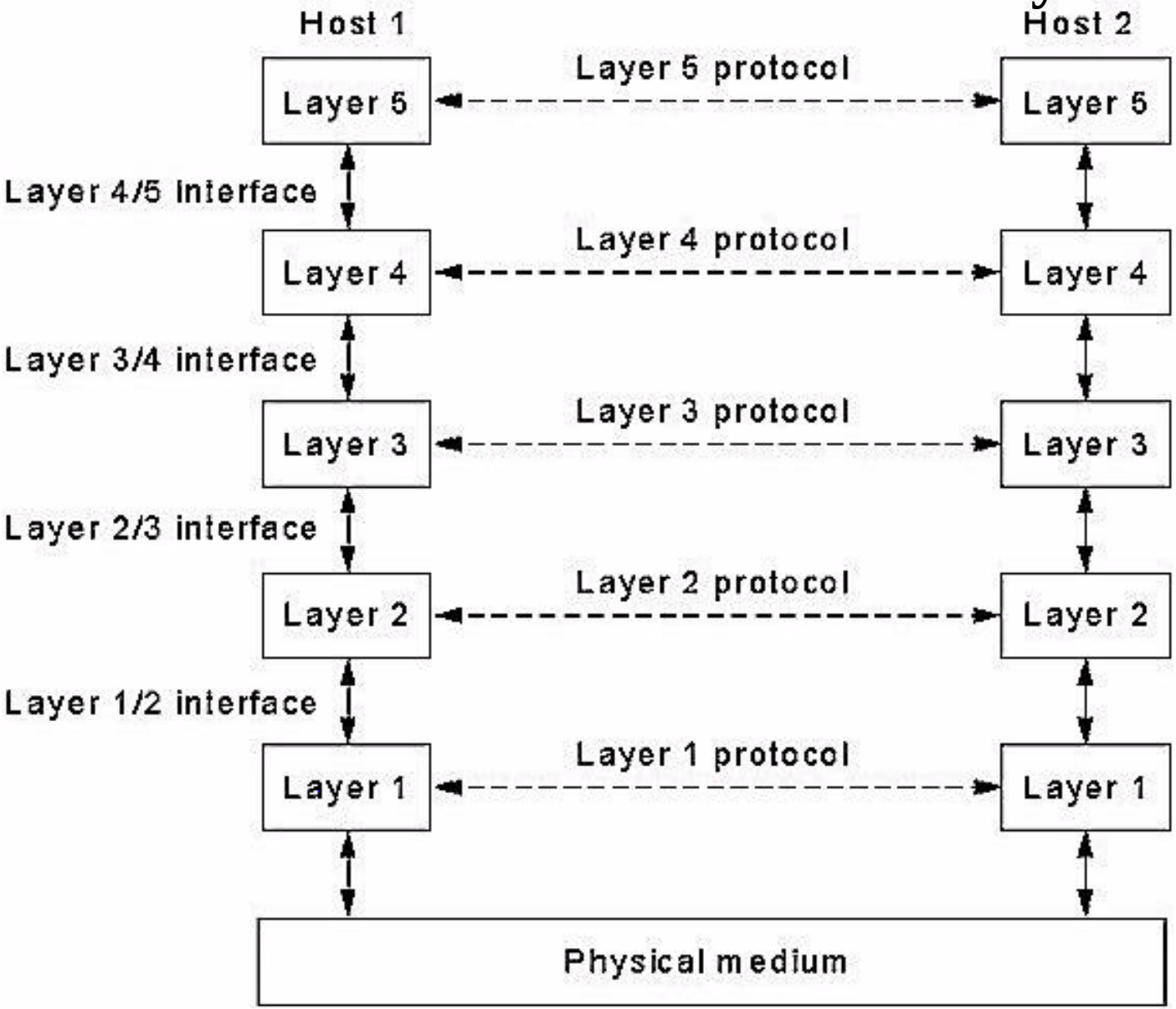
Network Software: The Protocol Hierarchy

- To reduce design complexity, most networks are organized as a series or hierarchy of layers.
- Depending on its functionality, a layer may be implemented in software, hardware or both.
- Layer *n* on one machine communicates with layer *n* on another machine on the network using an agreed upon protocol.
- The entities comprising the corresponding layers on two communicating machines over the network are called peers.
- A protocol is an agreement between the communicating layers on how the communication is to proceed:
  - A formal description of message formats and the rules the two layers must follow to exchange those messages.
  - Protocol definitions range from how bits are placed on a wire to the format of an e-mail message.
  - Standard protocols allow different manufacturers' computers to communicate. These computers can use completely different software/hardware, provided each computer's software can agree upon the meaning of the data.

