Chapter 1

Introduction

The contents may be based in part on "Computer Networks" by A. Tanenbaum, "Internetworking with TCP/IP" by D. Comer, "Patterns in Network Architecture: A Return to Fundamentals", by J. Day

Administrative

- **Instructor**: Hoda Baraka
- **Teaching Assistant**:
  - Salma Abdel Motaleb
- **Text**: *Andrew S. Tanenbaum, "Computer Networks", Fifth Edition.*

Administrative (cont)

- **Grading (semester)**:
  - Final: 70%
  - Midterm: 10%
  - Project : 10%
  - Labs 6%
  - Quizzes, : 4%

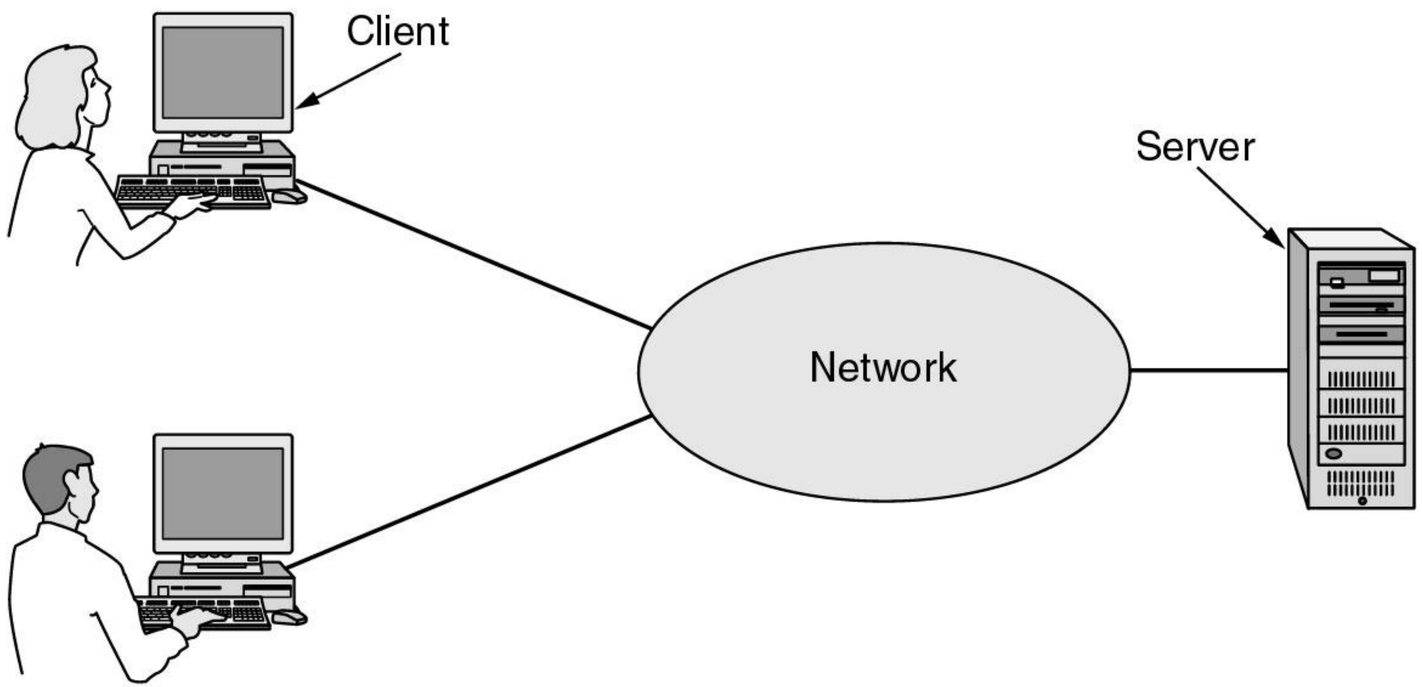
  Grading (Credit):
  - Final: 40%
  - Midterm: 20%
  - Project: 20%
  - Quizzes: 10%
  - Lab: 10%

Uses of Computer Networks

- Business Applications
- Home Applications
- Mobile Users
- Social Issues

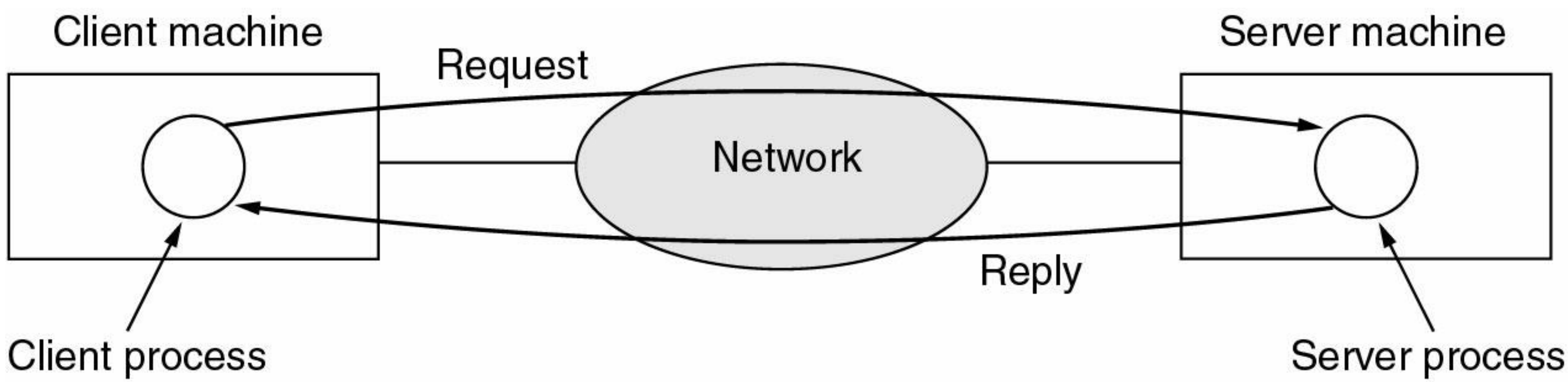
Business Applications of Networks

- A network with two clients and one server.



Business Applications of Networks (2)

- The client-server model involves requests and replies.
- Client-server models need *not* involve communication networks

