

# Computer Networks

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4<sup>th</sup> Edition

# Syllabus

## Module I

Introduction – Uses – Network Hardware – LAN – MAN – WAN, Internetworks – Network Software – Protocol hierarchies – Design issues for the layers – Interface & Service – Service Primitives. Reference models – OSI – TCP/IP.

Data Link layer Design Issues – Flow Control and ARQ techniques. Data link Protocols – HDLC. DLL in Internet.

# Introduction

- Computer Network:
  - Interconnected collection of autonomous computers
  - 2 computers are **interconnected** if they are able to exchange information
  - *Communication* is the process of *exchanging information* between two persons or devices
  - Connection can be made via *copper wire, fiber optics, microwaves or communication satellites* etc
  - If one computer cannot forcibly start, stop or control another computer then it is termed as **autonomous**

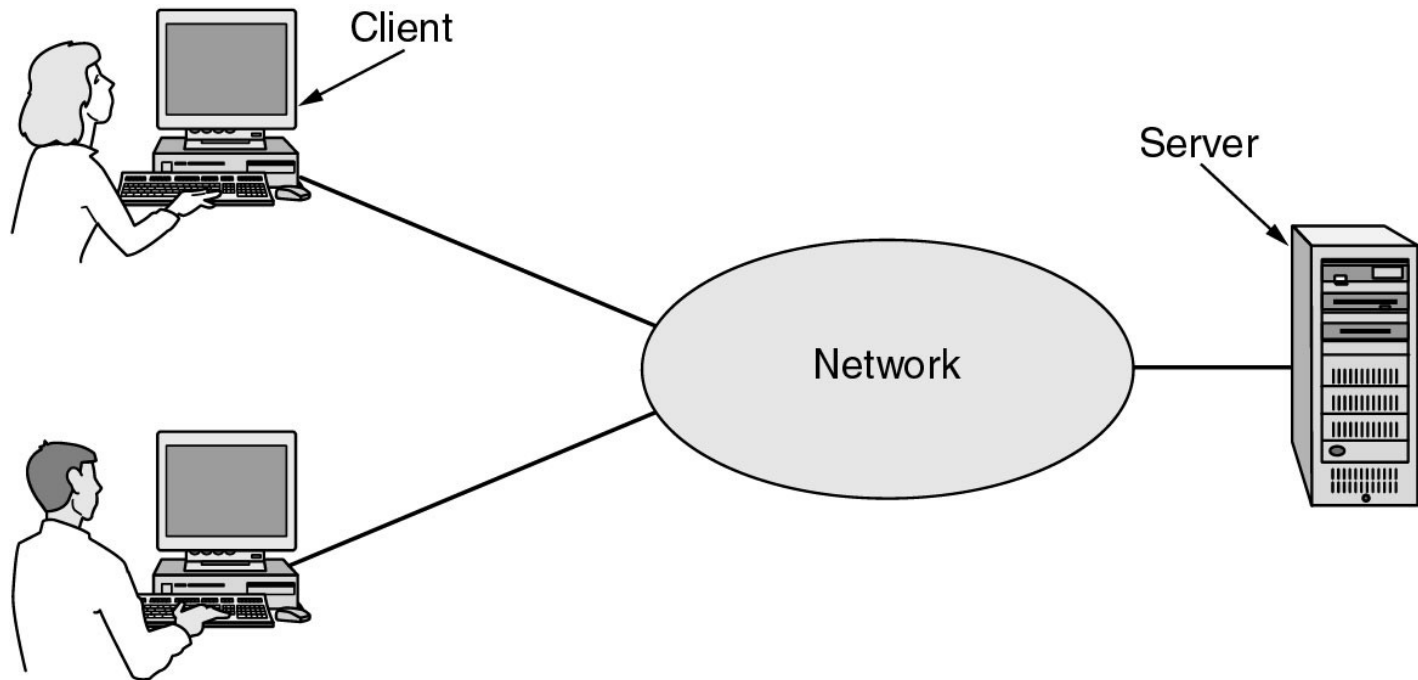
# Uses of Computer Networks

- Business Applications or  
Networks for companies
- Home applications or  
Networks for People
- Mobile Network Users
- Social Issues

# Uses of Computer Networks

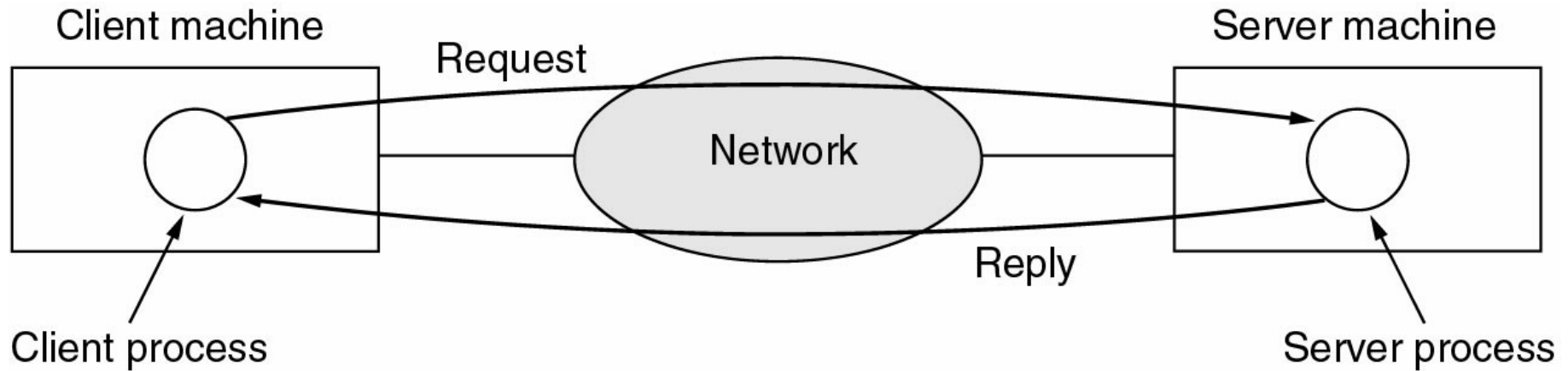
- Business Applications
  - Resource Sharing
    - programs, equipment, data etc
  - High reliability
    - alternative sources of supply
  - Saving money
    - by having client server model
  - Scalability
    - Ability to increase system performance
  - Powerful Communication medium
    - online documents, human to human communication

# Business Applications of Networks



A network with two clients and one server.

# Business Applications of Networks



The client-server model involves requests and replies.

# Home Network Applications

- Access to remote information
  - Home shopping
  - Online newspaper
  - Access to WWW
- Person-to-person communication
  - E-mails
  - Video conference
  - Worldwide newsgroup

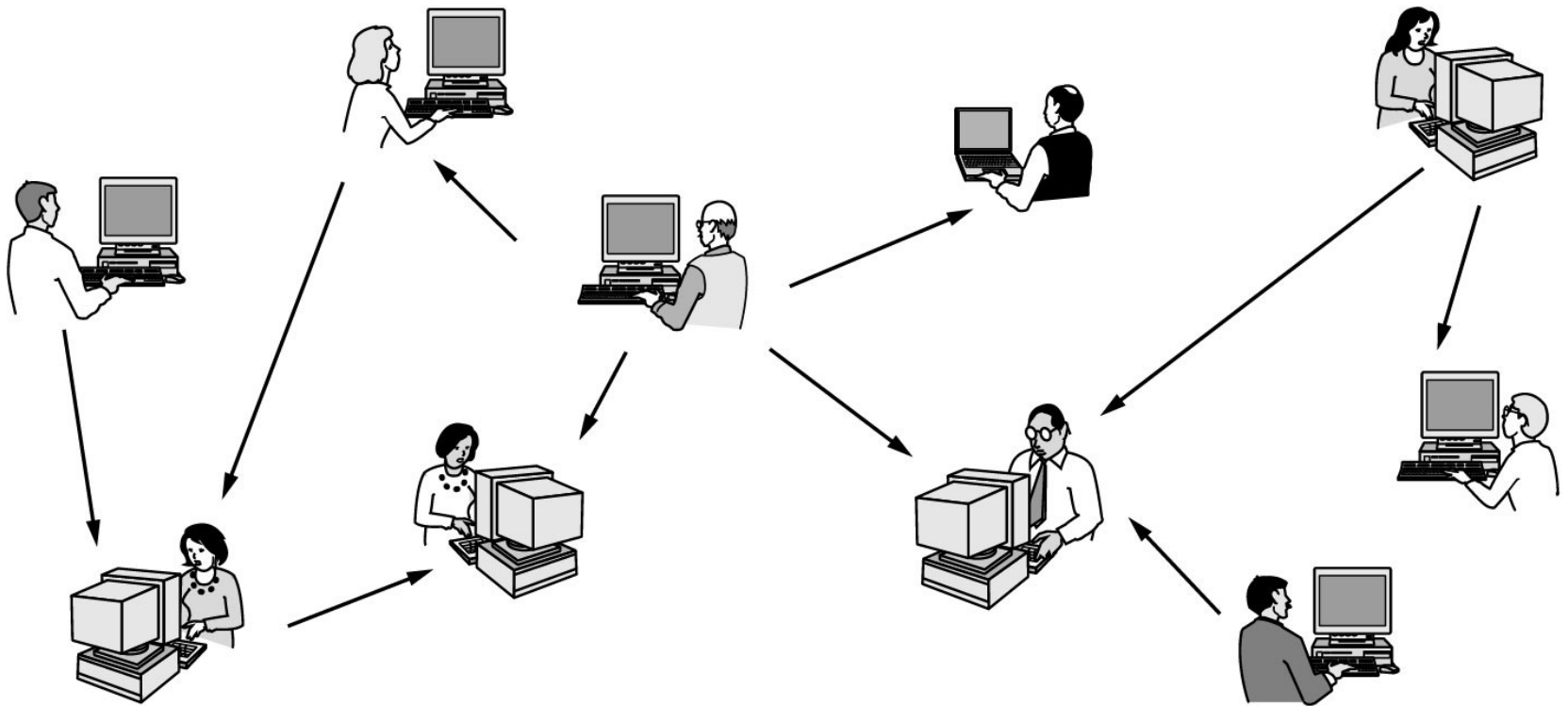


# Home Network Applications

- Interactive entertainment
  - Video on demand
  - Live Television
  - Game playing
- Electronic commerce (e-commerce)
  - convenience of shopping from home with online catalogs

Tag	Full name	Example
B2C	Business-to-consumer	Ordering books on-line
B2B	Business-to-business	Car manufacturer ordering tires from supplier
G2C	Government-to-consumer	Government distributing tax forms electronically
C2C	Consumer-to-consumer	Auctioning second-hand products on-line
P2P	Peer-to-peer	File sharing

# Home Network Applications



In peer-to-peer system there are no fixed clients and servers.