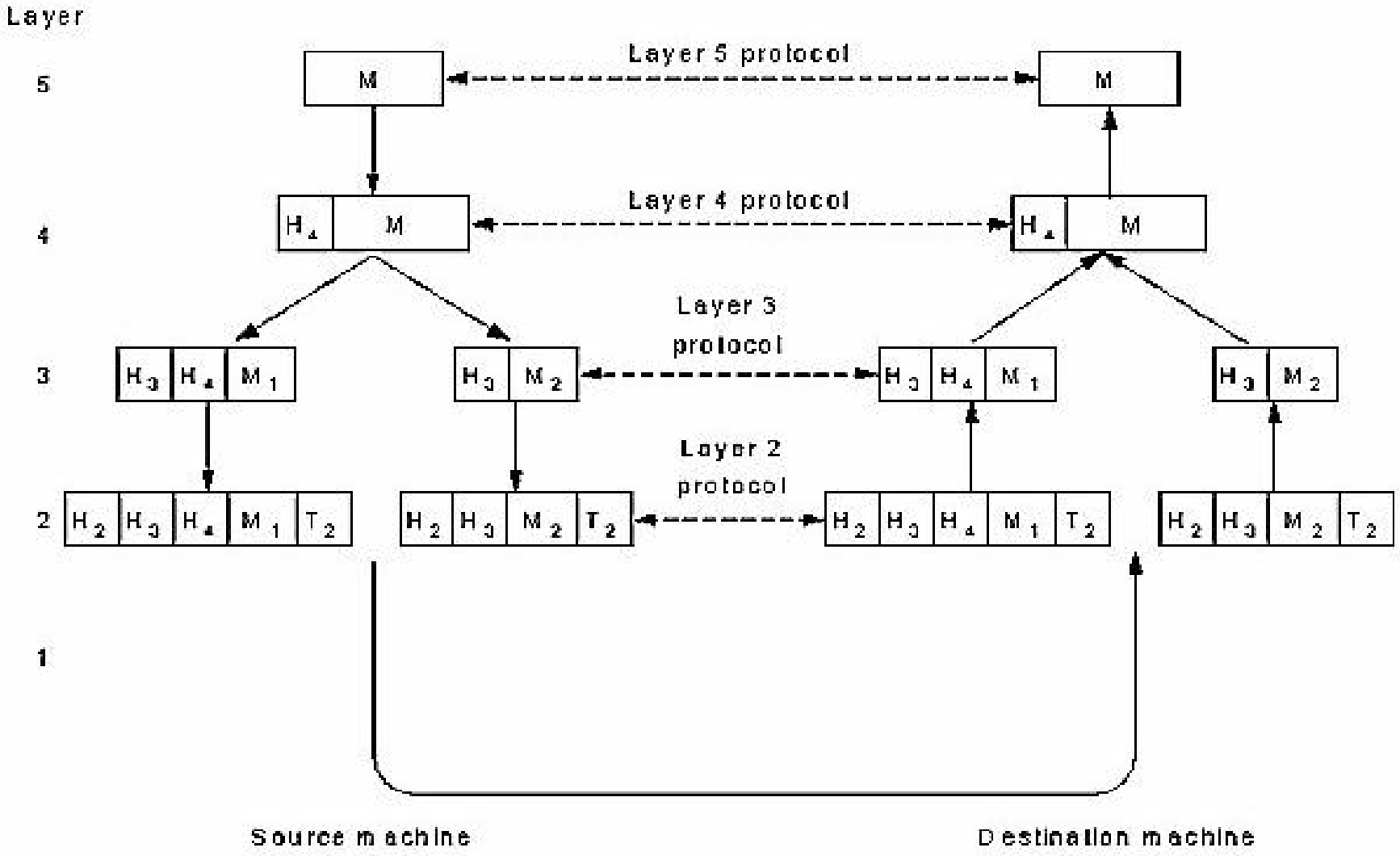
Network Software: The Protocol Hierarchy

- In realty, no data is transferred from layer *n* on any two machines. Data and control information is passed to the layer below.
- Additional information including protocol control information may be appended by each layer to data as it travels from higher to lower layers in the form of layer headers.
- Below layer 1 is the physical medium where the actual communication occur over communication channels (copper wires, optical fibers, wireless channel etc.)
- Between adjacent layers an interface defines which primitive operations and services the lower layer offers to the upper layer.
- The set of layers and associated protocols is called a network architecture.