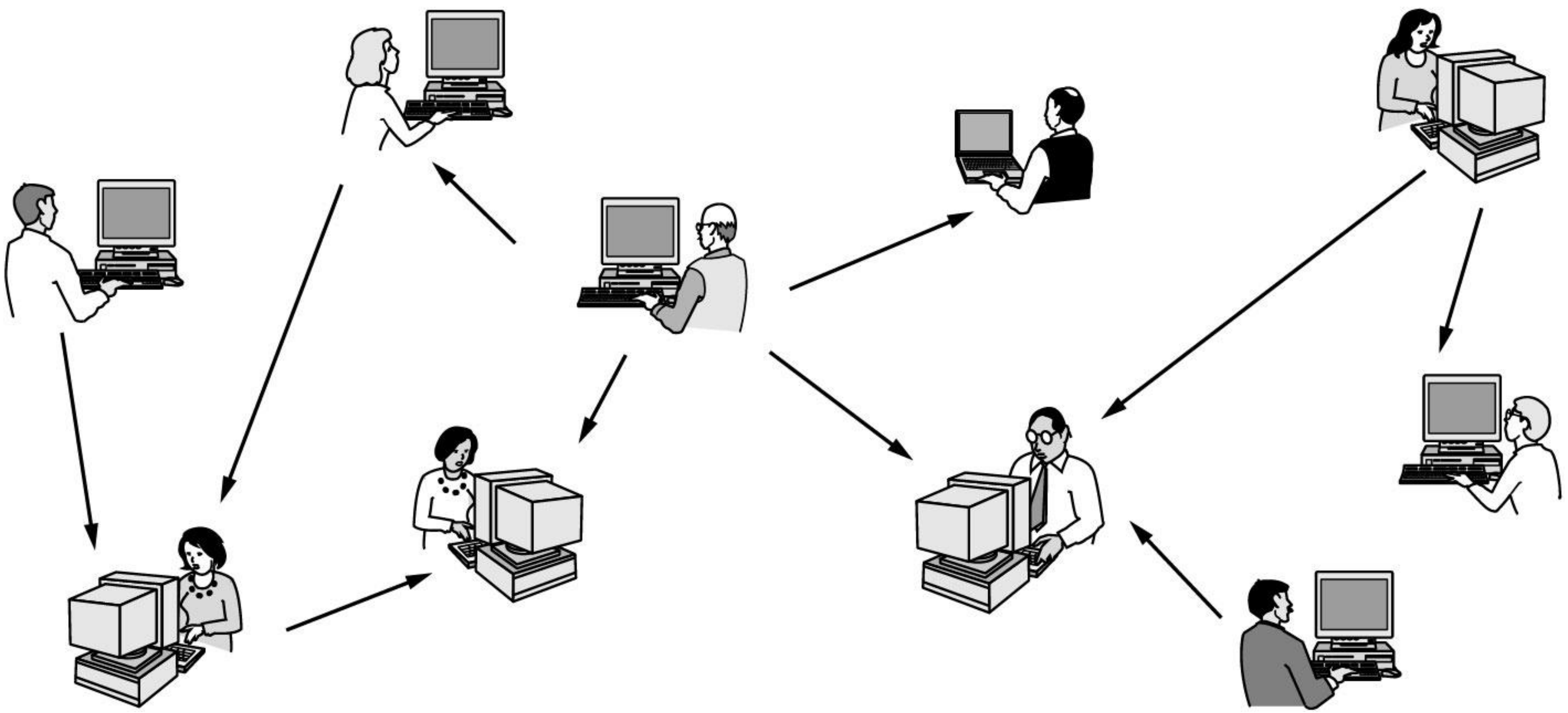


Home Network Applications

- Access to remote information
- Person-to-person communication
- Interactive entertainment
- Electronic commerce

Home Network Applications (2)

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



Home Network Applications (3)

- Some forms of e-commerce.

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

Mobile Network Users

- Combinations of wireless networks and mobile computing.
- Tablets, laptops, and smart phones are popular mobile devices;
- WiFi hotspots and 3G cellular provide wireless connectivity

Network Hardware

- Local Area Networks
- Metropolitan Area Networks
- Wide Area Networks
- Wireless Networks
- Home Networks
- Internetworks

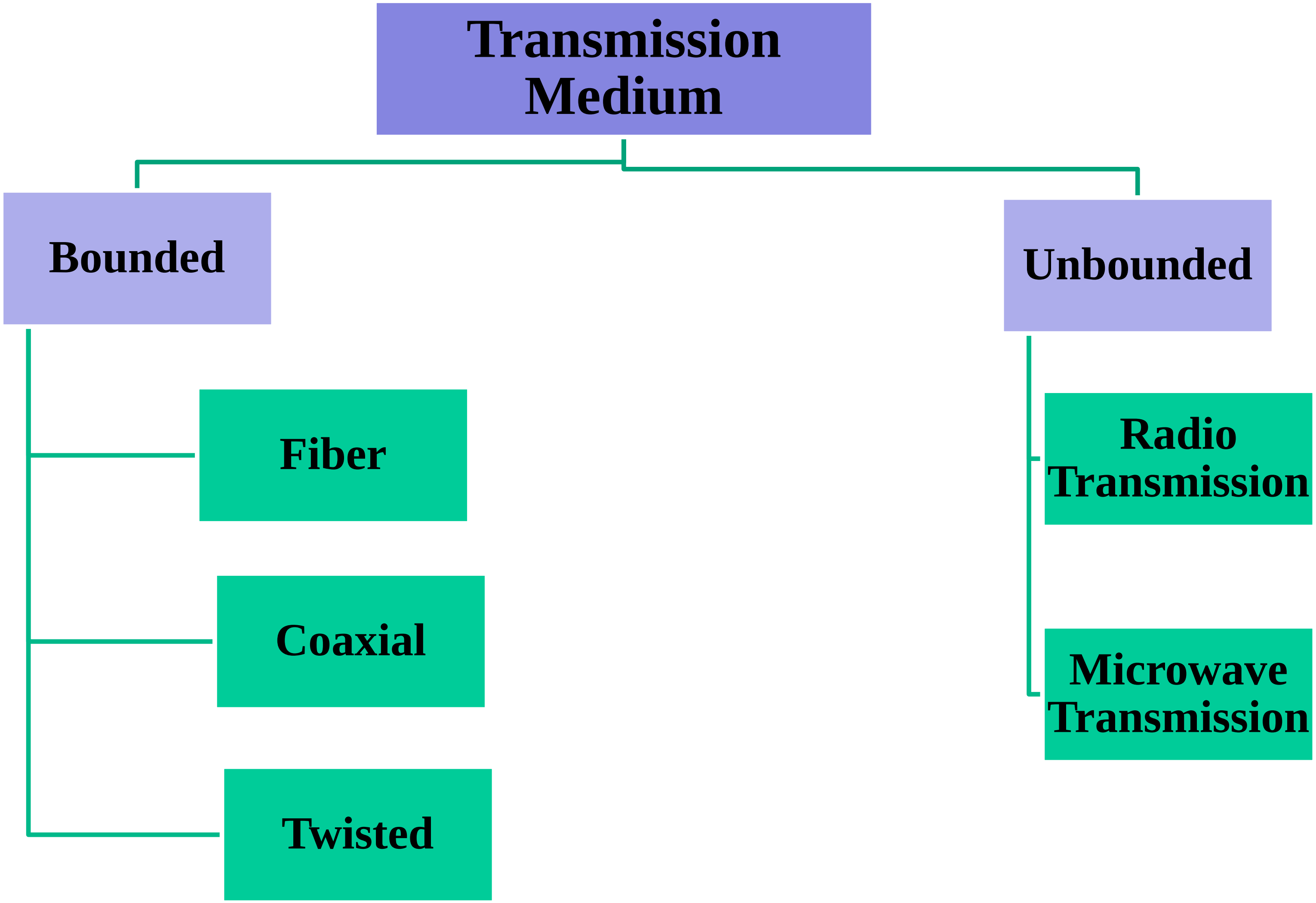
Classification by Transmission Technology

- Types of transmission technology
  - Broadcast links
  - Point-to-point links

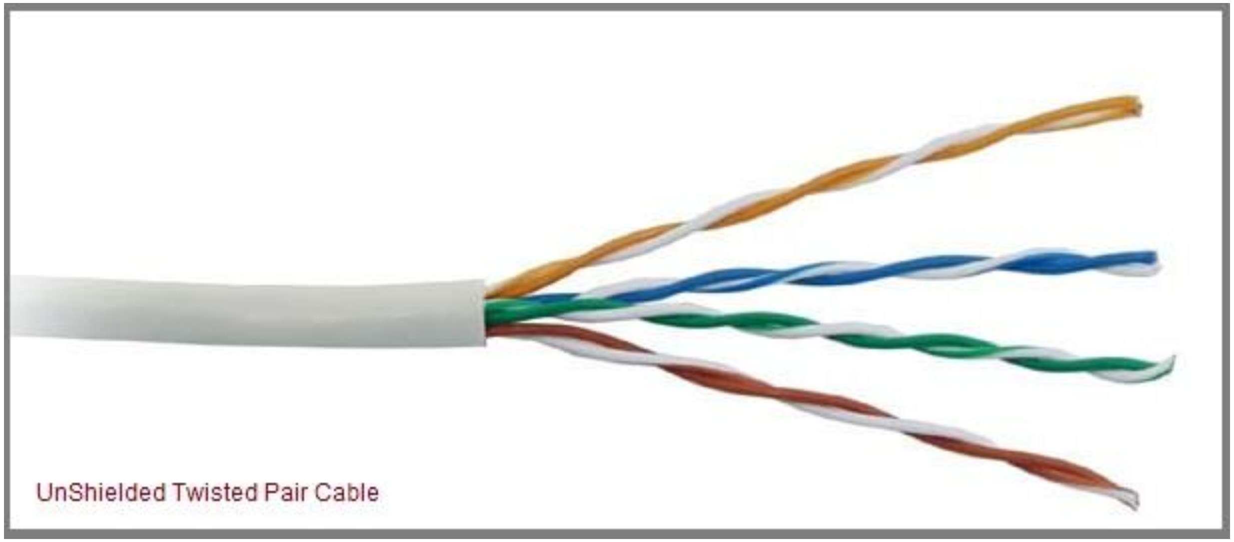
Classification by Transmission Technology