# Mobile Network Users

Wireless	Mobile	Applications
No	No	Desktop computers in offices
No	Yes	A notebook computer used in a hotel room
Yes	No	Networks in older, unwired buildings
Yes	Yes	Portable office; PDA for store inventory

- Mobile commerce (m-commerce)

## Social Issues

- Exchange messages using newsgroup may lead to **conflicts**
- Employee **rights** vs employer rights
- Network offers the potential to send **anonymous** messages
- Electronic junk mails (Spam) may contain **viruses**
- Copyright **violation** due to transmission of music & videos

# Network Hardware

➤ Based on types of transmission technology

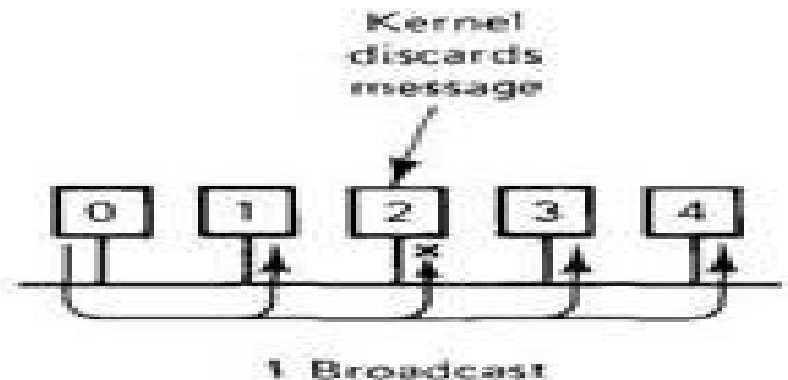
- Broadcast Networks
- Point-to-point Networks

➤ Based on Scale

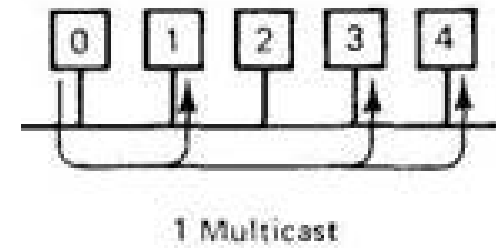
Interprocessor distance	Processors located in same	Example
1 m	Square meter	Personal area network
10 m	Room	Local area network
100 m	Building	
1 km	Campus	
10 km	City	Metropolitan area network
100 km	Country	Wide area network
1000 km	Continent	
10,000 km	Planet	The Internet

# Network Hardware

- Broadcast Networks
  - A *single communication channel* is shared by all the machines on the network
  - Short messages called *packets* sent by any machine are received by all the others
  - Address field in a packet specifies the recipient
  - After receiving the packet, the address field is checked
  - If it is intended for itself, it processes the packet, otherwise it is ignored

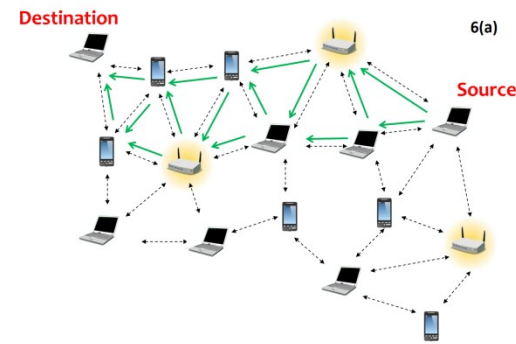


# Network Hardware

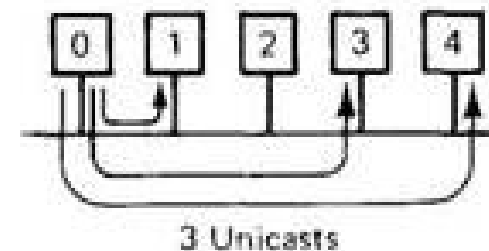


- Broadcasting
  - Broadcast systems allow the possibility of addressing a packet to all destinations by using **special code** in the address field
  - Smaller localized network use broadcasting
- Multicasting
  - Broadcast systems also support transmission to a **subset** of the machines
  - By reserving a bit to indicate multicasting & the remaining  $n-1$  address bits can hold the group number
  - Each machine can subscribe to any or one of the groups

# Network Hardware



- Point-to-point Networks
  - Many connections between individual pair of machines
  - Transfer from source to destination may includes one or more intermediate machines
  - Multiple routes of different lengths leads to the role of routing algorithm for **route selection**
  - Larger networks use point-to-point
  - Point-to-point transmission with one sender and one receiver is sometimes called **unicasting**



# Network Hardware

- Based on Scale
  - Personal Area Networks
  - Local Area Networks
  - Metropolitan Area Networks
  - Wide Area Networks
  - Internetworks or Internet



# Network Hardware

- ✓ **Personal Area Networks**
  - ✓ Networks that are meant for one person
  - ✓ Eg: a wireless network connecting a computer with its mouse, keyboard, and printer
- ✓ **Local Area Networks**
  - ✓ Generally called as LANs
  - ✓ Privately owned networks
  - ✓ Inter-processor distance: 10m to 1km
  - ✓ Networks placed in a single room or building or campus
  - ✓ LANs are distinguished by 3 characteristics –
    - ✓ Size
    - ✓ Transmission Technology
    - ✓ Topology

# LAN

- ✓ **Size :-**
  - ✓ Worst-case transmission time is bounded and known in advance.
  - ✓ Knowing this bound makes it possible to use certain kinds of designs
  - ✓ Simplifies Network management.
- ✓ **Transmission Technology :-**
  - ✓ consist of a single cable to which all the machines are attached .
  - ✓ Traditional LAN runs at speed of 10 to 100 Mbps
  - ✓ Newer LANs operate at 10 Gbps
  - ✓ Low delay
  - ✓ Makes very few errors

# LAN

## ✓ **Topology :-**

✓ 2 broadcast network types:

✓ Bus & Ring

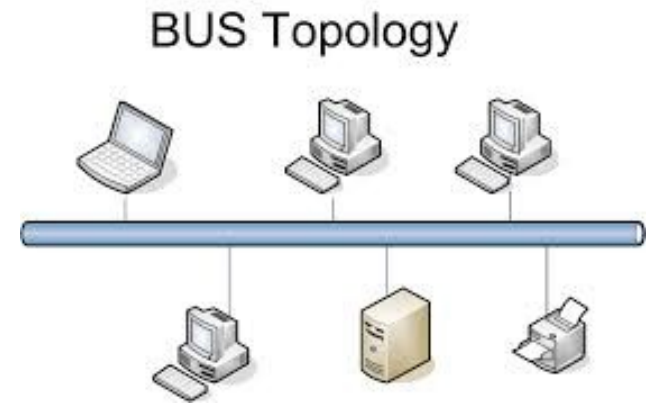
✓ Bus (Linear cable) network

✓ at any instant, at most one machine is the master and is allowed to transmit.

✓ All other machines are required to refrain from sending

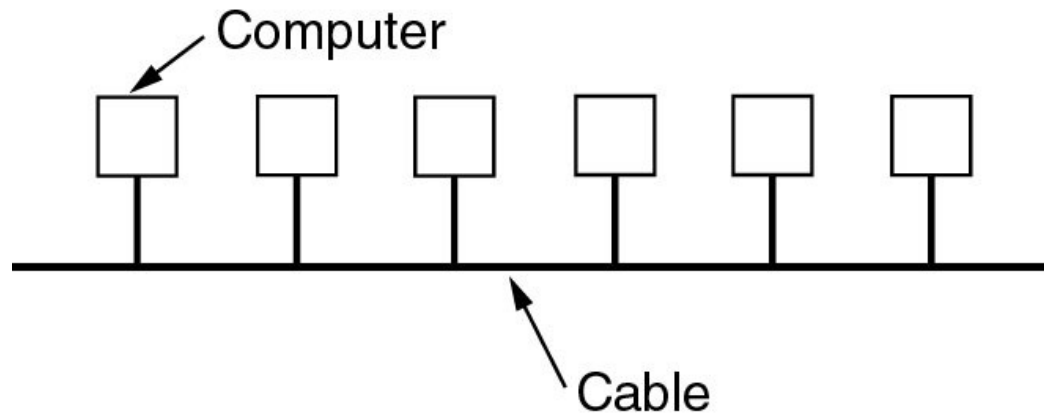
✓ **Arbitration mechanism :-** to resolve conflicts when two or more machines want to transmit simultaneously.

✓ It may be Centralized or distributed (decentralized)

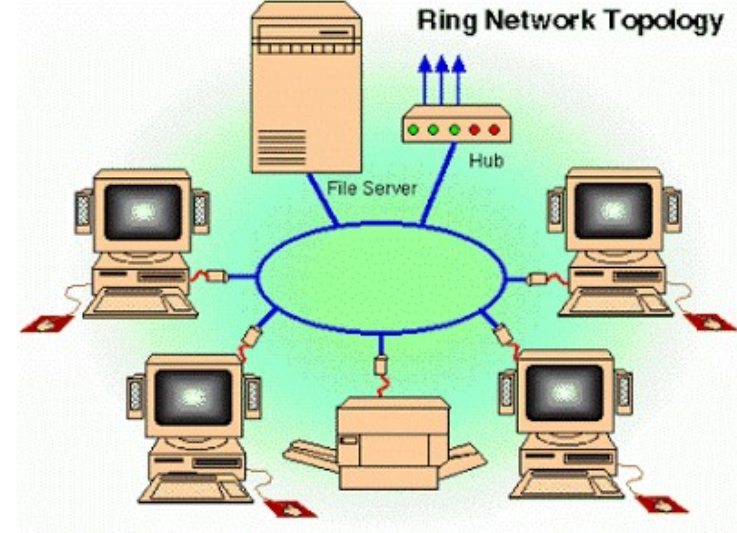


# LAN

- ✓ Eg:-IEEE 802.3 popularly called Ethernet is bus based broadcast network with decentralized control
- ✓ operates at 10 Mbps to 10 Gbps
- ✓ Computers on an Ethernet can transmit whenever they want to;
- ✓ if two or more packets collide, each computer just waits a random time and tries again later

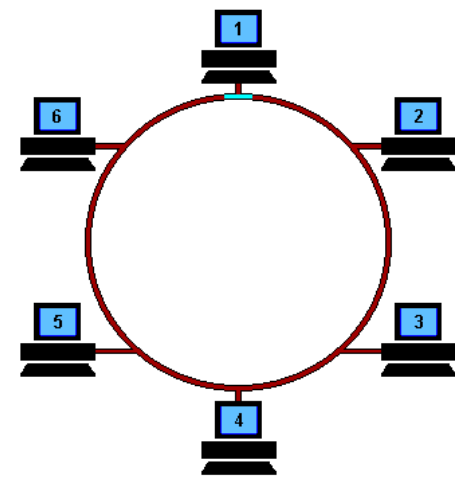


# LAN



- ✓ Ring Network:
  - ✓ Devices acts as repeaters to boost the signal
  - ✓ The transmission of data takes place by token passing.
  - ✓ A token is a special series of bits that contains control information.
  - ✓ Possession of the token allows a network device to transmit data to the network.
  - ✓ Each network has only one token.

# LAN



- ✓ **Working of Ring Network:**
  - ✓ The sending computer removes the token from the ring and sends the requested data around the ring.
  - ✓ Each computer passes the data until the packet finds the computer that matches the address on the data.
  - ✓ The receiving computer then returns a message to the sending computer indicating that the data has been received.
  - ✓ After verification, the sending computer creates a new token and releases it to the network.

# LAN

## ✓ Ring Network:

### *Advantages:*

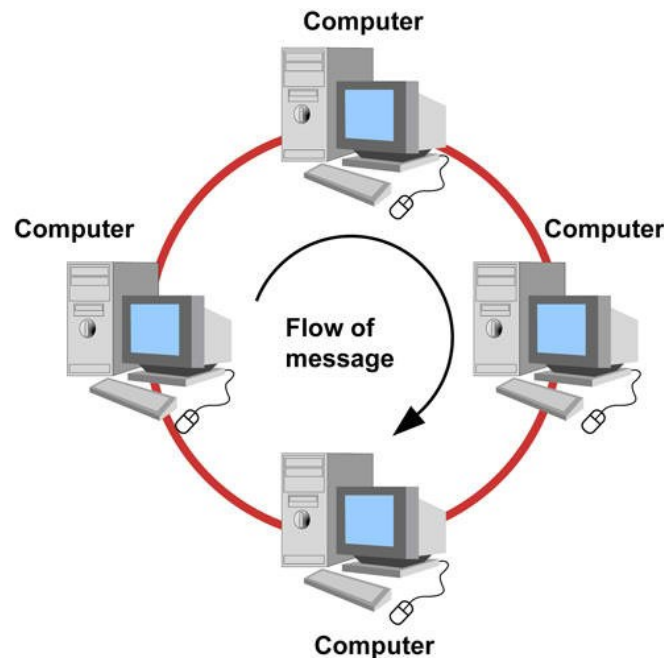
- **Very orderly network** where every device has access to the token and the opportunity to transmit
- **Performs better than a bus** topology under **heavy** network load
- **Does not require network server** to manage the connectivity between the computers

### *Disadvantages:*

- **One malfunctioning workstation or bad port** can create problems for the entire network
- Devices moved, added and changed can **affect** the network
- Network adapter cards are much more **expensive** than Ethernet cards and hubs
- Much **slower** than an Ethernet network under **normal** load

# LAN

- ✓ Ring Network:
  - ✓ Egs:
    - ✓ IEEE 802.5 (the IBM token ring), is a ring-based LAN
      - ✓ operates at 4 and 16 Mbps.
    - ✓ FDDI (*Fiber Distributed Data Interface*) is another example of a ring network