A Generic Network Hierarchy

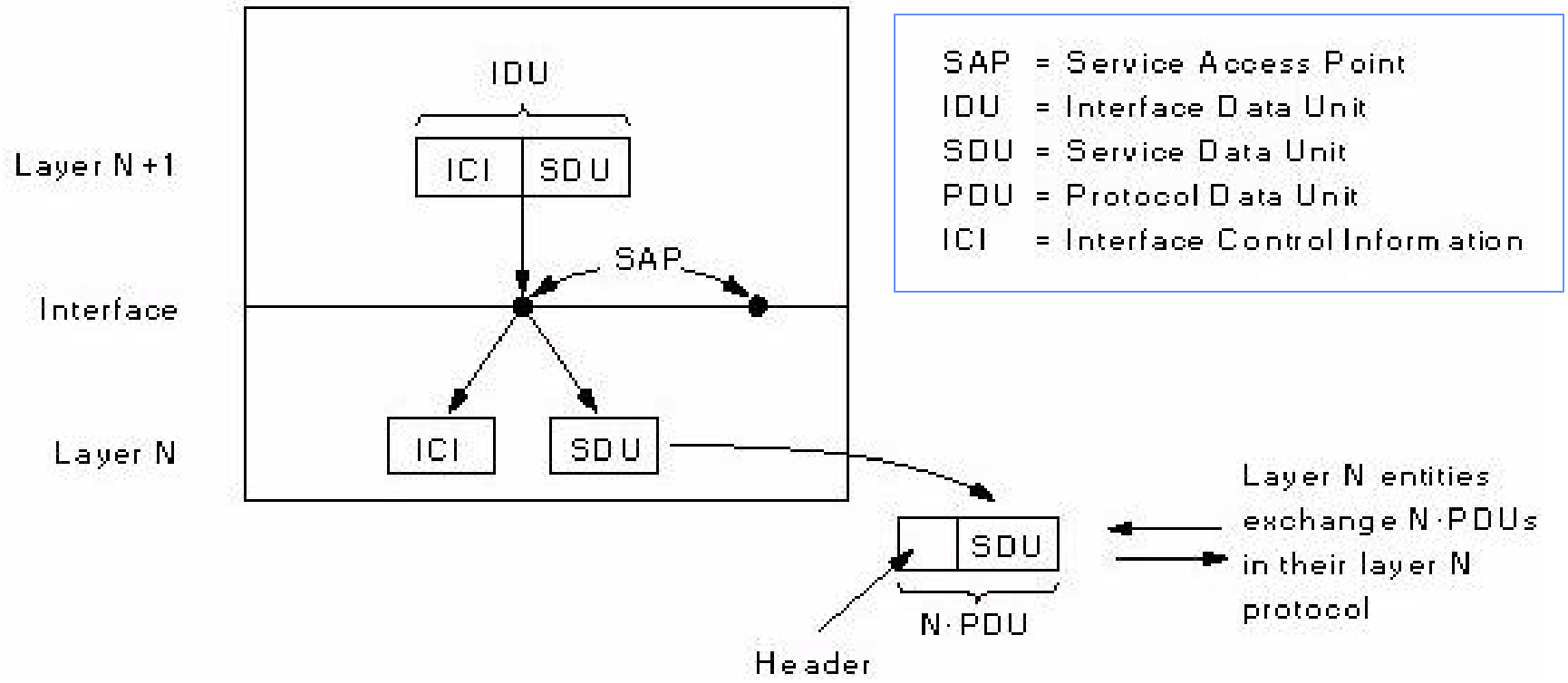


An Example of Information Flow In Layer 5

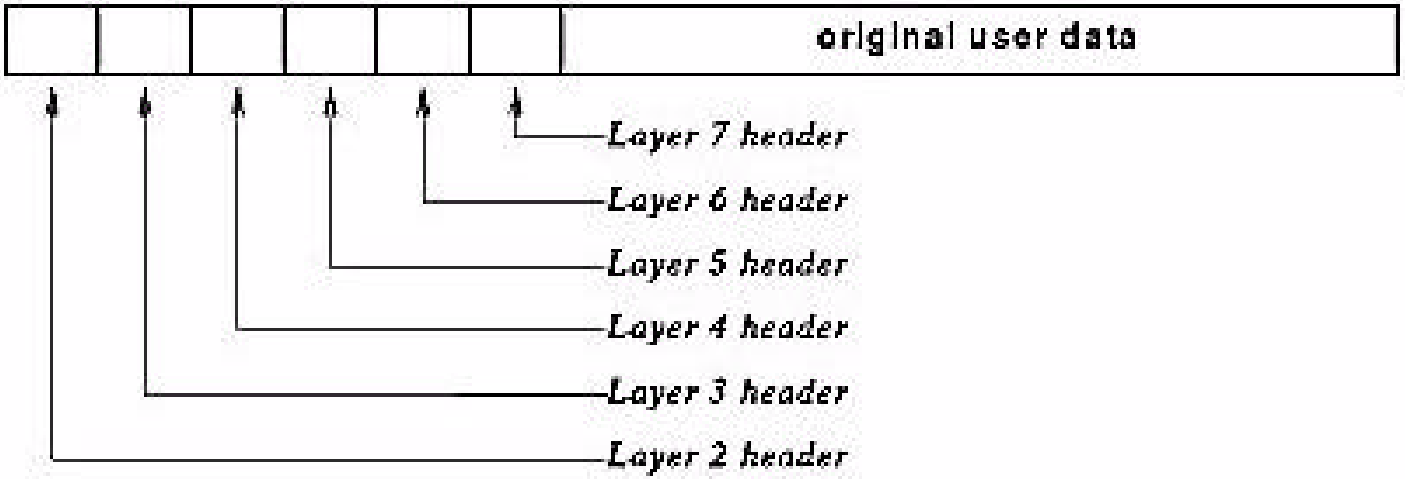


M = Message H = Header

Relationship Between Layers at An Interface



Nested Layer Protocol Headers



Layer headers are appended by each network layer to the original user data as it travels from higher to lower layers.

Types of Network Layer Services

Connection-oriented Service:

A connection is established. Information expected to be received in the order sent. The connection is released when data transmission is completed.