- **Broadcast Networks**
  - Single Medium Shared by all nodes
  - Data is sent in a *package* usually called packet or frame
  - All nodes hear the packet ⇒ need addressing mechanism
  - Packet is only processed by the intended node
  - Usually capable of broadcast ⇒ All nodes receive
  - Usually capable of multicast ⇒ a subset of the nodes receive the packet
  - Broadcast networks are usually small in size*
- **Point to Point**
  - Connection between a pair
  - No need for addressing
  - May be very large (thousands of KM)
  - Still packaged (cell, packet, frame)

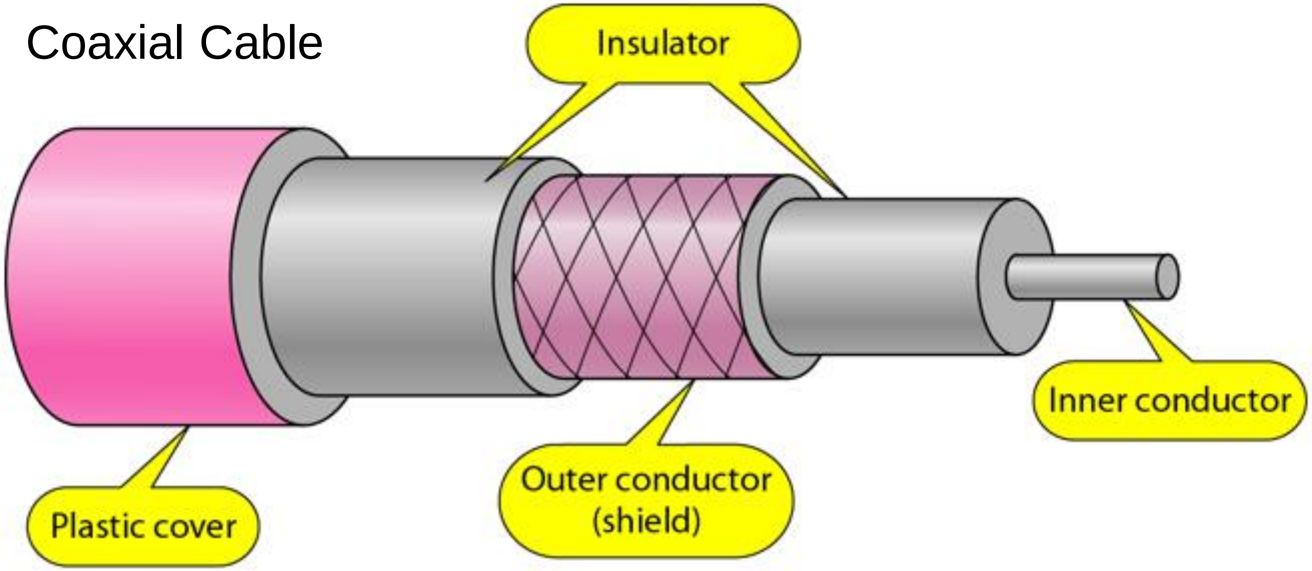
Transmission Medium



Twisted Pairs



Coaxial Cable



Category	*Impedance*	*Use*
RG-59	75 Ω	Cable TV
RG-58	50 Ω	Thin Ethernet
RG-11	50 Ω	Thick Ethernet

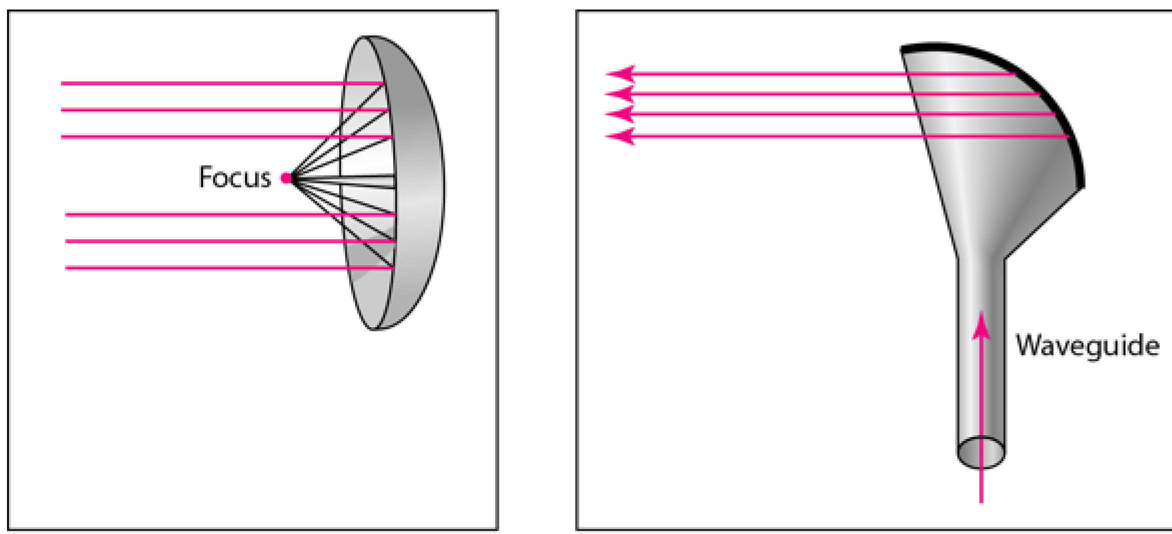
Unbounded Medium

Radio Waves

Electromagnetic waves ranging in frequencies between 3 KHz and 1 GHz are normally called radio waves.