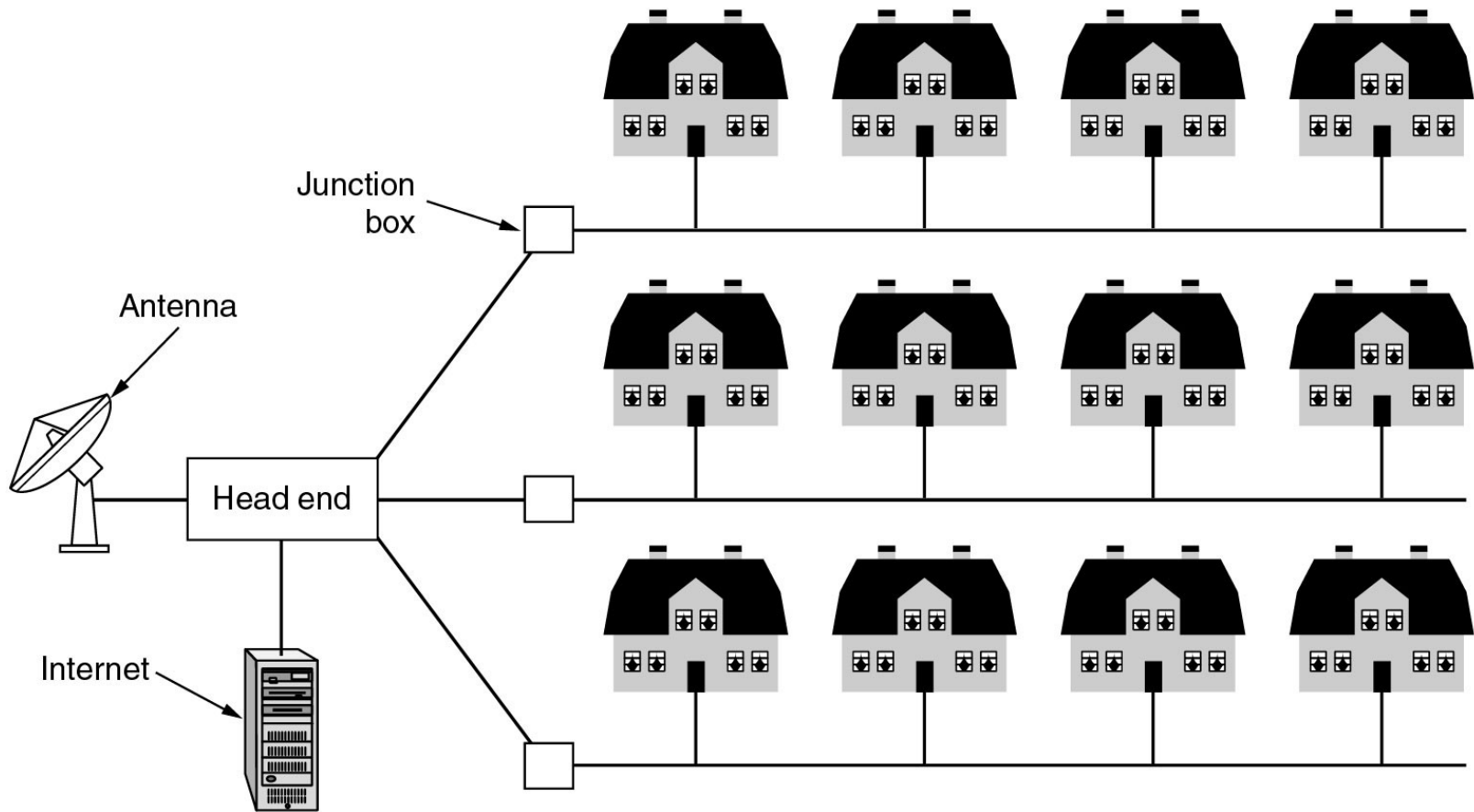
# LAN

- ✓ Broadcast networks can be further divided into 2, depending on how the channel is allocated
  - ✓ Static and Dynamic
- ✓ A typical **static** allocation is
  - ✓ to divide time into discrete intervals and use a round-robin algorithm
  - ✓ allowing each machine to broadcast only when its time slot comes up
  - ✓ **Drawback:** wastes channel capacity when a machine has nothing to say during its allocated slot
  - ✓ So, most systems attempt to allocate the channel dynamically (i.e., on demand).

# LAN

- ✓ Dynamic allocation methods are either centralized or decentralized.
- ✓ In the **centralized channel allocation** method,
  - ✓ there is a single entity,
  - ✓ for example, a bus arbitration unit,
  - ✓ which determines who goes next.
  - ✓ It might do this by accepting requests and making a decision according to some internal algorithm.
- ✓ In the **decentralized channel allocation** method,
  - ✓ there is no central entity;
  - ✓ each machine must decide for itself whether to transmit.

# Metropolitan Area Networks (MAN)



A metropolitan area network based on cable TV in a city.

Another eg: IEEE 802.16 (Broadband wireless MANs) for high-speed wireless Internet access

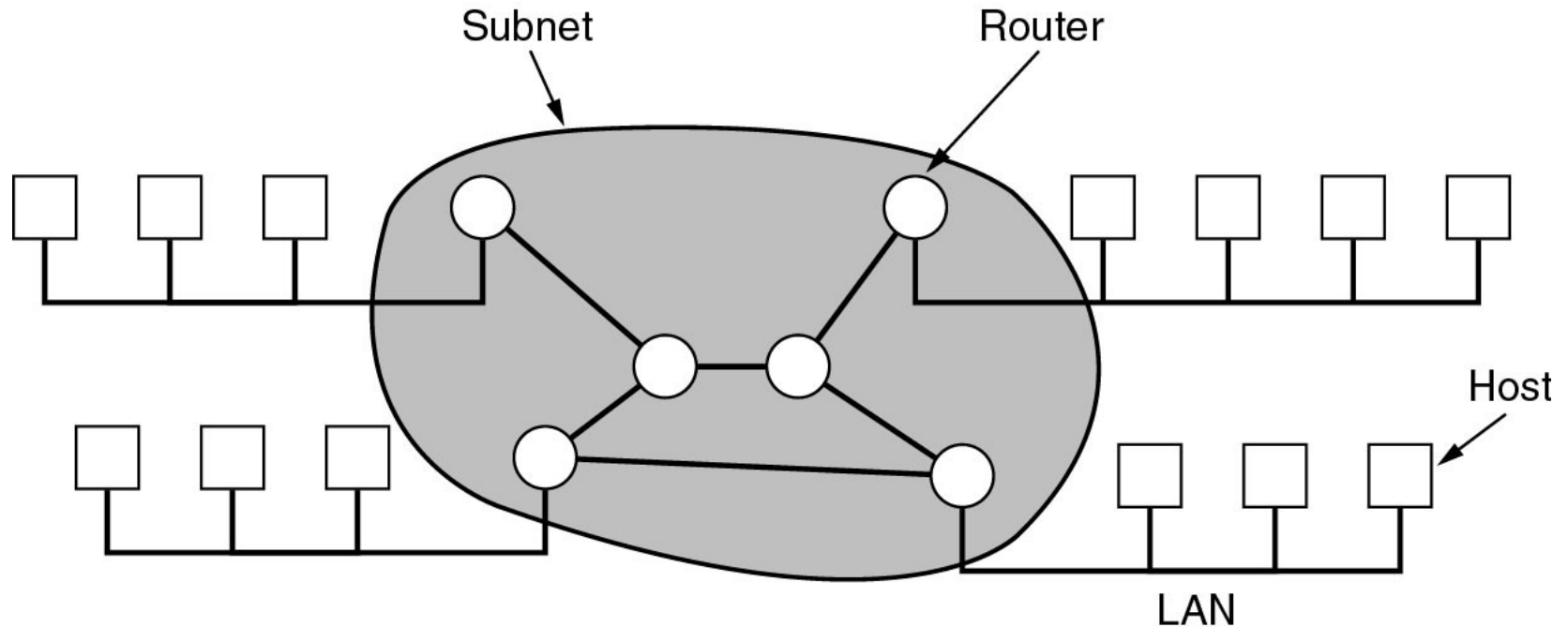
# Wide Area Networks (WAN)

- WAN spans a large geographical area, often a country or continent
- It contains a collection of machines called hosts intended for running user (i.e., application) programs
- The hosts are owned by the customers
- The hosts are connected by a communication subnet, or just subnet
- The communication subnet is typically owned and operated by a telephone company or Internet service provider
- The job of the subnet is to carry messages from host to host, just as the telephone system carries words from speaker to listener

# Wide Area Networks (WAN)

- Subnet consists of two distinct components:
  - transmission lines
  - switching elements
- **Transmission lines**
  - move bits between machines.
  - made of copper wire, optical fiber, or even radio links.
- **Switching elements**
  - Specialized computers that connect three or more transmission lines.
  - When data arrive on an incoming line, it must choose an outgoing line on which to forward them.
  - Switching elements are also called as **routers**

# Wide Area Networks (WAN)



Relation between hosts on LANs and the subnet.

# Wide Area Networks (WAN)

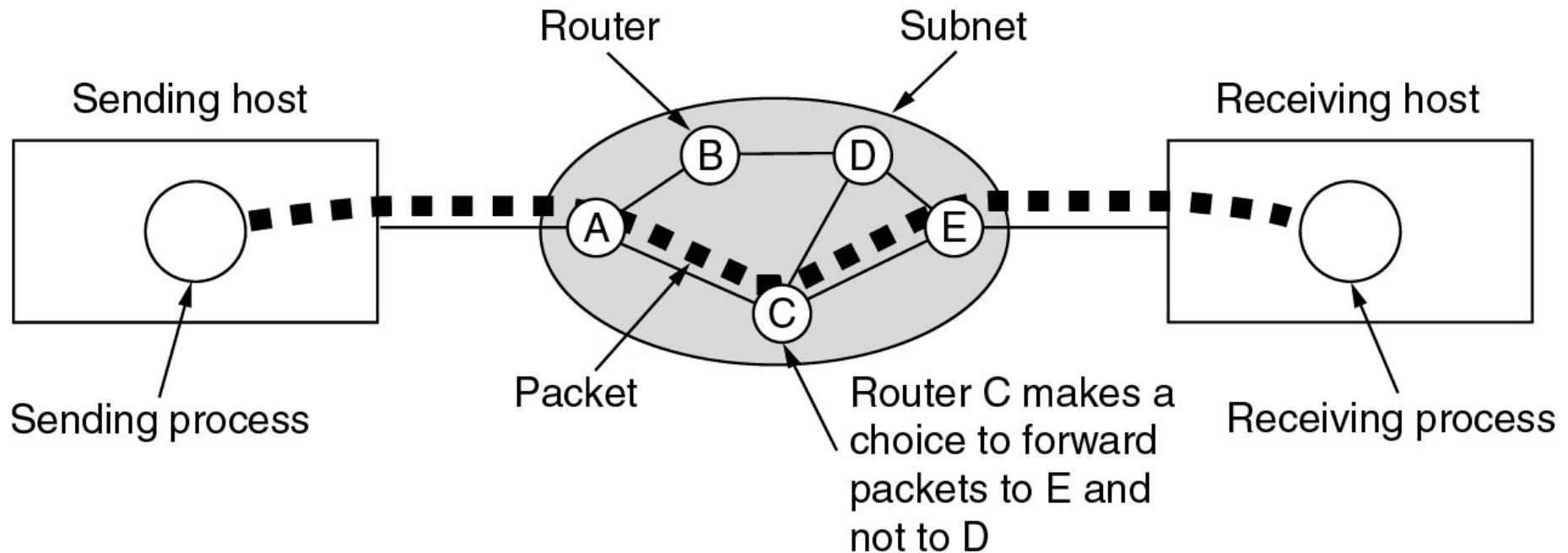
- Store-and-forward or packet-switched subnet
  - When a packet is sent from one router to another via one or more intermediate routers,
  - the packet is received at each intermediate router in its entirety,
  - stored there until the required output line is free, and then forwarded.
  - When the packets are small and all of the same size, they are often called cells

# Wide Area Networks (WAN)

- Principle of a packet-switched WAN:
  - When a process on some host has a message to be sent to a process on some other host,
  - the sending host first cuts the message into packets,
  - each one bearing its number in the sequence.
  - These packets are then injected into the network one at a time in quick succession.
  - The packets are transported individually over the network and deposited at the receiving host,
  - where they are reassembled into the original message and delivered to the receiving process



# Wide Area Networks



A stream of packets from sender to receiver.

- Routing decisions are made locally.
- When a packet arrives at router A, it is up to A to decide if this packet should be sent on the line to B or the line to C.
- How A makes that decision is called the routing algorithm.