Connectionless Service:

Each message caries the full destination address and routed through the system independent of other messages. Thus messages can arrive out of order.

	Service	Example
Connection-oriented	Reliable message stream	Sequence of pages
	Reliable byte stream	Remote login
	Unreliable connection	Digitized voice
Connection-less	Unreliable datagram	Electronic junk mail
	Acknowledged datagram	Registered mail
	Request-reply	Database query

Four Classes of Service Primitives

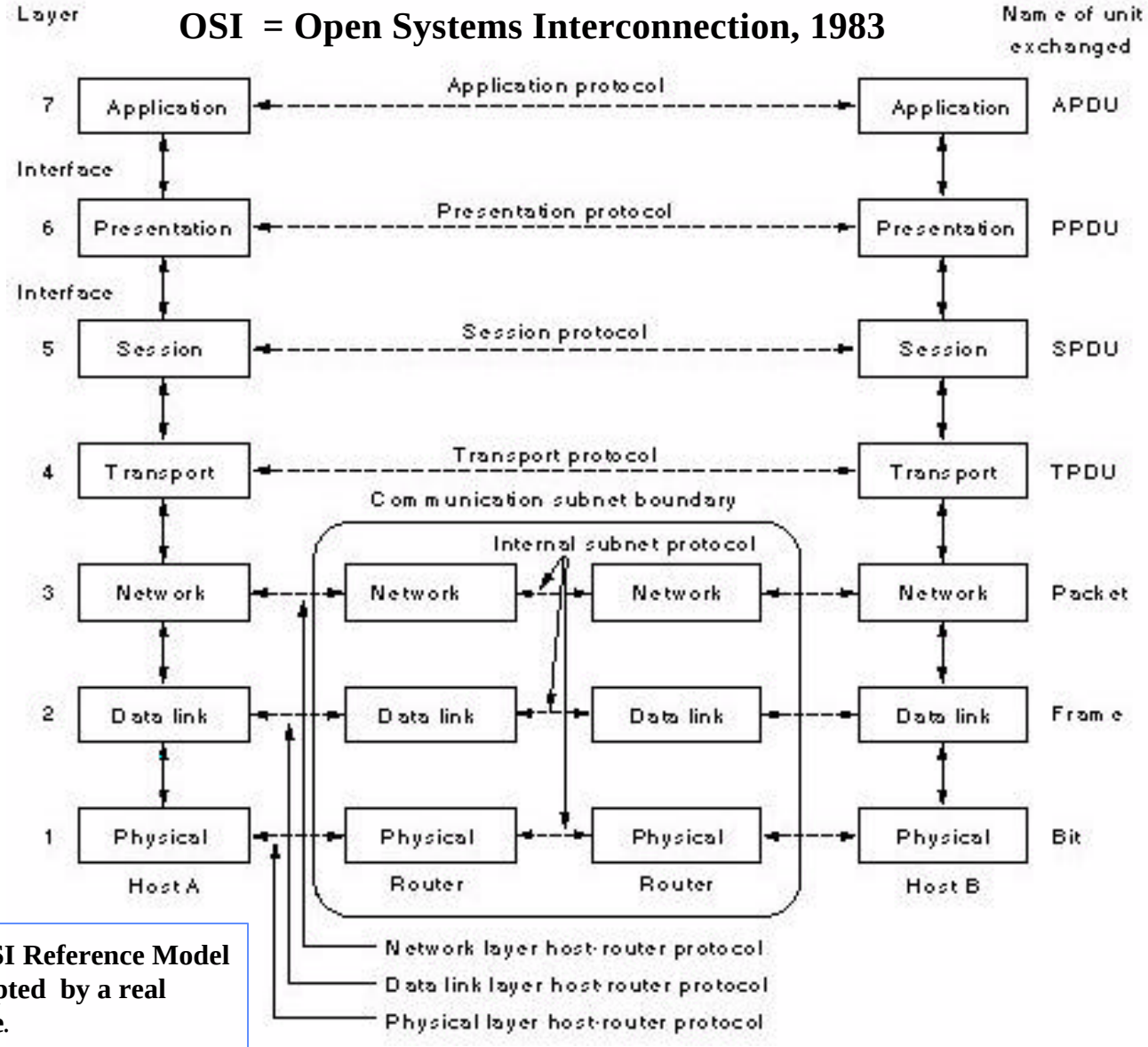
A service is formally specified by a set of primitives (basic operations).