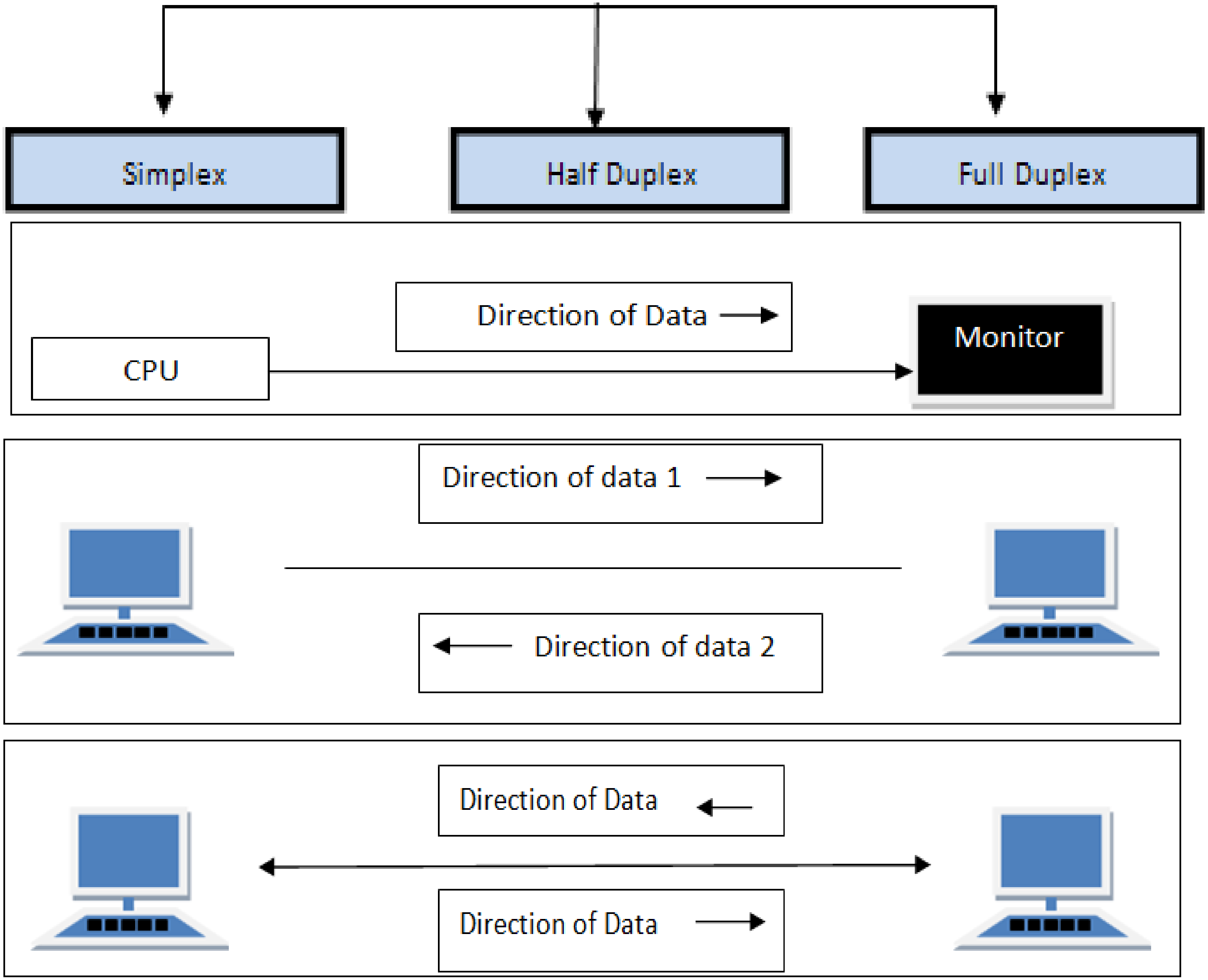
Micro Waves

Electromagnetic waves having frequencies between 1 and 300 GHz are called micro waves