# Wide Area Networks (WAN)

- Not all WANs are packet switched.
- A second possibility for a WAN is a **satellite system**.
- Each router has an **antenna** through which it can send and receive.
- All routers can hear the output from the satellite
- In some cases, they can also hear the upward transmissions of their fellow routers to the satellite as well.
- Sometimes the routers are connected to a substantial point-to-point subnet, with only some of them having a satellite antenna.
- Satellite networks are inherently **broadcast** and are most useful when the broadcast property is important

# Internetworks

- A collection of interconnected networks is called an **internetwork or internet**
- A common form of internet is a collection of LANs connected by a WAN
- If the intermediate system contains only routers, it is a subnet
- if it contains both routers and hosts, it is a WAN
- An internetwork is formed when distinct networks are interconnected

# Wireless Networks

- Digital wireless communication is not a new idea.
- As early as 1901, the Italian physicist Marconi demonstrated a ship-to-shore wireless telegraph, using Morse Code (dots and dashes as binary).
- Modern digital wireless systems have better performance, but the basic idea is the same.
- **Categories of wireless networks:**
  - System interconnection
  - Wireless LANs
  - Wireless WANs

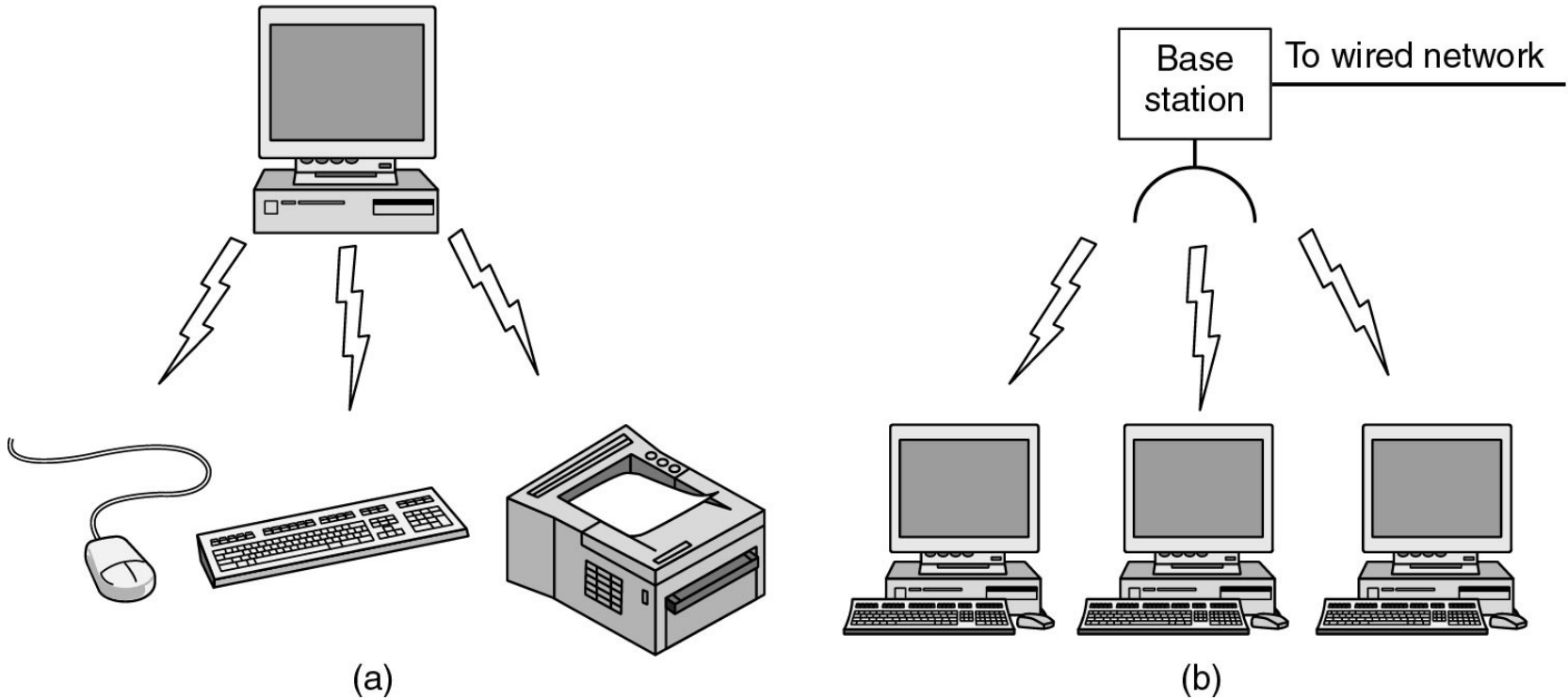
# Wireless Networks

- System interconnection
  - interconnecting the components of a computer using **short-range radio**
  - every computer has a monitor, keyboard, mouse, and printer connected to the main unit by cables
  - some companies got together to design a short-range wireless network called **Bluetooth** to connect these components without wires
  - Bluetooth also allows digital cameras, headsets, scanners, and other devices to connect to a computer by merely being brought within range

# Wireless Networks

- System interconnection
  - System interconnection networks use the **master-slave** paradigm
  - System unit is normally the master, talking to the mouse, keyboard, etc., as slaves.
  - The master tells the slaves
    - what addresses to use,
    - when they can broadcast,
    - how long they can transmit,
    - what frequencies they can use, and so on

# Wireless Networks



(a) Bluetooth configuration

(b) Wireless LAN

# Wireless Networks

- Wireless LANs
  - systems in which every computer has a radio modem and antenna with which it can communicate with other systems
  - if the systems are close enough, they can communicate directly with one another in a peer-to-peer configuration
  - Wireless LANs are becoming increasingly common in small offices and homes, where installing Ethernet is considered too much trouble
  - Standard for wireless LANs is called IEEE 802.11



# Wireless Networks

- Wireless WANs
  - radio network used for **cellular telephones** is an example of a low-bandwidth wireless system.
  - This system has already gone through three generations.
    1. The first generation was **analog** and for **voice** only.
    2. The second generation was **digital** and for **voice** only.
    3. The third generation is **digital** and is for **both voice and data**.

# Wireless Networks



## Wireless WANs



In a certain sense, cellular wireless networks are like wireless LANs, except that the **distances** involved are much **greater** and **the bit rates** much **lower**.

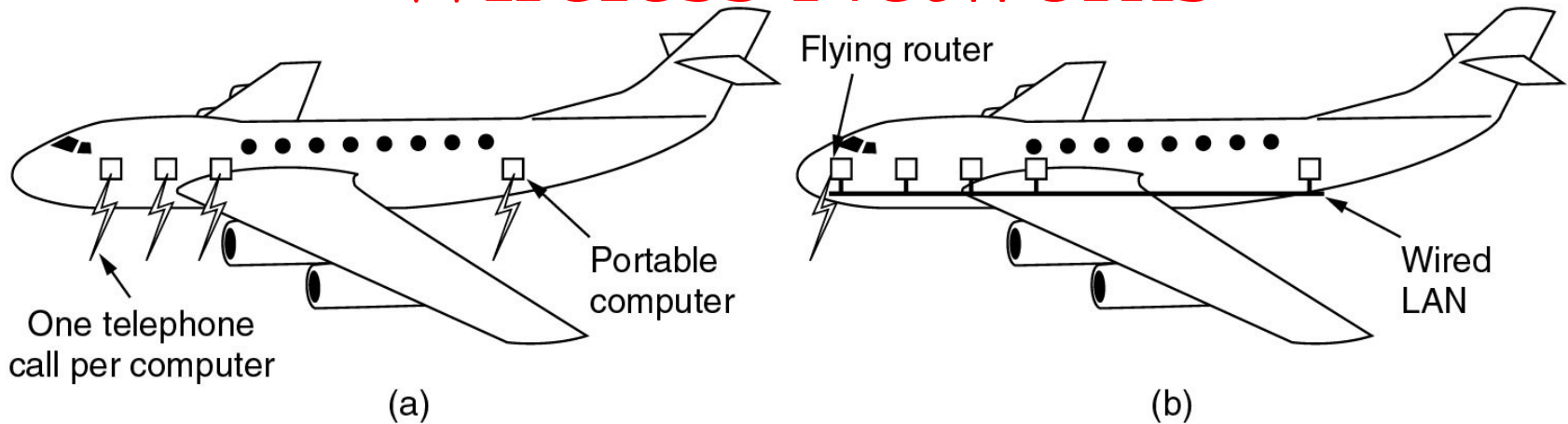


**Wireless LANs** can operate at rates up to about **50 Mbps** over distances of **tens of meters**.



**Cellular systems** operate **below 1 Mbps**, but the distance between the base station and the computer or telephone is measured in **kilometers**

# Wireless Networks



- (a) Individual independent mobile computers
  - airplane with a number of people using modems and seat-back telephones to call the office independently.
- (b) A flying LAN (more efficient)
  - each seat comes equipped with an Ethernet connector into which passengers can plug their computers.
  - A single router on the aircraft maintains a radio link with some router on the ground, changing routers as it flies along.
  - This is just a traditional LAN, except that its connection to the outside world is a radio link instead of a hardwired line

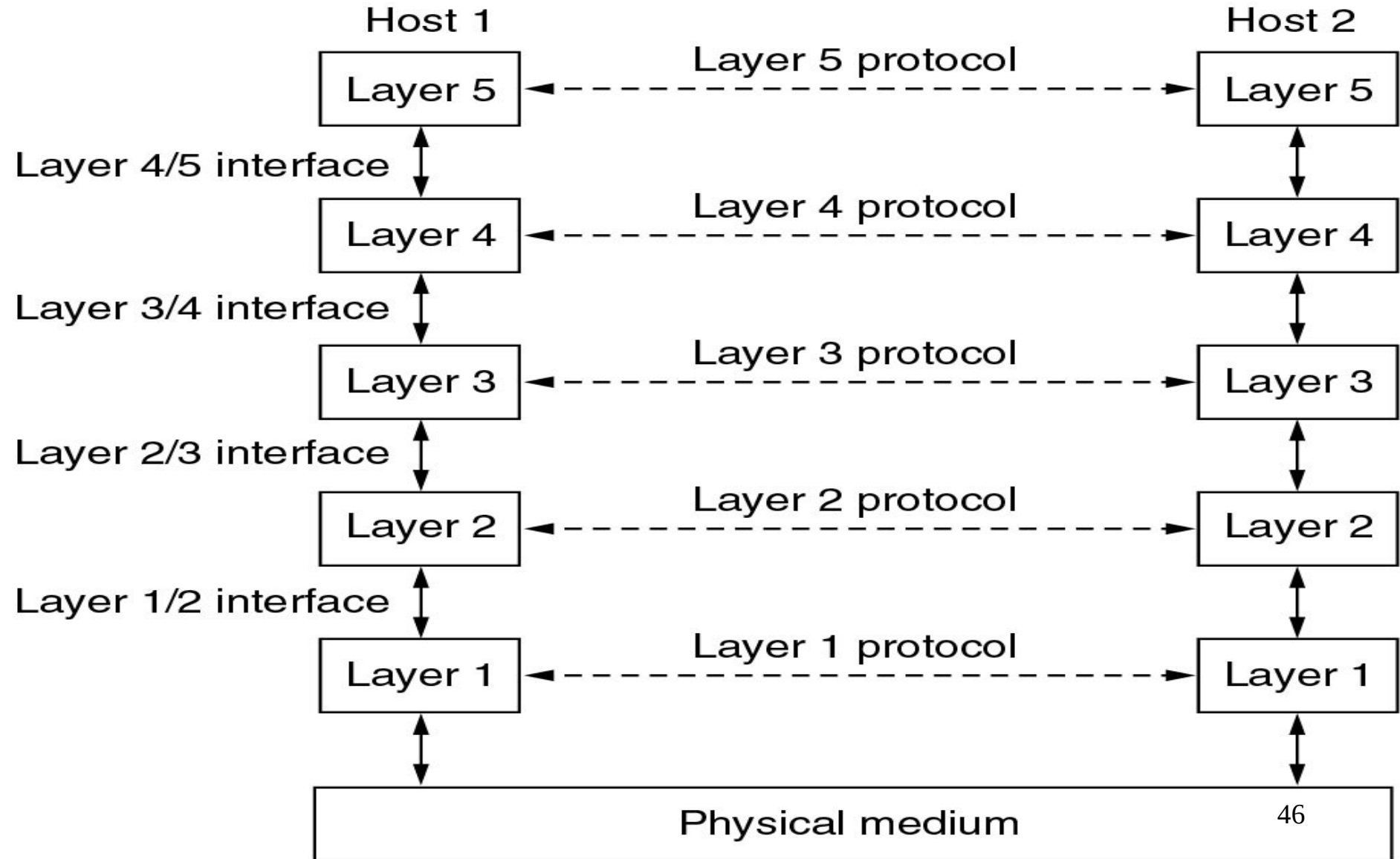
# Home Network Categories

- Computers (desktop PC, PDA, shared peripherals)
- Entertainment (TV, DVD, VCR, camera, stereo, MP3)
- Telecomm (telephone, cell phone, intercom, fax)
- Appliances (microwave, fridge, lights)
- Telemetry (utility meter, burglar alarm, thermostat, babycam).