These primitives request the service to perform some action or report an action by a peer entity.

Primitive	Meaning
Request	An entity wants the service to do some work
Indication	An entity is to be informed about an event
Response	An entity wants to respond to an event
Confirm	The response to an earlier request has come back

The OSI Reference Model

OSI = Open Systems Interconnection, 1983



The layers of The OSI Reference Model were never fully adopted by a real network architecture.

OSI Reference Model Layers

1 **The Physical Layer:**

- **Concerned with transmitting raw bits over a communication channel (bit timing, voltage ..)**

2 **The Data Link Layer:**

- **Transform raw transmissions into error-free data.**
- **Data grouped in frames with error detection and/or correction bits added.**
- **Frames are sent and acknowledged by this layer.**

3 **The Network Layer:**

- **Controls the operation of the subnet.**
- **Concerned with routing of data packets from source to destination.**
- **Handles protocol incompatibilities between different networks.**

OSI Reference Model Layers

4 The Transport Layer:

- Accepts data from the session layer and may split it into smaller units.
- Ensures that message units arrive correctly at the destination.
- Determines what type of service is provided to the session layer.

5 The Session Layer:

- Allows users on different machines to establish sessions (login, file transfer, etc.)

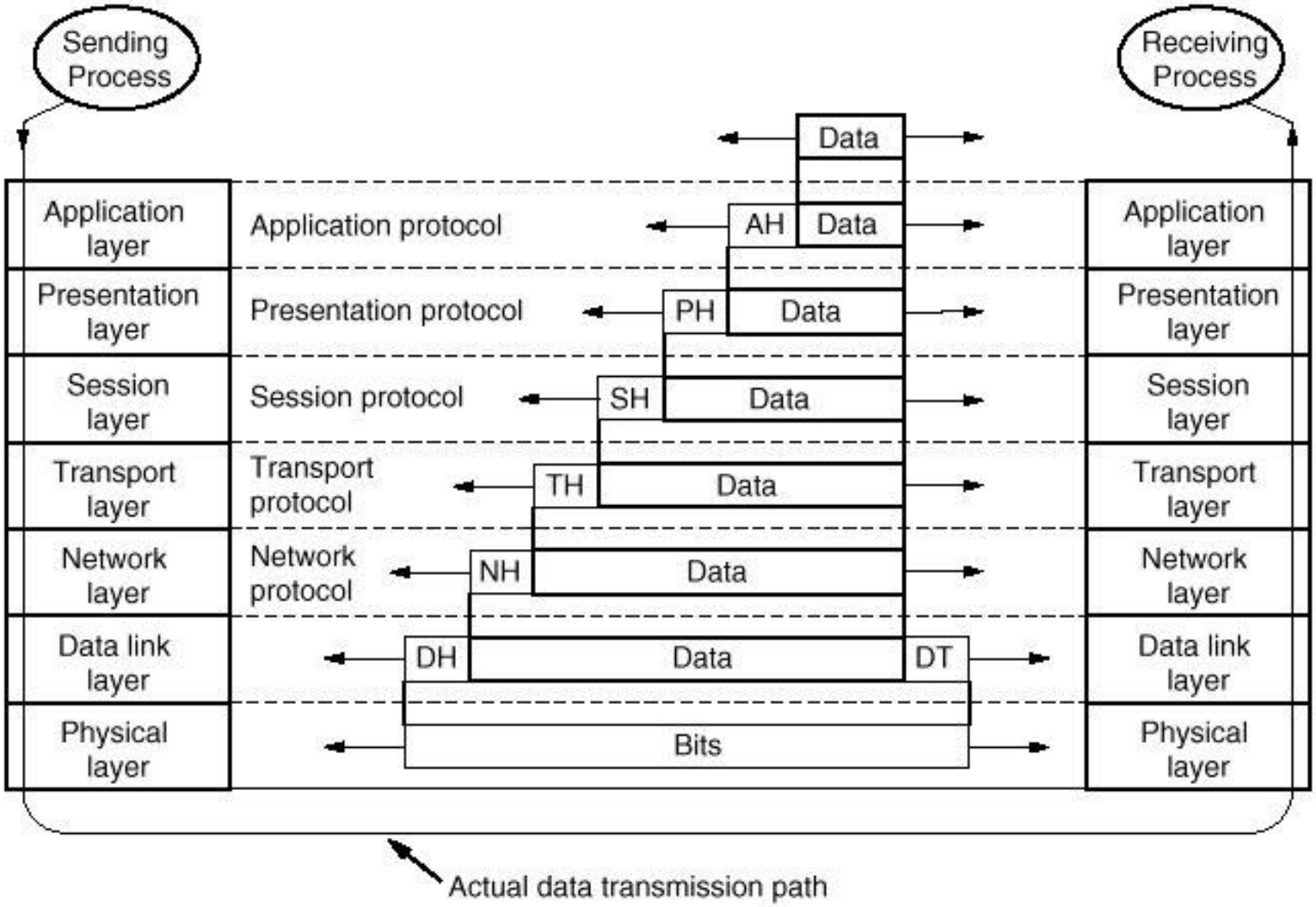
6 The Presentation Layer:

- Concerned with syntax and semantics of the information transmitted.

7 The Application Layer:

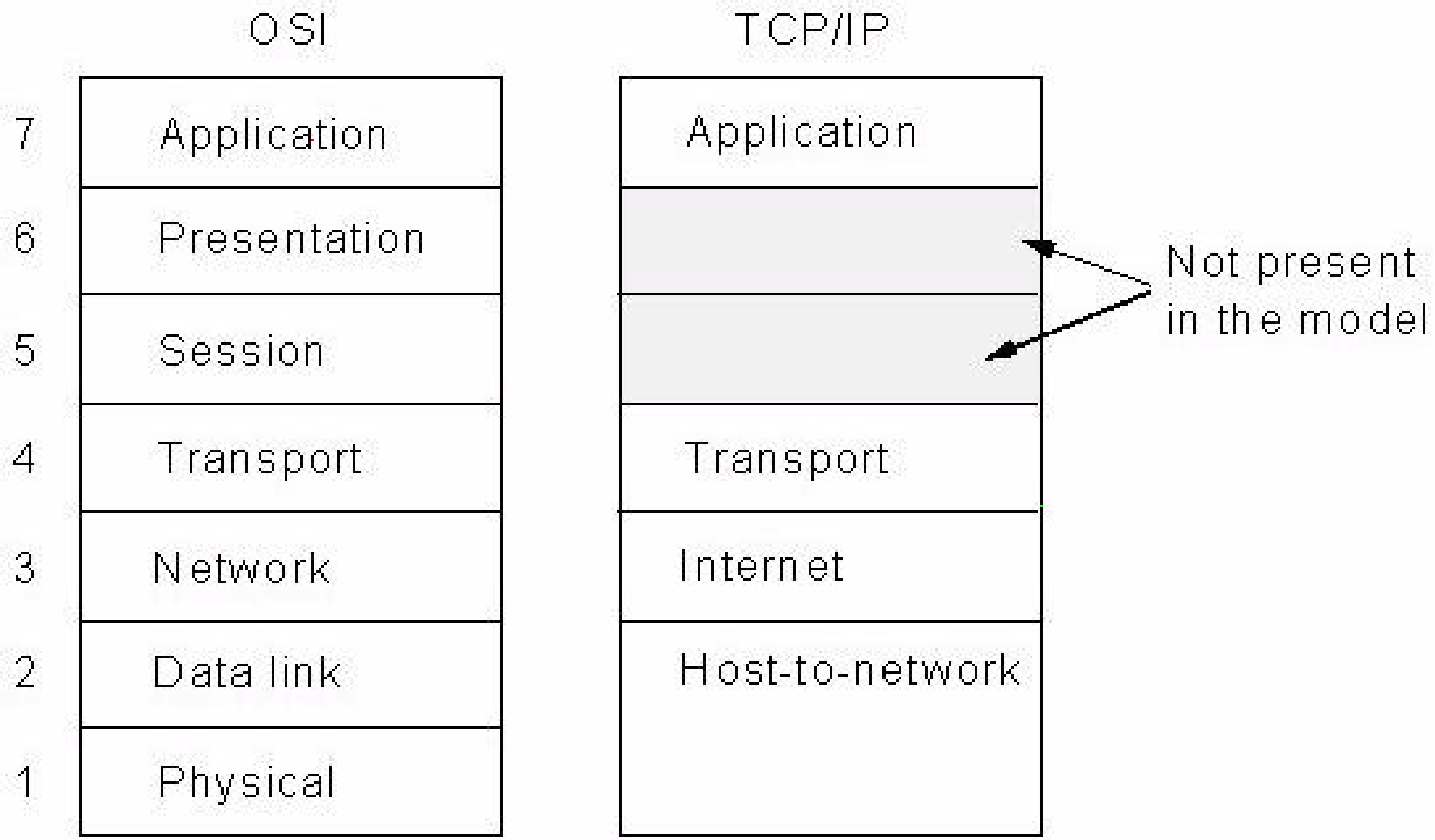
- Handles common needed high level network protocols (e.g. email, FTP, HTTP, TELNET, etc.)