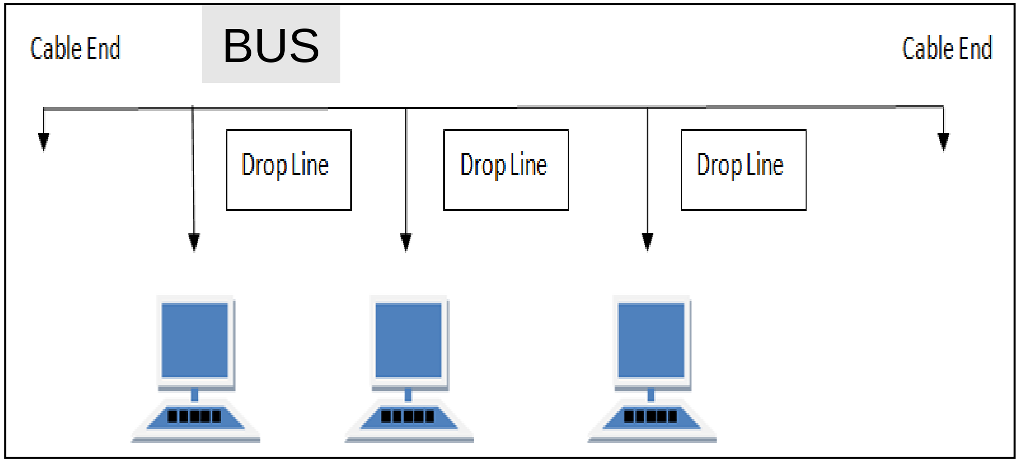


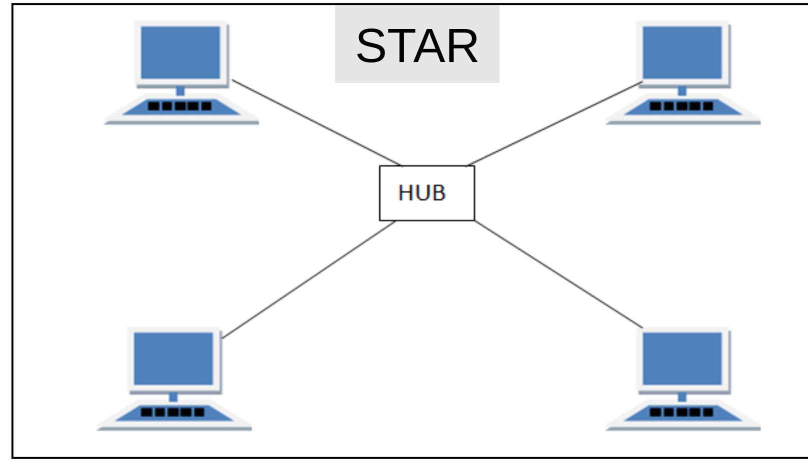
a. Dish antenna b. Horn antenna

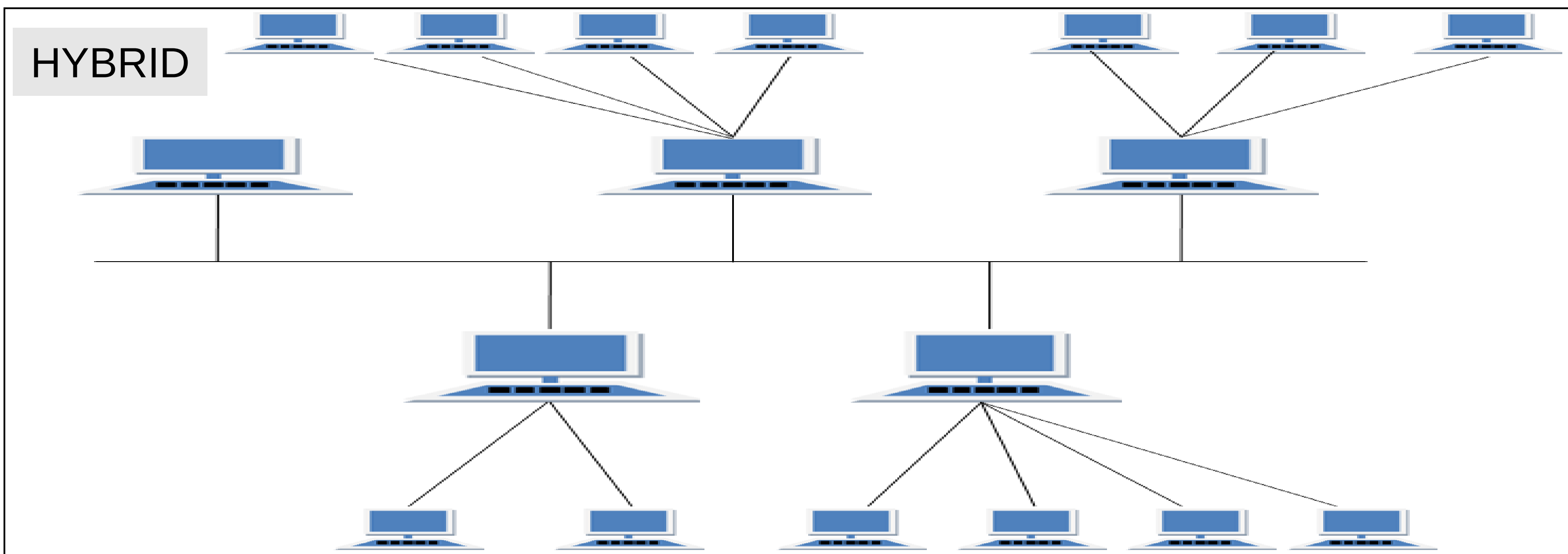
Transfer Modes



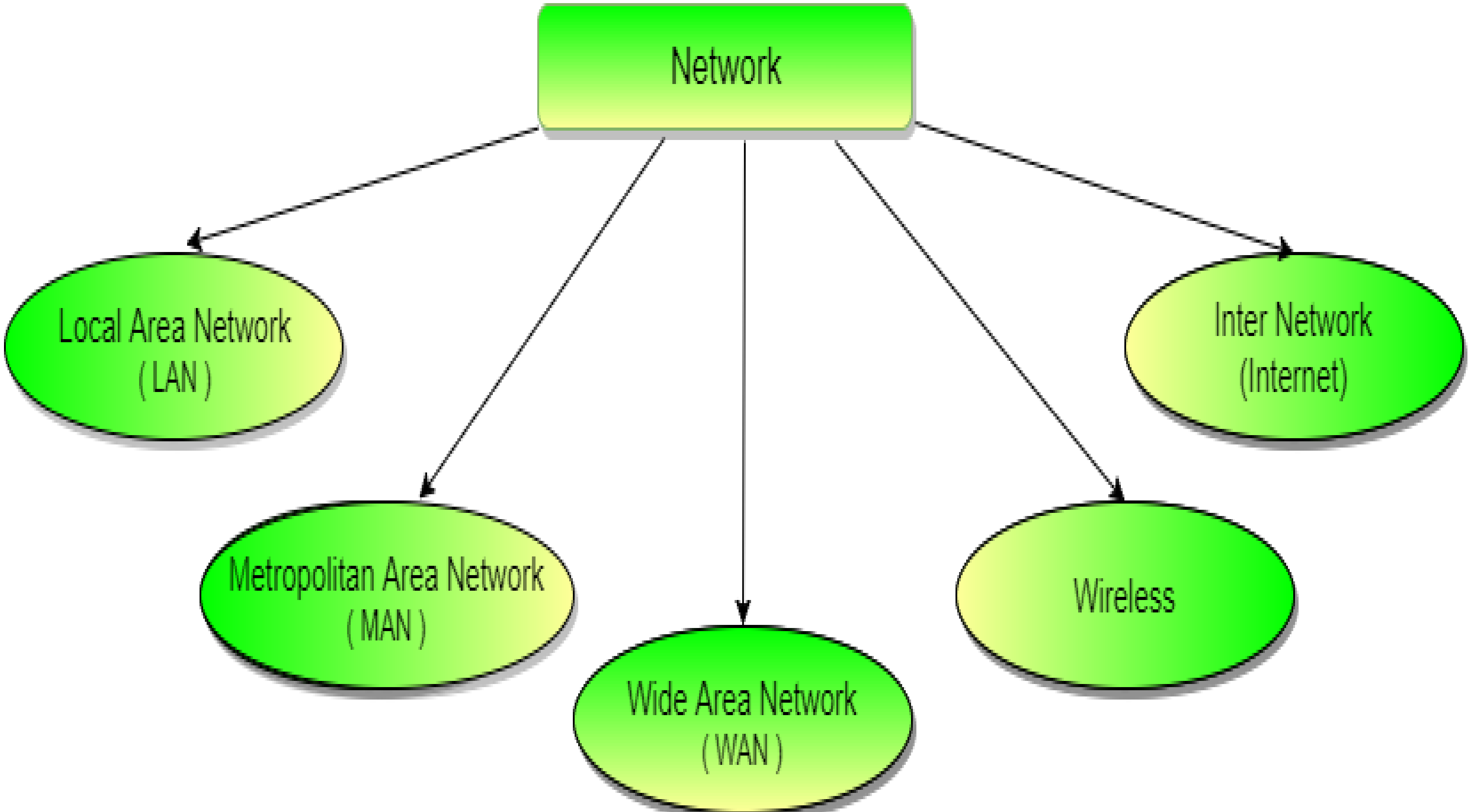
Network Topologies







Types of Networks

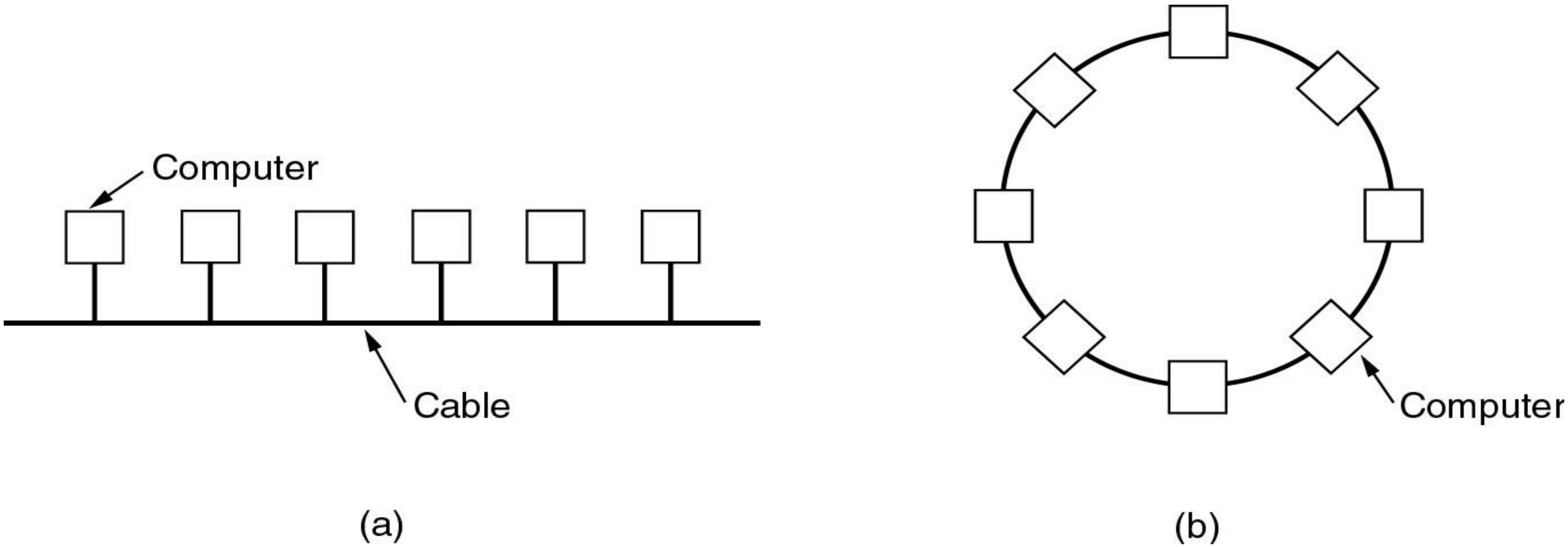


Classification by Scale

- Classification of interconnected processors by scale.