# Network Software

- Protocol Hierarchies
- Design Issues for the Layers
- Connection-Oriented and Connectionless Services
- Service Primitives
- The Relationship of Services to Protocols

# Network Software Protocol Hierarchies



# Protocol Hierarchies

- To reduce their **design complexity**, most networks are organized as a stack of layers or levels
- Number of layers, name of each layer, contents of each layer, and function of each layer differ from network to network
- **Purpose of each layer**
  - to offer certain services to the higher layers,
  - shielding those layers from the details of how the offered services are actually implemented
- The rules and conventions used in this conversation are collectively known as the **layer n protocol**
- **Protocol** is an agreement between the communicating parties on how communication is to proceed

# Protocol Hierarchies

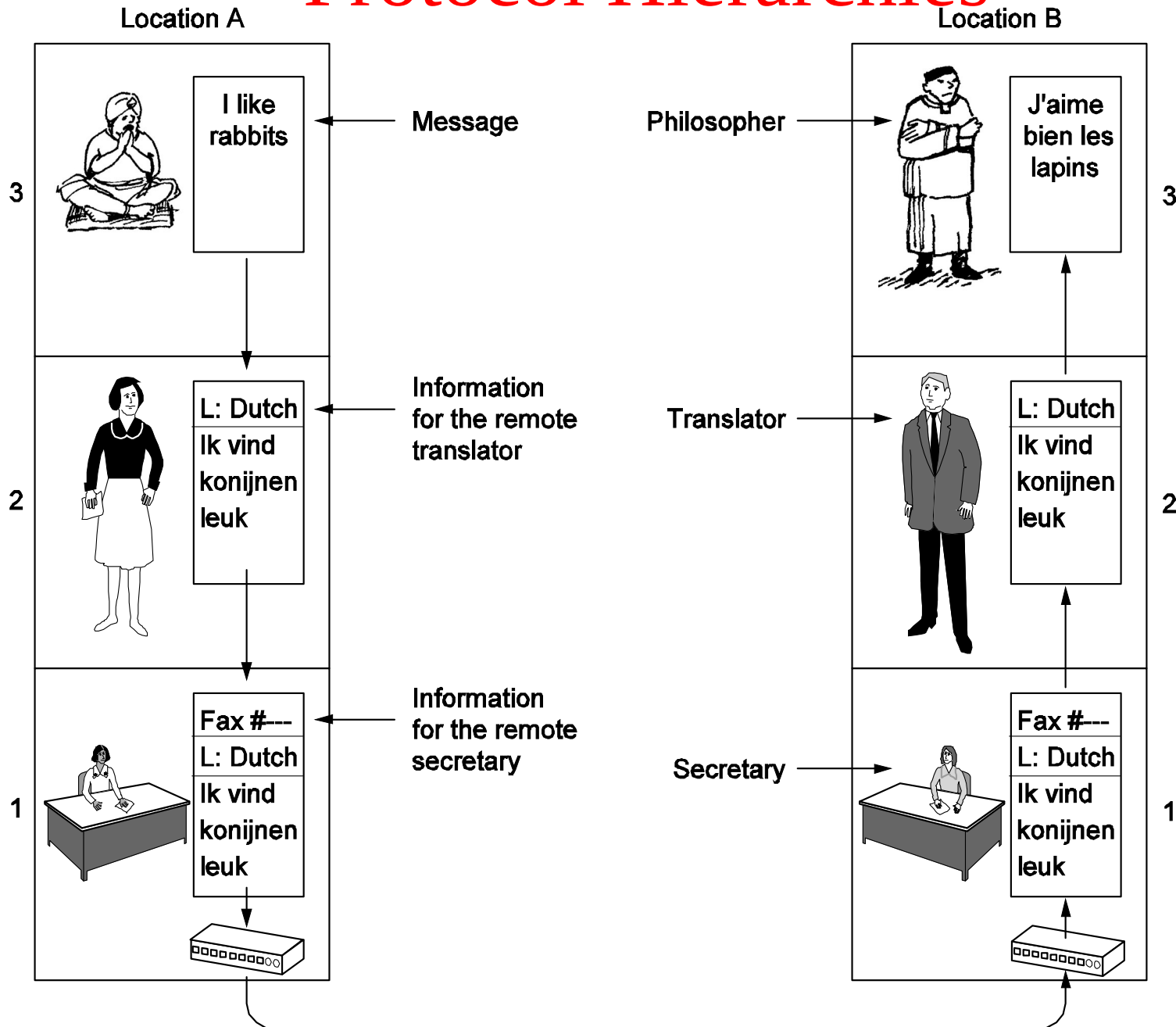
- No data are directly transferred from layer n on one machine to layer n on another machine.
- Instead, each layer passes data and control information to the layer immediately below it, until the lowest layer is reached.
- Below layer 1 is the physical medium through which actual communication occurs
- Between each pair of adjacent layers is an **interface**
- **Interface** defines which primitive operations and services the lower layer makes available to the upper one



# Protocol Hierarchies

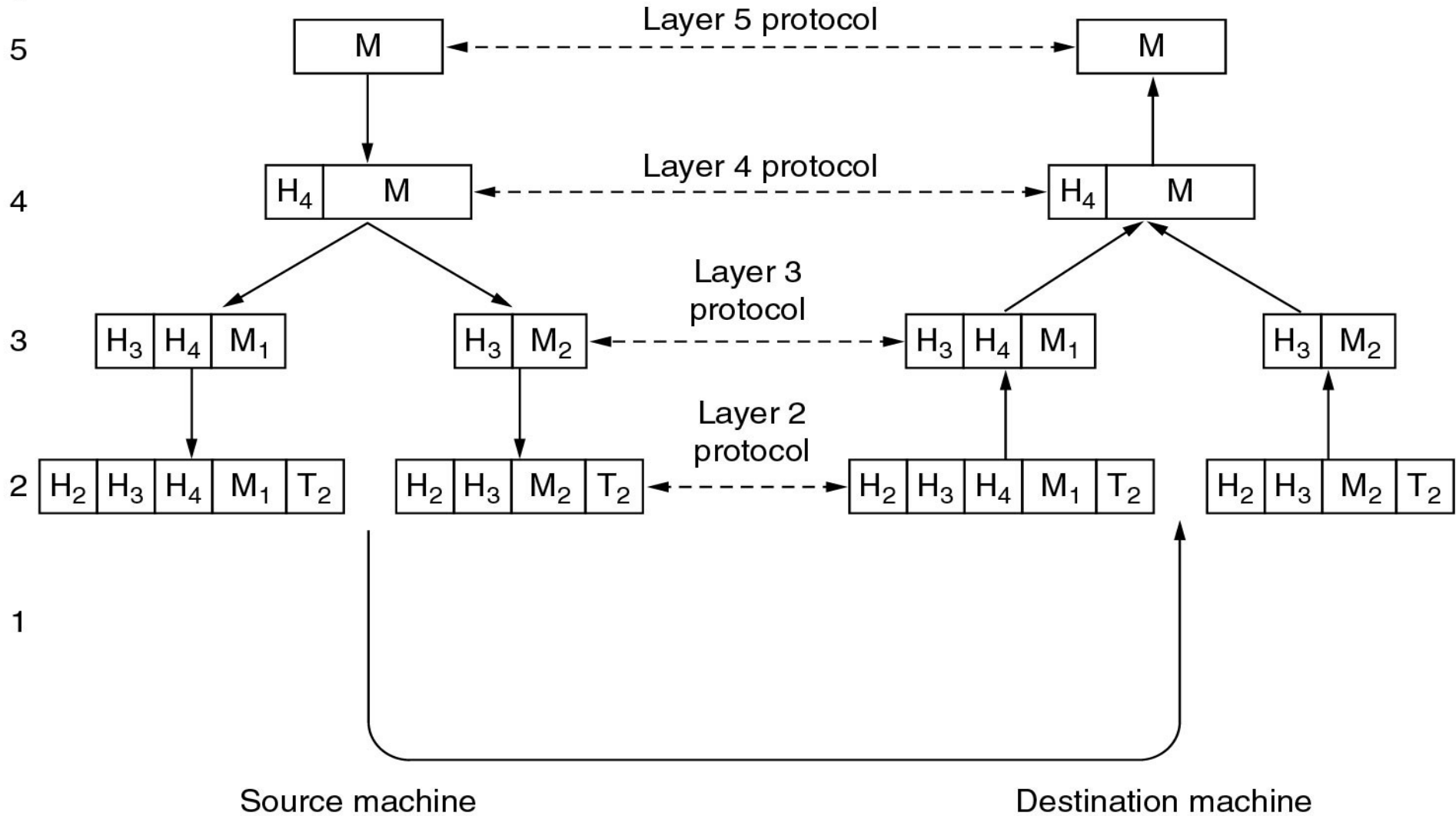
- clear-cut interfaces makes it simpler to replace the implementation of one layer with a completely different implementation
- e.g., all the telephone lines are replaced by satellite channels
- A set of layers and protocols is called a **network architecture**
- A list of protocols used by a certain system, one protocol per layer, is called a **protocol stack**

# Protocol Hierarchies



# Protocol Hierarchies

Layer



header & trailer includes control information, such as sequence numbers, sizes, times, and other control fields

# Design Issues for the Layers

- Addressing
- Rules for data transfer
- Error Control
- Flow Control
- Long messages
- Too short messages
- Multiplexing & demultiplexing
- Routing

# Design Issues for the Layers

- Addressing
  - Every layer needs a mechanism for identifying senders and receivers
  - So, addressing is required
- Rules for data transfer
  - **Unidirectional or bidirectional** (Simplex / Half duplex / Full duplex)
  - Protocol must determine how many **logical channels** the connection corresponds to and what their **priorities** are
  - Many networks provide at least two logical channels per connection, one for **normal** data and one for **urgent** data.