Data Transmission in The OSI Model

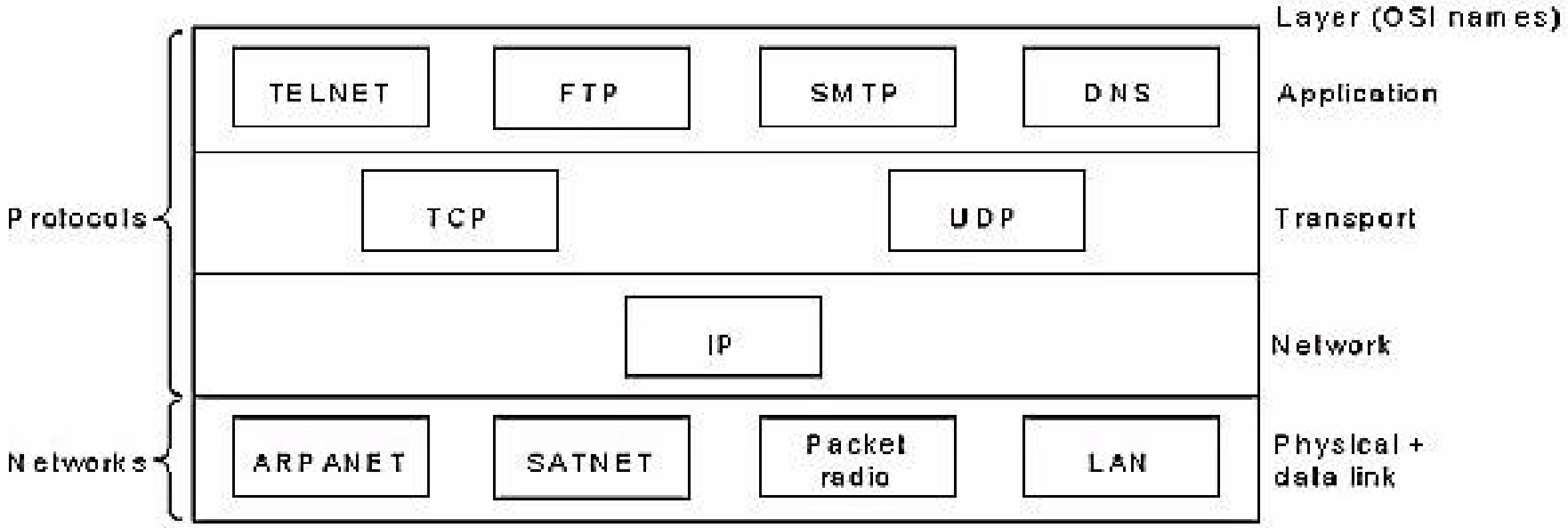


Some headers may be empty

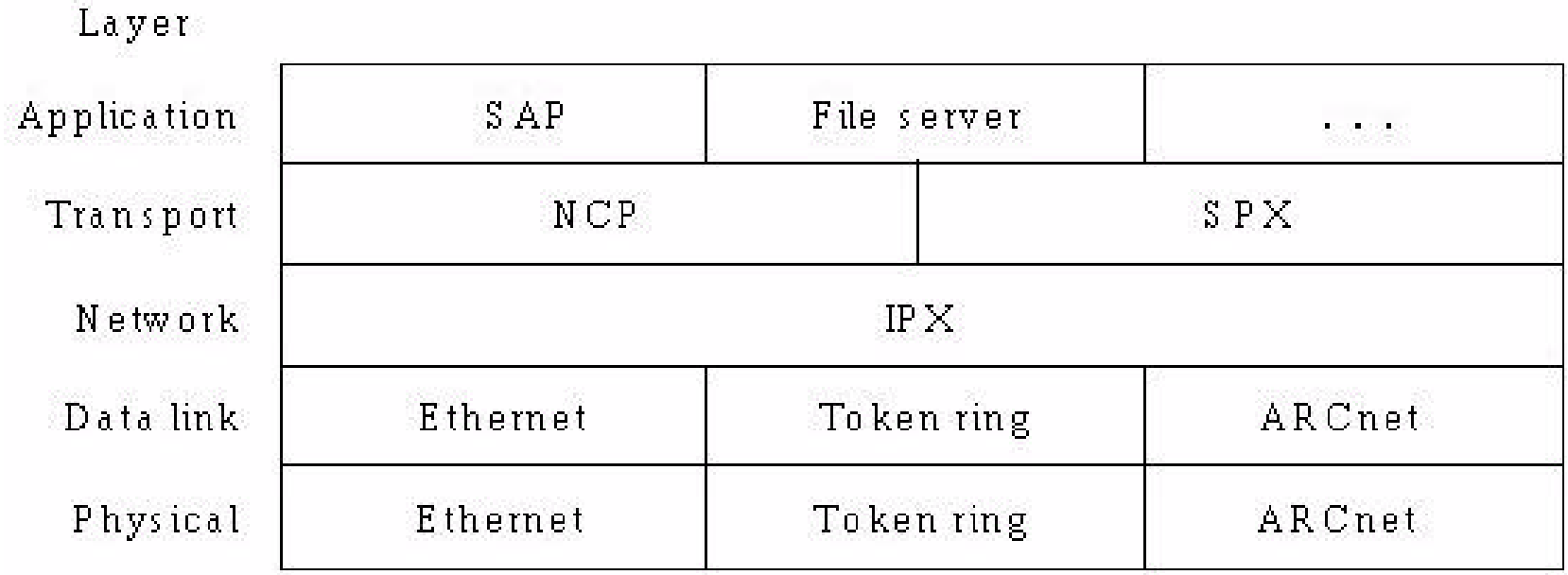
An Example Network Architecture: The TCP/IP Reference Model