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

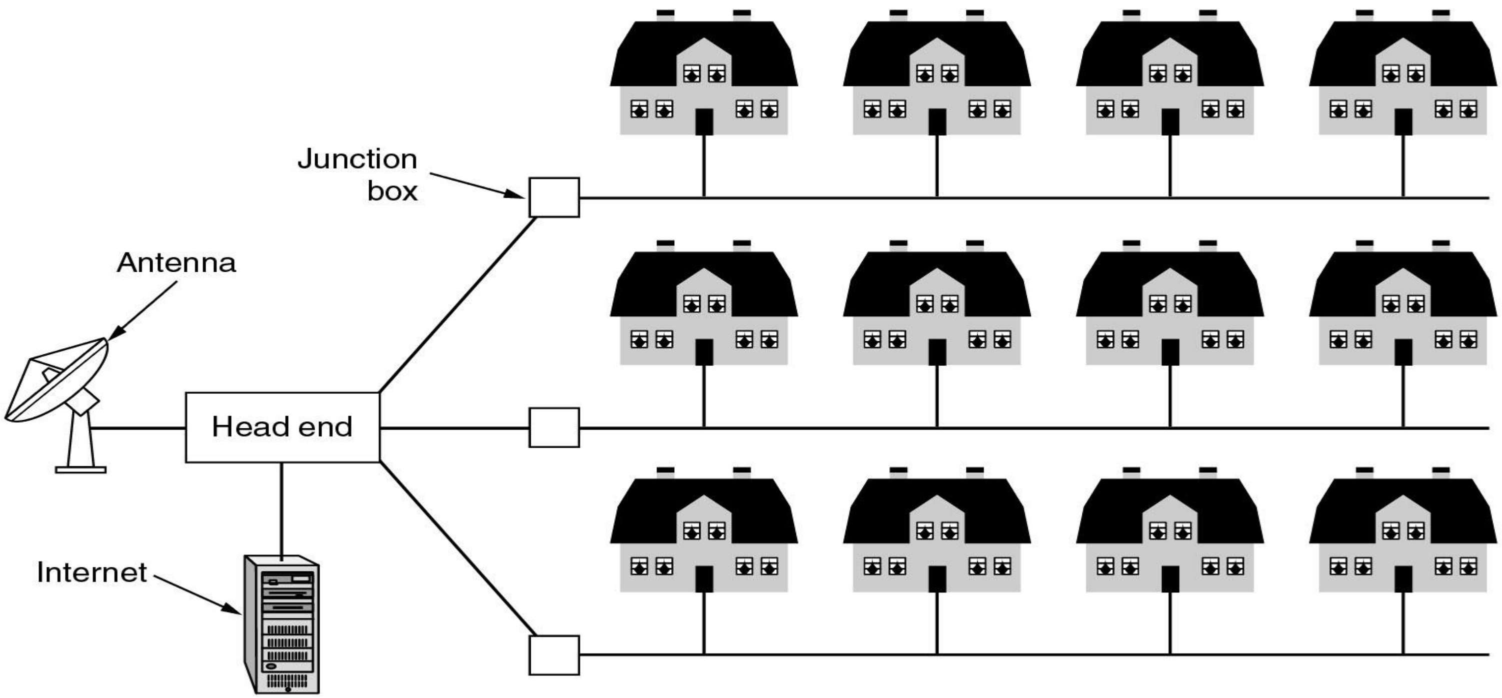
Local Area Networks



- Two broadcast networks
  - Bus
  - Ring
- Restricted in Size $\Rightarrow$ bounded delay, easy management
- Various arbitration techniques
  - Token
  - Collision detection or avoidance
  - Centralized
  - Static

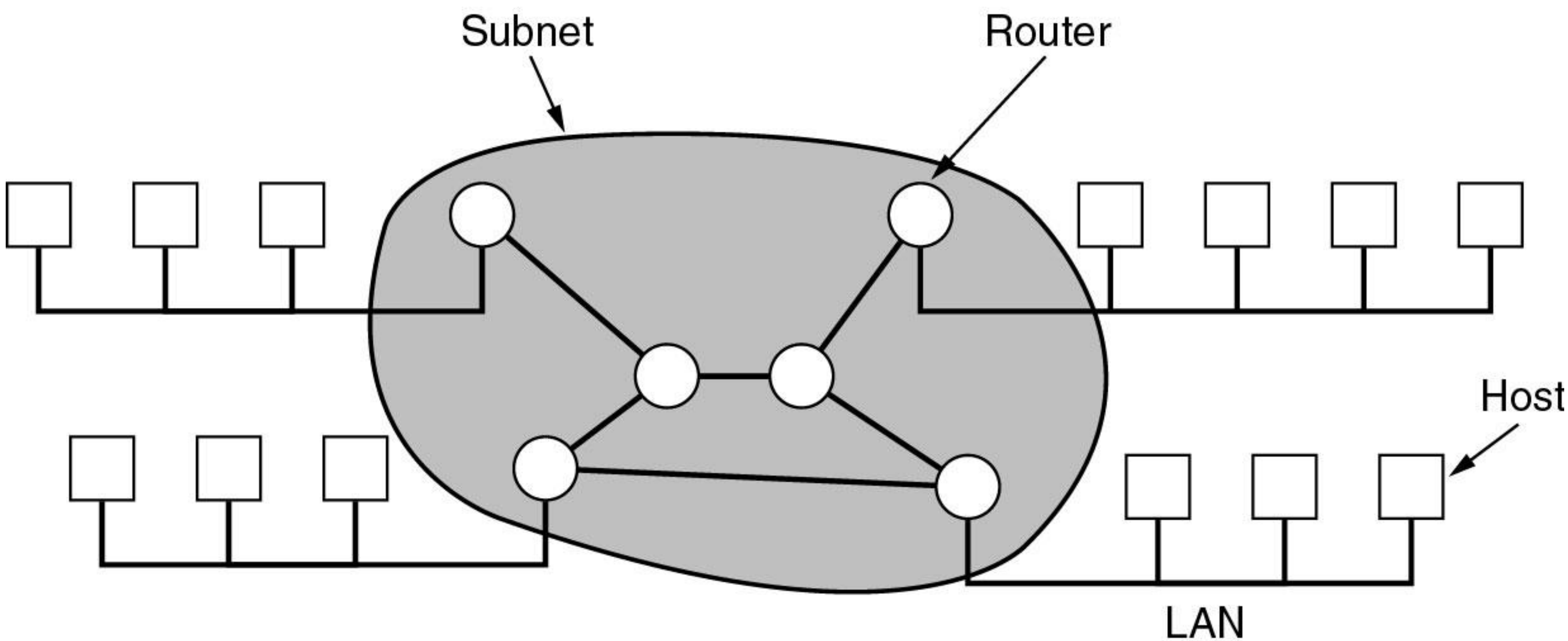
Metropolitan Area Networks

- IEEE 802-2001 defines MAN as optimized for areas larger than LAN
- Spans few blocks to entire cities
- Ranges can grow to 50 Km
- Example: A metropolitan area network based on cable TV.



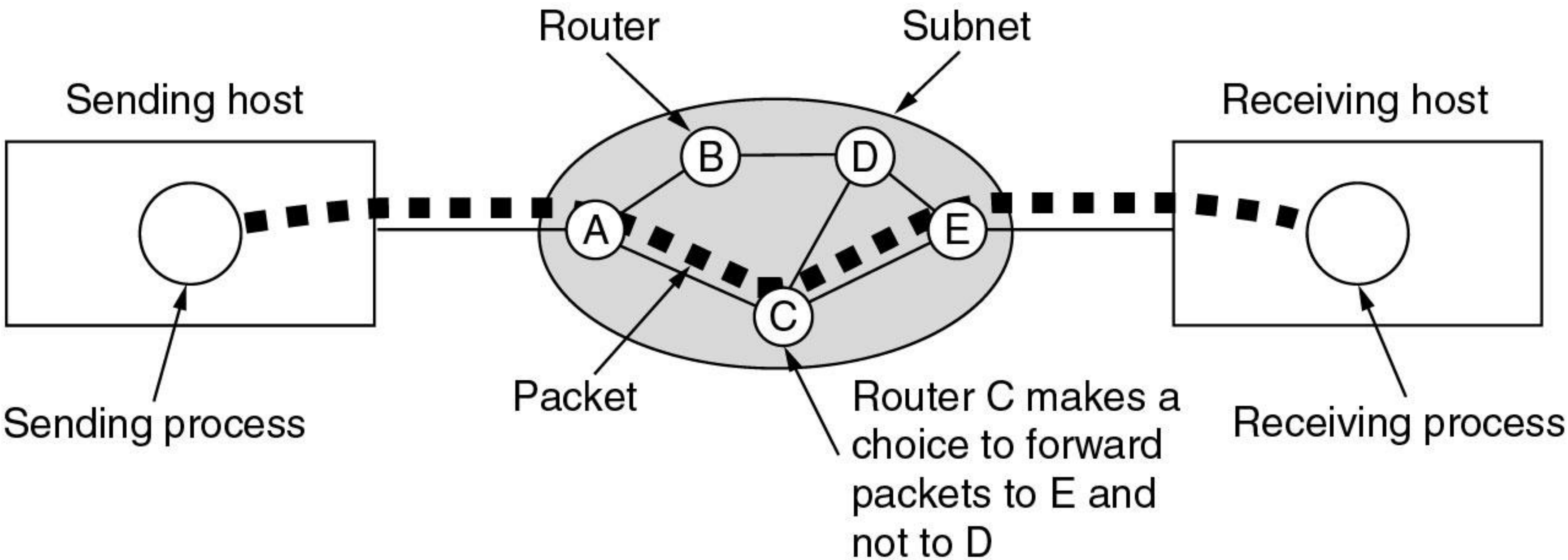
Wide Area Networks

- Consists of communication lines and switching elements (routers)
- Relation between hosts on LANs and the subnet.