# Design Issues for the Layers

- Error Control
  - **Problem:** physical communication **circuits** are **not perfect**
  - **error-detecting and error-correcting** codes are available
  - both ends of the connection must agree on which one is being used
  - receiver must have some way of telling the sender which messages have been **correctly received** and which have not
  - To deal with a possible loss of sequencing, the protocol must make explicit provision for the receiver to allow the pieces to be **reassembled** properly

# Design Issues for the Layers

- Flow Control
  - **Problem:** how to keep a fast sender from swamping (overloading) a slow receiver with data
  - **Solution 1:** some kind of **feedback** from the receiver to the sender, about the receiver's current situation
  - **Solution 2:** **limit** the sender to an agreed-on transmission rate (flow control)
- Long messages
  - **Problem:** **inability** of all processes to accept arbitrarily long messages
  - **Solution:** disassembling, transmitting, and then reassembling messages

# Design Issues for the Layers

- Too short messages
  - **Problem:** transmitting data in units that are so small that sending each one separately is inefficient.
  - **Solution:** to **gather** several small messages heading toward a common destination into a single large message and **dismember** the large message at the other side.
- Multiplexing & demultiplexing
  - underlying layer may decide to use the same connection for **multiple, unrelated conversations** (Physical layer)
- Routing
  - When there are **multiple paths** between source and destination, a route must be chosen based on the current traffic load

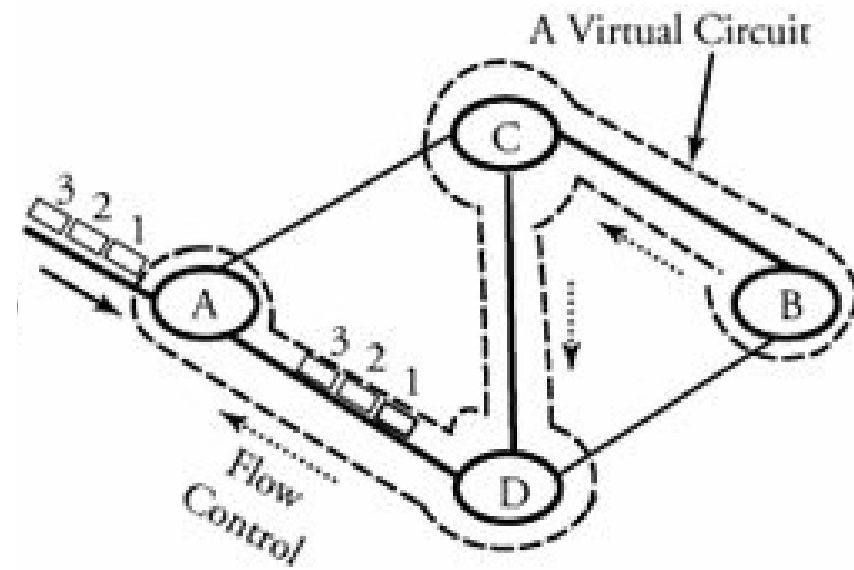


# Connection-Oriented Services

- Similar to **telephone** service
- to use a connection-oriented network service, the service user
  - **establishes** a connection,
  - **uses** the connection, and
  - **releases** the connection
- acts like a **tube**
  - sender pushes objects (bits) in at one end, and the receiver takes them out at the other end
  - the order is preserved so that the bits arrive in the order they were sent

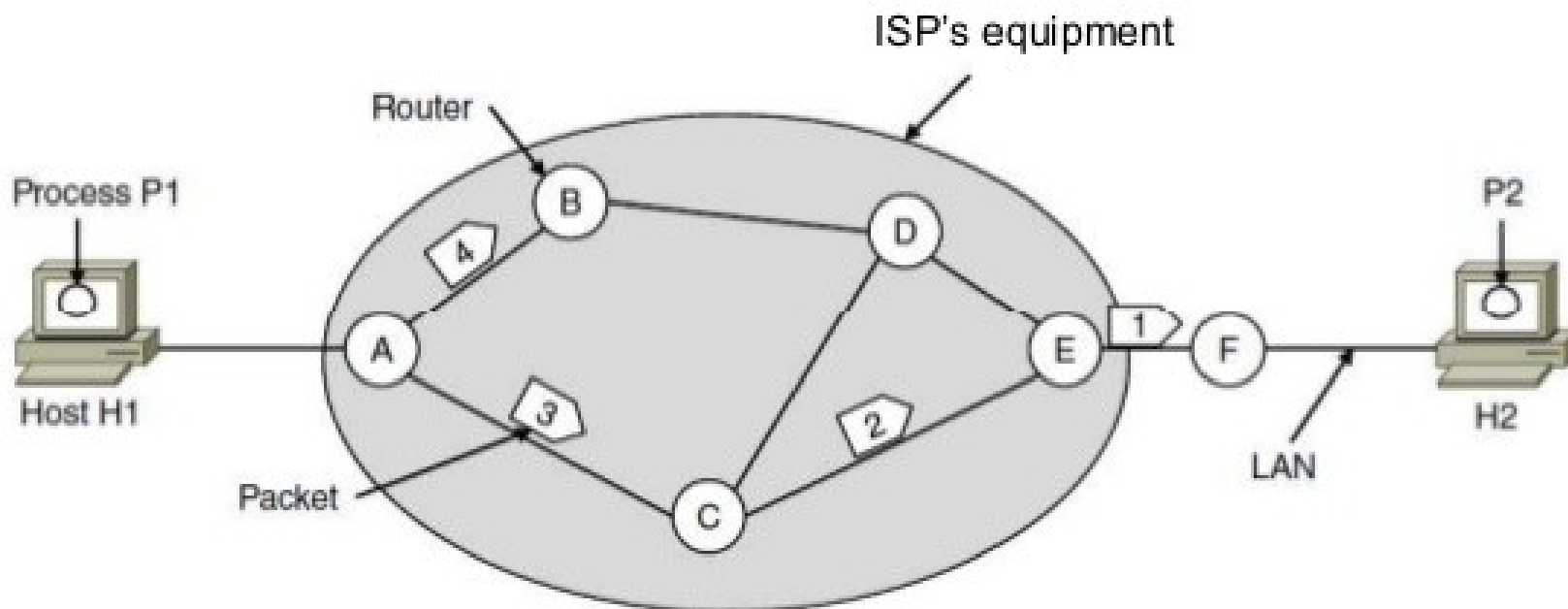
# Connection-Oriented Services

- When a connection is established, the sender, receiver, and subnet conduct a **negotiation**
- about parameters to be used, such as
  - maximum message size,
  - quality of service
    - error rates,
    - bandwidth,
    - throughput,
    - transmission delay,
    - jitter,
    - Availability
  - other issues.
- Typically, one side makes a proposal and the other side can accept it, reject it, or make a counterproposal



# Connectionless Services

- Similar to **postal** system
- Each message (letter) carries the full destination address
- Each one is routed through the system independent of all the others



# Connection-Oriented Services

- Classifications: Reliable & Unreliable
- Each service can be characterized by a quality of service
- Some services are **reliable** that they never lose data.
- A **reliable** service is implemented by having the receiver **acknowledge** the receipt of each message so the sender is sure that it arrived.
- The acknowledgement process introduces **overhead** and **delays**, which are often worth it but are sometimes undesirable
- Eg for reliable connection-oriented service is **file transfer**
- Reliable connection-oriented service has two minor variations:
  - message sequences and
  - byte streams

# Connection-Oriented Services

- **Message sequences**
  - message boundaries are preserved.
  - When two 1024-byte messages are sent, they arrive as two distinct 1024-byte messages, never as one 2048-byte message
  - Eg: Sending the pages of book
- **Byte streams**
  - connection is simply a stream of bytes, with no message boundaries.
  - When 2048 bytes arrive at the receiver, there is no way to tell if they were sent as one 2048-byte message, two 1024-byte messages, or 2048 1-byte messages
  - Eg: user logging details to a remote server

# Connection-Oriented Services

- For some applications, transit delays introduced by acknowledgements are unacceptable. (Unreliable is better)
- **Application 1:** digitized voice traffic.
  - It is preferable for telephone users to hear a bit of noise on the line from time to time than to experience a delay waiting for acknowledgements.
- **Application 2:** video conference
  - when transmitting a video conference, having a few pixels wrong is no problem, but having the image jerk along as the flow stops to correct errors is irritating

# Connectionless Services

- Connectionless service is often called **datagram service**
- **Unreliable (meaning not acknowledged) datagram service**
  - does not return an acknowledgement to the sender
  - Eg: junk mails
- **acknowledged datagram service**
  - convenience of not having to establish a connection to send one short message is desired,
  - but reliability is essential.
  - Eg: sending a registered letter and requesting a return receipt
- **request-reply service**
  - the sender transmits a single datagram containing a request; the reply contains the answer
    - Egs: a query to the local library, Client server model

# Connection-Oriented and Connectionless Services

		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

Six different types of service.

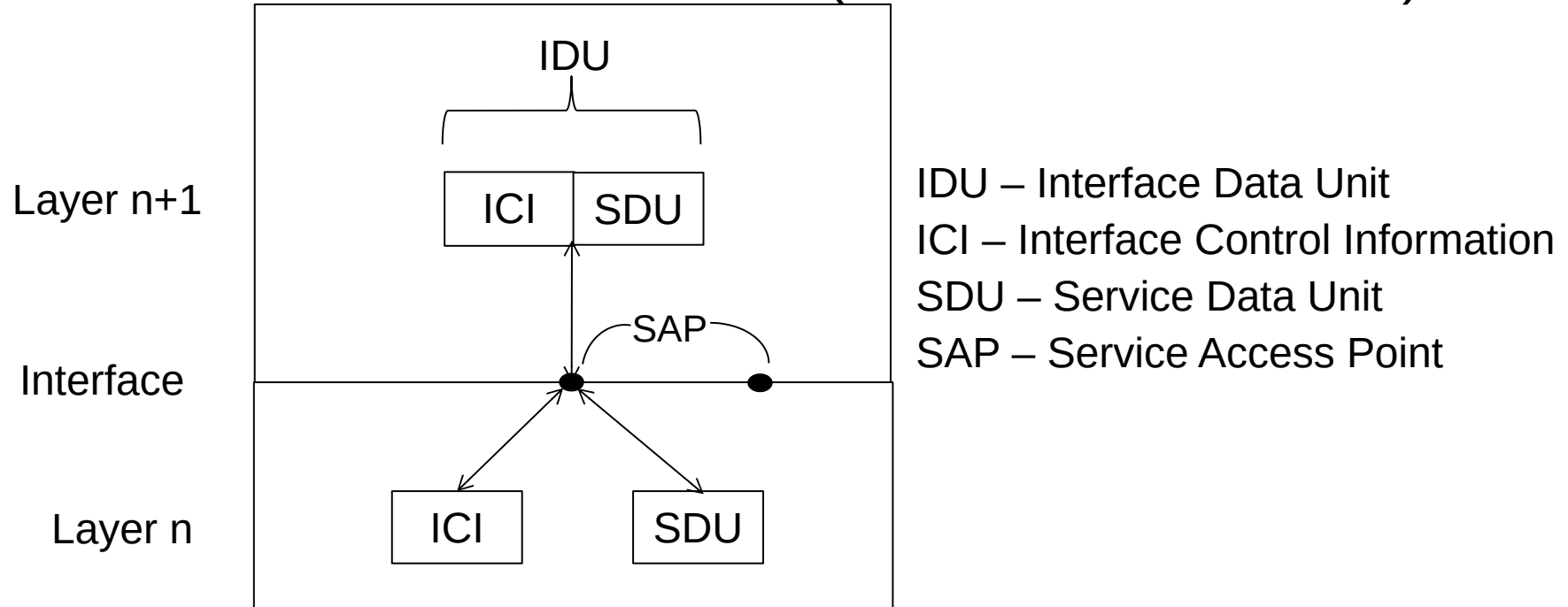


# Interfaces & Services

- active elements in each layer are called **entities**
- An entity can be a
  - software entity (such as a process), or
  - hardware entity (such as an intelligent I/O chip)
- Entities in the same layer on different machines are called **peer entities**
- entities in layer  $n$  implement a service used by layer  $n+1$ 
  - Layer  $n$  is the service provider
  - Layer  $n+1$  is the service user
- **Classes of services**
  - Fast & expensive communication
  - Slow & cheap communication

# Interfaces & Services

- Services are available at SAPs (Service Access Points)



- Each SAP has an address that uniquely identifies it
  - Eg: SAPs are the sockets into which telephones are plugged
  - SAP addresses are telephone numbers of sockets

# Service Primitives

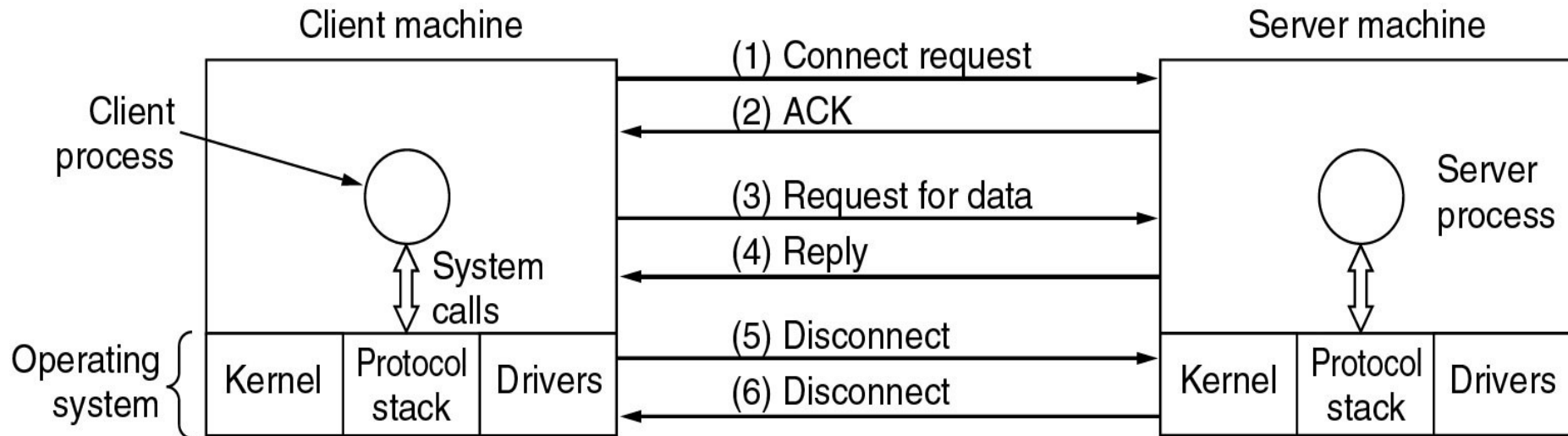
- A service is specified by a set of primitives (operations) available to a user process to access the service.
- These primitives tell the service to **perform** some **action** or **report** on an **action** taken by a peer entity.
- If the protocol stack is located in the operating system, the primitives are normally **system calls**.
- These calls cause a trap to kernel mode, which then turns control of the machine over to the operating system to send the necessary packets.