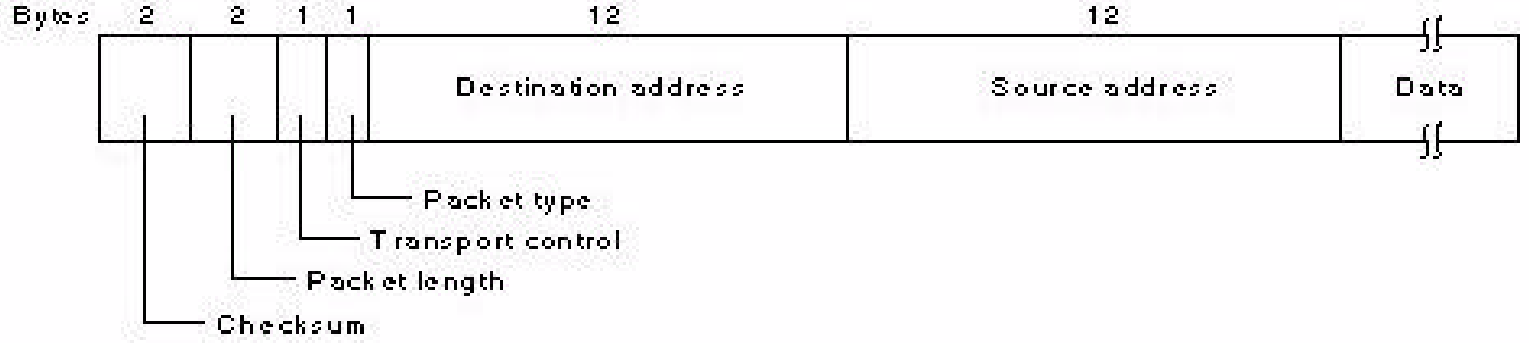


Initial TCP/IP Model Protocols



An Example Network Architecture: Novell NetWare





Hybrid Reference Model Used in This Course