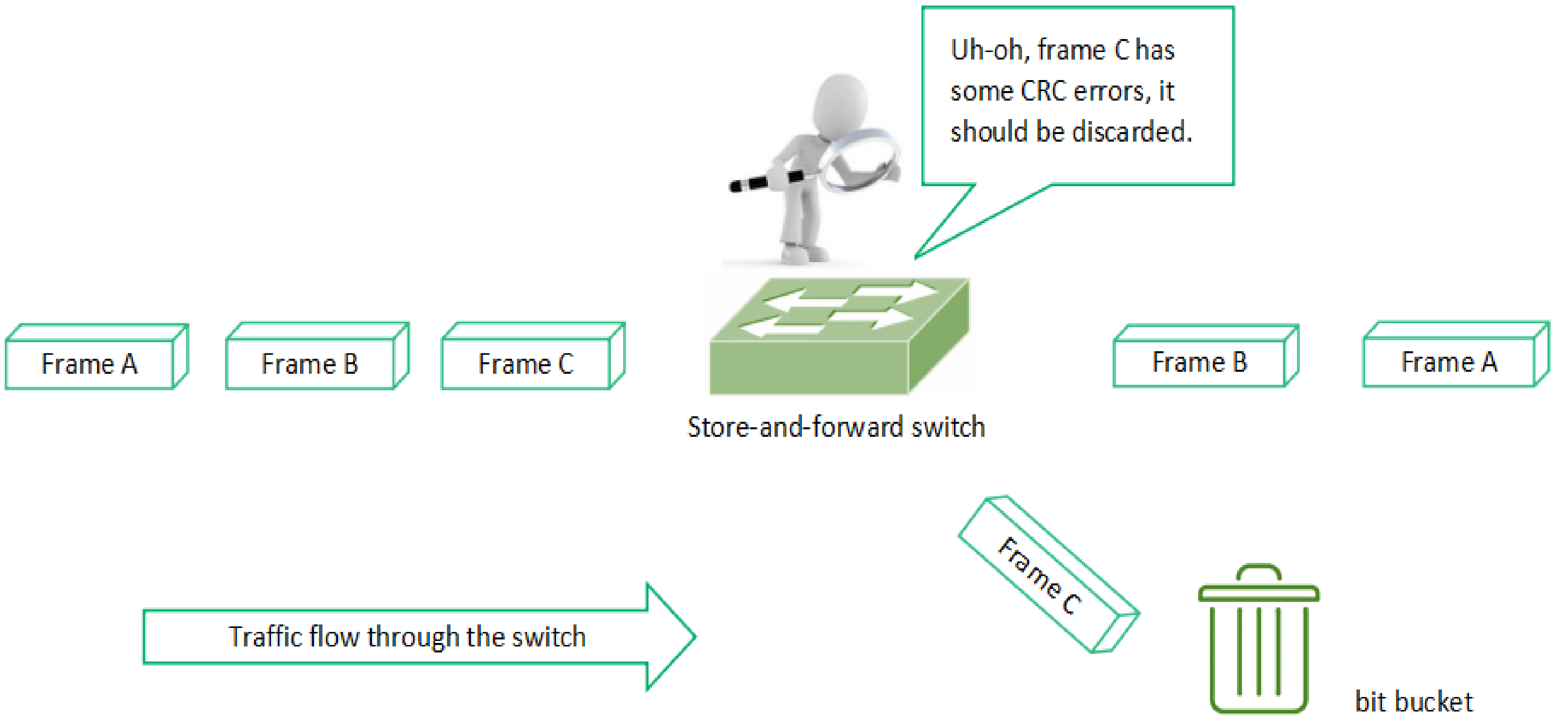
Wide Area Networks (2)

- A stream of packets from sender to receiver.



- Packet switched network ⇒ packet forwarded independently
- Usually routers use "**store-and-forward**"
- Few routers use "cut-through" (*what is cut-through?*)
- WAN can also go over satellites