# Service Primitives

Five service primitives for implementing a simple connection-oriented service.

Primitive	Meaning
LISTEN	Block waiting for an incoming connection
CONNECT	Establish a connection with a waiting peer
RECEIVE	Block waiting for an incoming message
SEND	Send a message to the peer
DISCONNECT	Terminate a connection

# Service Primitives



Packets sent in a simple client-server interaction on a connection-oriented network.

# Service Primitives

- Eg Illustration:
- **Server** executes **LISTEN** to indicate that it is prepared to accept incoming connections.
- A common way to implement LISTEN is to make it a **blocking system call**.
- After executing the primitive, the server process is blocked until a request for connection appears
- **Client** process executes **CONNECT** to establish a connection with the server
- Operating system then typically sends a packet to the peer asking it to connect
- **Client process is suspended** until there is a response

# Service Primitives

- When the packet arrives at the server, it is processed by its operating system
- When the system sees that the packet is requesting a connection, it checks to see if there is a listener.
- If so, it does two things:
  - **unblocks** the **listener** and
  - **sends** back an **acknowledgement**
- arrival of this acknowledgement then releases the Client
- At this point the Client and Server are both running and they have a connection established
- If a connection request arrives and there is no listener, the result is undefined

# Service Primitives

- The next step is for the **Server** to execute **RECEIVE** to prepare to accept the first request.
- Normally, the server does this immediately upon being released from the LISTEN, before the acknowledgement can get back to the client.
- The RECEIVE call **blocks** the **Server**
- Then the **Client** executes **SEND** to transmit its request **followed** by the execution of **RECEIVE** to get the reply
- The arrival of the request packet at the server machine unblocks the Server process so it can process the request.
- After it has done the work, it uses **SEND** to return the answer to the Client.
- The arrival of this packet **unblocks** the **Client**, which can now inspect the answer.



# Service Primitives

- If the Client has additional requests, it can make them now.
- If it is done, it can use **DISCONNECT** to terminate the connection.
- Usually, an initial **DISCONNECT** is a **blocking call**, suspending the client and sending a packet to the server saying that the connection is no longer needed.
- When the **Server** gets the packet, it also issues a **DISCONNECT** of its own, acknowledging the client and releasing the connection.
- When the Server's packet gets back to the Client machine, the **Client** process is **released** and the **connection** is **broken**.

# Reference Models

- The OSI Reference Model
- The TCP/IP Reference Model

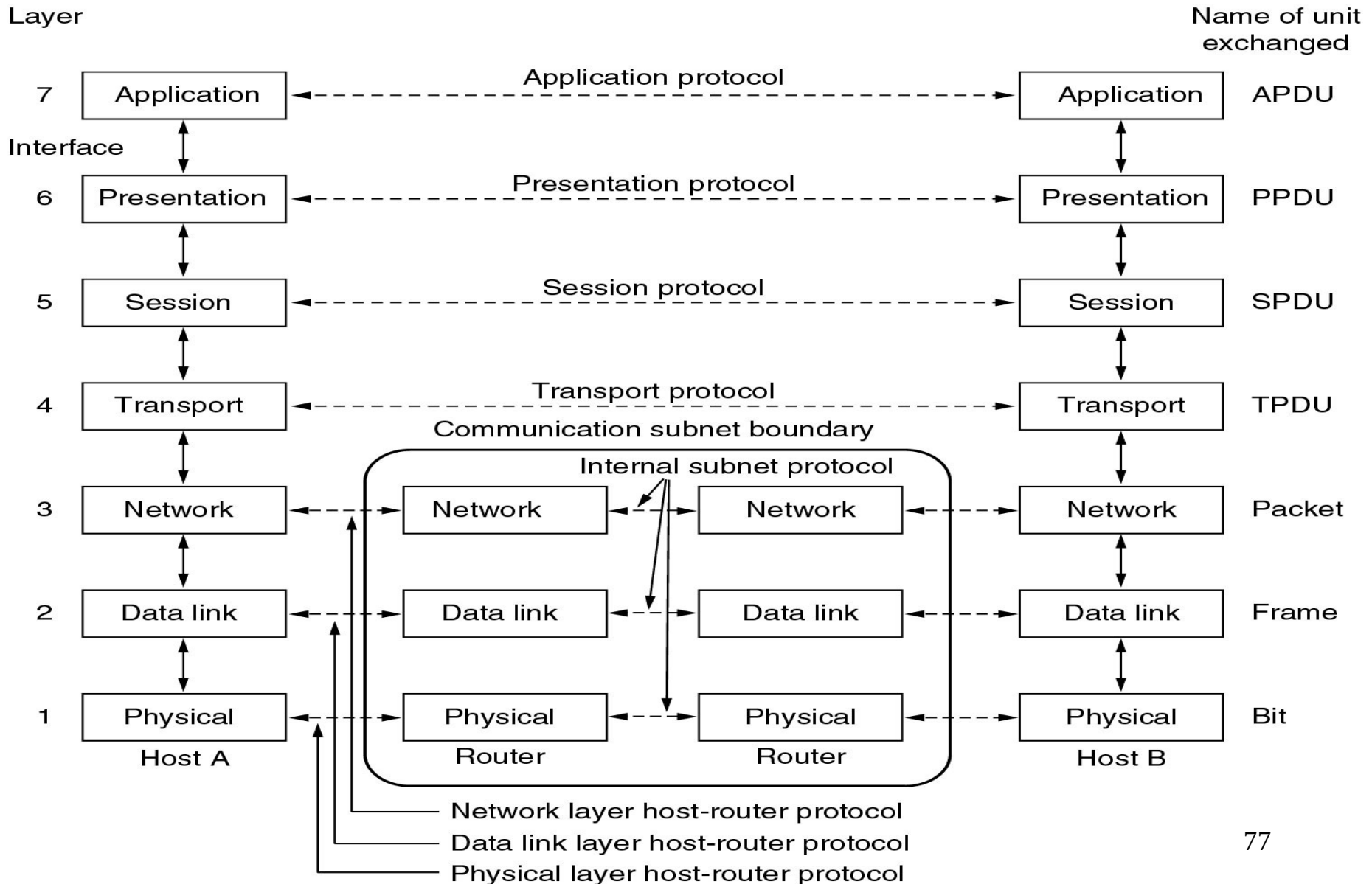
# OSI Reference Model

- The model is called the **ISO OSI** (International Organization for Standardization Open Systems Interconnection) Reference Model.
- because it deals with connecting open systems
  - ie, systems that are open for communication with other systems
- OSI model has **seven layers**
  1. Physical layer
  2. Data link layer
  3. Network Layer
  4. Transport Layer
  5. Session Layer
  6. Presentation Layer
  7. Application Layer

# OSI Reference Model

- Principles behind the seven layer design
  - A layer should be created where a different **abstraction (concept)** is needed.
  - Each layer should perform a well-defined **function**.
  - The function of each layer should be based on internationally **Standardized Protocols**
  - The layer boundaries should be chosen to minimize the information flow across the **interfaces**
  - number of layers should be
    - **large** enough that distinct functions need not be thrown together in the same layer out of necessity
    - **small** enough that the architecture does not become unmanageable

# OSI Reference Models



# OSI Reference Model

- *Physical Layer*
  - concerned with transmitting **raw bits** over a communication channel
  - **Design issues** are
    1. when one side sends a **1 bit**, it is received by the other side as a 1 bit, not as a 0 bit.
    2. how many **volts** should be used to represent a 1 and how many for a 0,
    3. how many **nanoseconds** a bit lasts,
    4. whether transmission may proceed simultaneously in both **directions**,
    5. how the initial connection is **established** and
    6. how it is **torn down** when both sides are finished,
    7. how many **pins** the network connector has
    8. what each pin is **used for**

# OSI Reference Model

- *Physical Layer*
  - Design issues deal with
    - Mechanical, electrical, & timing interfaces, and
    - physical transmission medium, which lies below the physical layer
- *Data link Layer*
  - Main task: **Error Control**
    - to transform a raw transmission facility into a line that appears **free of** undetected transmission **errors** to the network layer
    - sender break up the input data into **data frames** (typically a few hundred or a few thousand bytes) and transmit the frames sequentially
    - If the service is **reliable**, the receiver confirms correct receipt of each frame by sending back an acknowledgement frame

# OSI Reference Model

- *Data link Layer*
  - Another Issue: **Flow control**
    - how to keep a fast transmitter from drowning a slow receiver in data
    - traffic regulation mechanism is often needed to let the transmitter know how much buffer space the receiver has
  - Additional issue in broadcast networks:
    - how to **control access** to the **shared channel**
  - Data link layer is subdivided into 2 for this purpose
    - Logical Link Control (LLC) sub layer
    - Medium Access Control (MAC) sub layer
      - MAC handles the broadcast networks



# OSI Reference Model

- *Network Layer*
  - controls the operation of the **subnet**
  - design issues
    - determining how packets are **routed** from source to destination
    - Routes
      - can be based on **static tables** that are fixed into the network and are rarely changed
      - can be highly **dynamic**, being determined anew for each packet, to reflect the current network load
      - can also be determined at the **start** of each conversation (e.g., a login to a remote machine)

# OSI Reference Model

- *Network Layer*
  - Congestion control
    - If too many packets are present in the subnet at the same time, they will get in one another's way creating congestion
  - Providing QOS
    - transit time, delay, jitter, error rate, bandwidth, availability, throughput, etc
  - to allow heterogeneous networks (different addressing, protocols, message size, etc) to be interconnected
  - In broadcast networks, the routing problem is simple
    - so the network layer is often thin or even nonexistent

# OSI Reference Model

- *Transport Layer*
  - Basic function
    - to **accept** data from above,
    - **split** it up into smaller units if needed,
    - **pass** these to the network layer, and
    - ensure that all the pieces **arrive correctly** at the other end.
    - All this must be done **efficiently** in a way that **isolates** the upper layers from the inevitable changes in the **hardware technology**
    - determines what **type of service** to provide to the session layer, and, ultimately, to the users of the network

# OSI Reference Model

- *Transport Layer*
  - most popular type of transport connection
    - **error-free point-to-point channel** that delivers messages or bytes in the order in which they were sent
  - other possible kinds of transport service
    - transporting of **isolated messages**, with no guarantee about the order of delivery, and
    - the **broadcasting** of messages to multiple destinations
  - Type of service is determined when the connection is established

# OSI Reference Model

- *Transport Layer*
  - transport layer is a **true end-to-end layer**, all the way from the source to the destination
  - ie, a program on the source machine carries on a conversation with a similar program on the destination machine, using the message headers and control messages.
  - In the lower layers, the protocols are between each machine and its immediate neighbors (routers), and not between the ultimate source and destination machines

# OSI Reference Model

- *Session Layer*
  - allows users on different machines to **establish sessions** between them
  - Sessions offer various services, including
    - **Dialog control**
      - keeping track of whose **turn** it is to transmit
    - **Token management**
      - preventing two parties from attempting the same critical operation at the same time
    - **Synchronization**
      - checkpointing long transmissions to allow them to continue from where they were after a crash

# OSI Reference Model

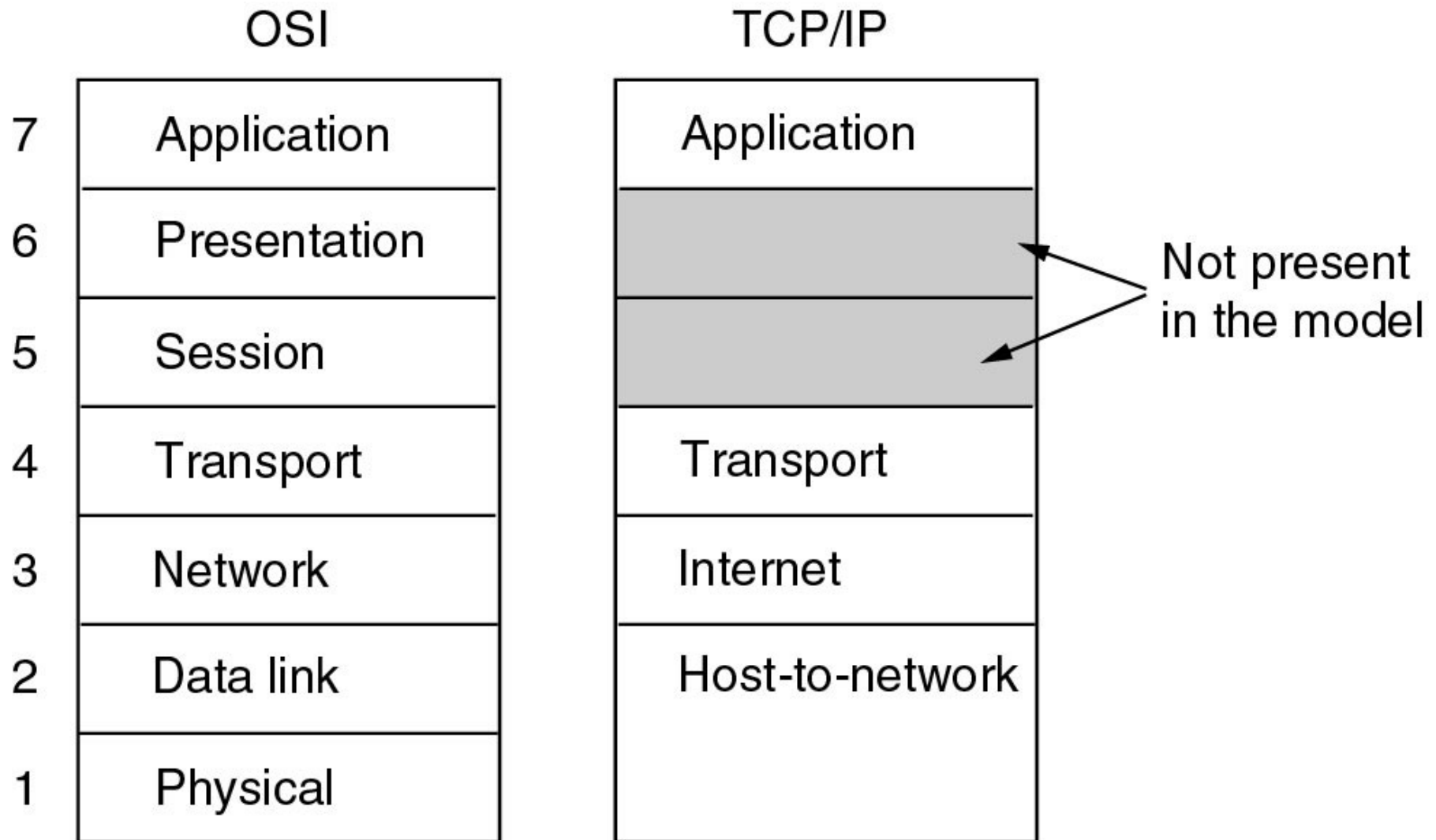
- *Presentation Layer*
  - concerned with the *syntax* and *semantics* of the information transmitted
  - In order to make it possible for computers with *different data representations* to communicate
    - the *data structures* to be exchanged can be defined in an abstract way
    - along with a standard *encoding* to be used on the wire
  - manages these abstract data structures and allows higher-level data structures (e.g., banking records) to be defined and exchanged

# OSI Reference Model

- *Application Layer*
  - Contains a variety of **protocols** that are commonly **needed by users**
  - Widely-used application protocol
    - HTTP (Hyper Text Transfer Protocol)
      - basis for the World Wide Web
      - When a browser wants a Web page, it sends the name of the page it wants to server using HTTP
      - server then sends the page back
  - Other application protocols
    - File transfer (FTP)
    - Electronic mail (SMTP)
    - Domain Name System (DNS)
    - Network News Transfer Protocol (NNTP)



# TCP/IP Reference Models



# TCP/IP Reference Model

- Reference model used in the ARPANET (grandparent of all WAN) and its successor, the worldwide Internet
- **ARPANET** (Advanced Research Projects Agency Network)
  - Research network sponsored by the DoD (U.S. Department of Defense)
  - Connected hundreds of Universities and Government installations, using **leased telephone lines**
  - When **satellite and radio networks** were added later, the existing protocols had trouble interworking with them
  - So, a new reference architecture was needed
  - Thus, the ability to connect multiple networks in a seamless way was one of the **major design goals** from the very beginning
  - This architecture later became known as the TCP/IP Reference Model, after its two primary protocols

# TCP/IP Reference Model

- Another major goal
  - network must be able to **survive** loss of subnet hardware, with existing conversations not being broken off.
  - ie, DoD wanted connections to remain intact as long as the source and destination machines were functioning
    - even if some of the machines or transmission lines in between were suddenly put out of operation.
  - Also, a **flexible** architecture was needed
    - since applications with divergent requirements were envisioned, ranging from transferring files to real-time speech transmission

# TCP/IP Reference Model

- ***Host-to-Network Layer***

- host has to **connect** to the network using some protocol so that it can send IP packets to it
- protocol is not defined and varies from host to host and network to network
- TCP/IP reference model does not really say much about what happens here

- ***Internet Layer***

- All requirements of DoD led to the choice of a **packet-switching** network based on a **connectionless** internetwork layer
- This layer is called the **internet** layer, because it is the key player that holds the whole architecture together

# TCP/IP Reference Model

- ***Internet Layer***
  - Job is to permit hosts to **inject** packets into any network and
  - have them travel **independently** to the destination on a different network
  - They may even arrive in a **different order** than they were sent
  - it is the job of higher layers to **rearrange** them, if in-order delivery is desired
  - Note that "internet" is used here in a generic sense, even though this layer is present in the Internet

# TCP/IP Reference Model

- ***Internet Layer***
  - Internet layer defines an official **packet format** and protocol called **IP** (Internet Protocol).
  - The job of the internet layer is to deliver IP packets where they are supposed to go.
  - **Packet routing** & avoiding **congestion** are the major issue here
  - For these reasons, it is reasonable to say that the TCP/IP internet layer is similar in functionality to the OSI network layer

# TCP/IP Reference Model

- ***Transport Layer***
  - designed to allow peer entities on the source and destination hosts to carry on a conversation
  - Two end-to-end transport protocols
    - TCP (Transmission Control Protocol)
    - UDP (User Datagram Protocol)
- ***TCP***
  - **Reliable connection-oriented** protocol
  - allows a byte stream originating on one machine to be delivered **without error** on any other machine in the internet.
  - It **fragments** the incoming byte stream into discrete messages and passes each one on to the internet layer.

# TCP/IP Reference Model

- ***Transport Layer***
  - ***TCP***
    - At the destination, the receiving TCP process **reassembles** the received messages into the output stream
    - TCP also handles **flow control** to make sure a fast sender cannot swamp a slow receiver with more messages than it can handle



# TCP/IP Reference Model

- ***Transport Layer***
  - ***UDP***
    - **Unreliable connectionless** protocol
    - for applications that do not want TCP's sequencing or flow control and wish to provide their own
    - also widely used for **one-shot**, client-server-type request-reply queries and
    - applications in which **prompt delivery** is more important than accurate delivery, such as transmitting speech or video

# TCP/IP Reference Model

- ***Application Layer***
  - TCP/IP model does not have session or presentation layers
  - Because they are of little use to most applications
  - contains all the higher-level protocols like
    - virtual terminal (TELNET)
    - file transfer (FTP)
    - electronic mail (SMTP)
    - Domain Name System (DNS)
    - Network News Transfer Protocol (NNTP)
    - Hyper Text Transfer Protocol (HTTP)

# TCP/IP Reference Model

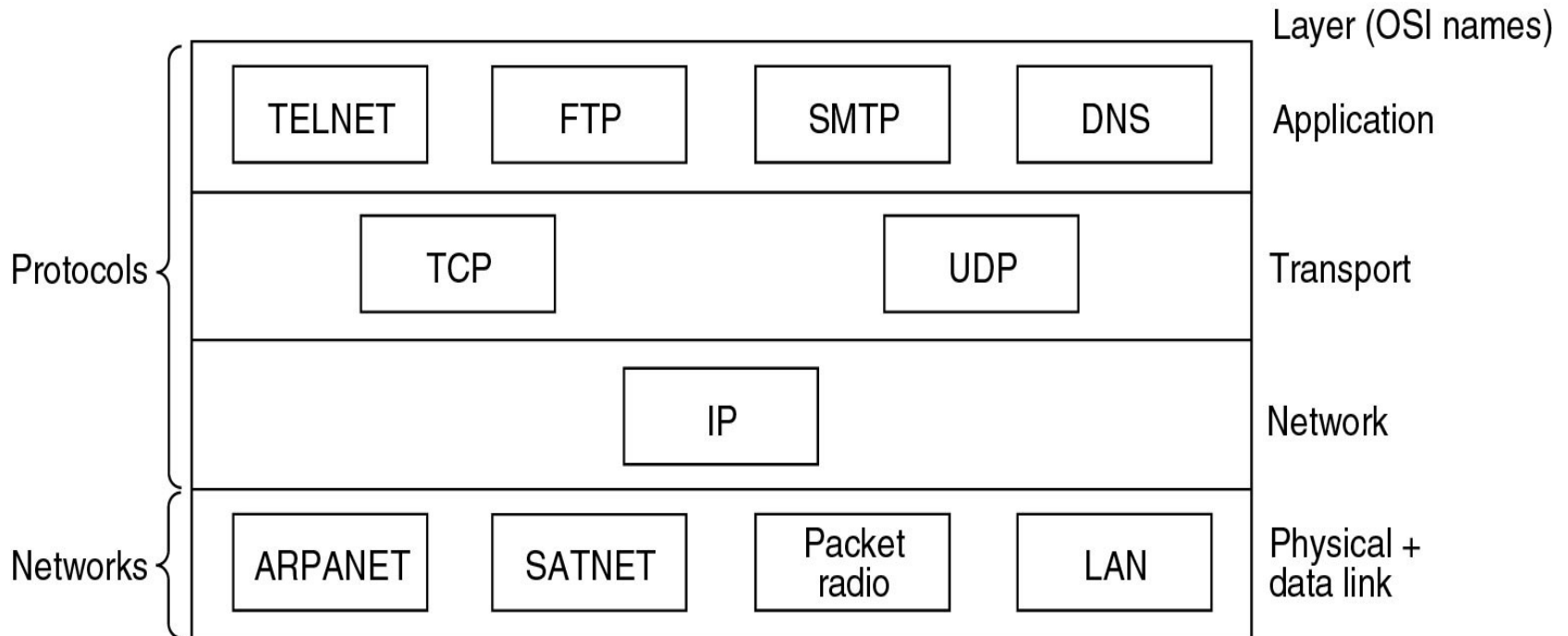
- ***Application Layer***
  - TELNET
    - virtual terminal protocol allows a user on one machine to **log onto a distant machine** and work there
  - FTP (File Transfer Protocol )
    - provides a way to **move data efficiently** from one machine to another
  - SMTP (Simple Mail Transfer Protocol)
    - Electronic mail was originally just a kind of file transfer, but later a specialized protocol (SMTP) was developed for it

# TCP/IP Reference Model

- ***Application Layer***
  - DNS (Domain Name System)
    - for mapping host names onto their network addresses
  - NNTP (Network News Transfer Protocol )
    - protocol for moving USENET news articles around
    - USENET (worldwide distributed Internet discussion system)
  - HTTP (Hyper Text Transfer Protocol )
    - protocol for fetching pages on the World Wide Web (WWW)

# Reference Models

Protocols and networks in the TCP/IP model initially.



ARPANET - Advanced Research Projects Agency Network

SATNET – Sustainable Agriculture Trainers Network

# Assignment I

## Comparison & critiques of OSI and TCP/IP Models