Store & Forward

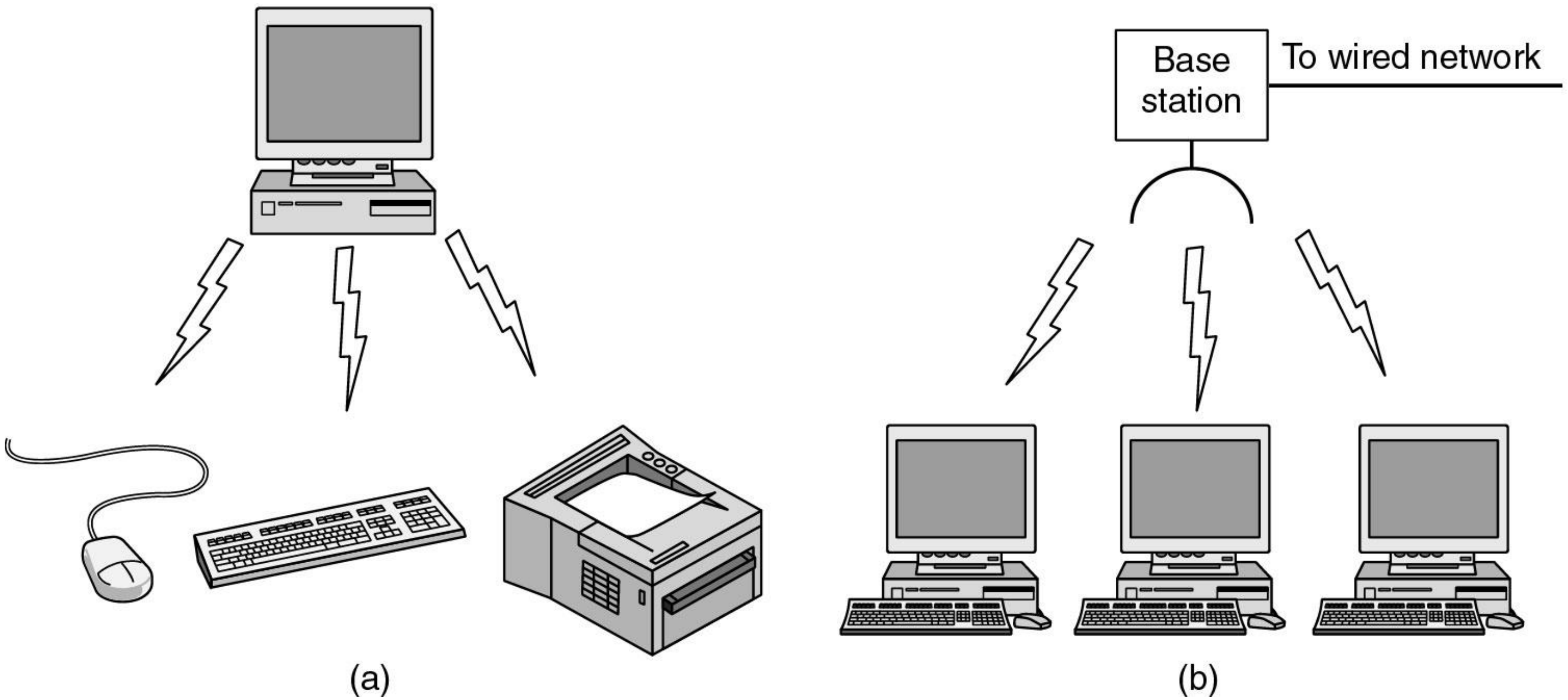


Comparison between store & forward and Cut through switching

Wireless Networks

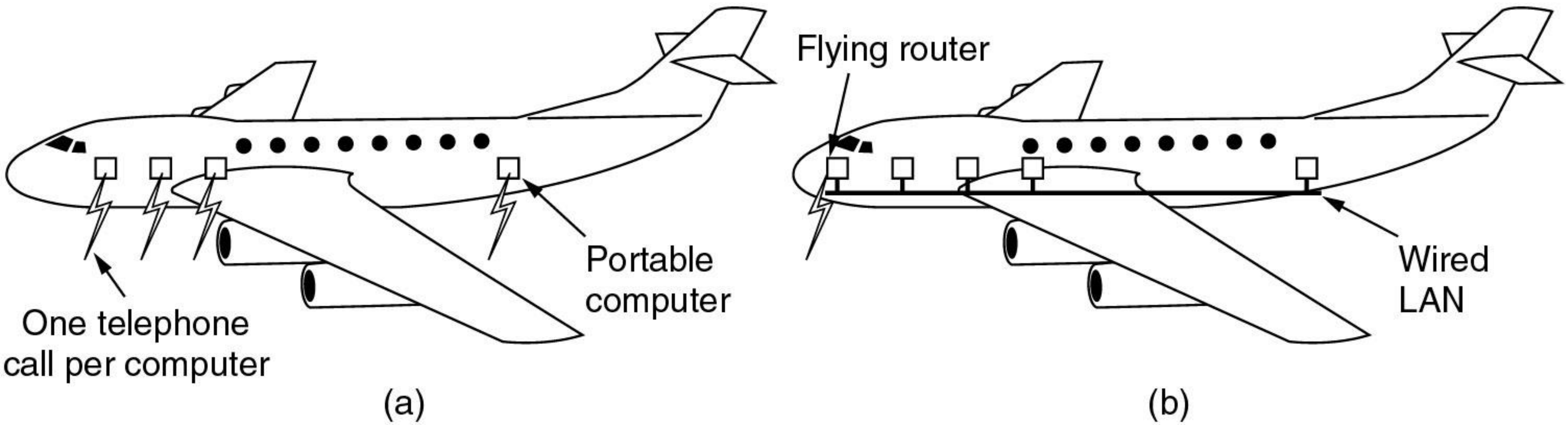
- Categories of wireless networks:
  - System interconnection
  - Wireless LANs
  - Wireless WANs

Wireless Networks (2)



- (a) Bluetooth configuration
- (b) Wireless LAN

Wireless Networks (3)



- (a) Individual mobile computers
- (b) A flying LAN

Home Network Categories

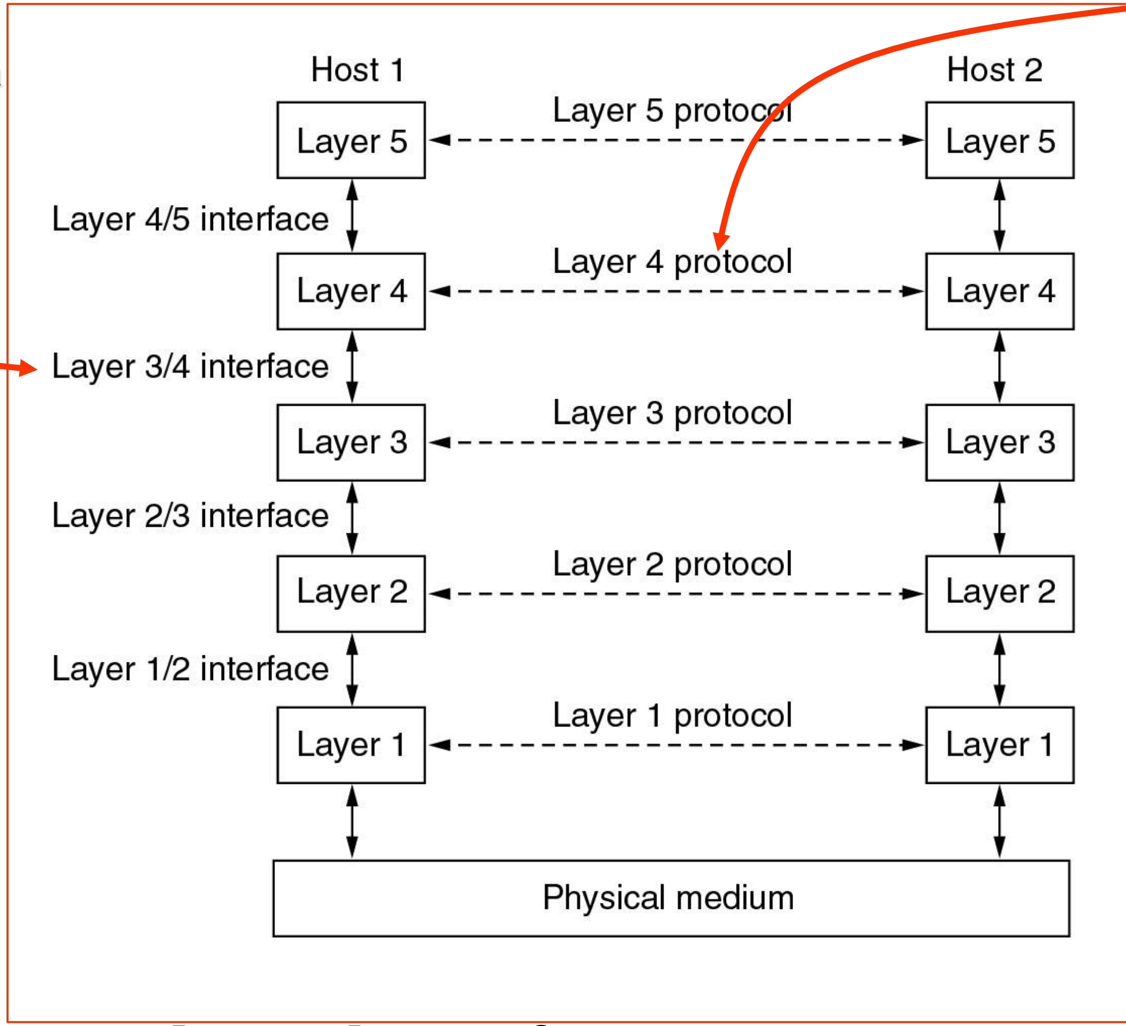
- Idea
  - All devices can communicate with each other and with the internet
- Computers (desktop PC, PDA, shared peripherals
- Entertainment (TV, DVD, VCR, camera, stereo, MP3)
- Telecomm (telephone, cell phone, intercom, fax)
- Appliances (microwave, fridge, clock, furnace, airco)
- Telemetry (utility meter, burglar alarm, babycam).

Network Architecture

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

Network Architecture
Protocol Hierarchies

Well defined interface between every pair of adjacent **layers**



Well defined protocol between **peers**

Example: 5 layer protocol hierarchy

- Layers, protocols, and interfaces.

Protocol Hierarchy Terminology

- **Protocol**:
  - It is a well defined agreement on how to communicate between communication parties
  - It is the definition of the rules and behavior required by an entity participating in the transfer of data*
- **Peers**: corresponding layers in different parties
- **Interface**: defines the primitives** a lower layer makes available to an adjacent upper layer
  - Must be well defined and unambiguous
  - Minimize the amount of **control** information transfer between layers
  - Allows replacing implementation of one layer without touching adjacent layers (e.g Telephone wires with optical fiber)
- **Protocol Stack**: the list of protocols used by a system
- A **network Architecture**
  - The set of protocols and layers
  - Must be specific enough to allow an implementation
  - Does **not** include details of protocols and interfaces

*Patterns in Network Architecture: A Return to Fundamentals, by John Day, Chapter 1

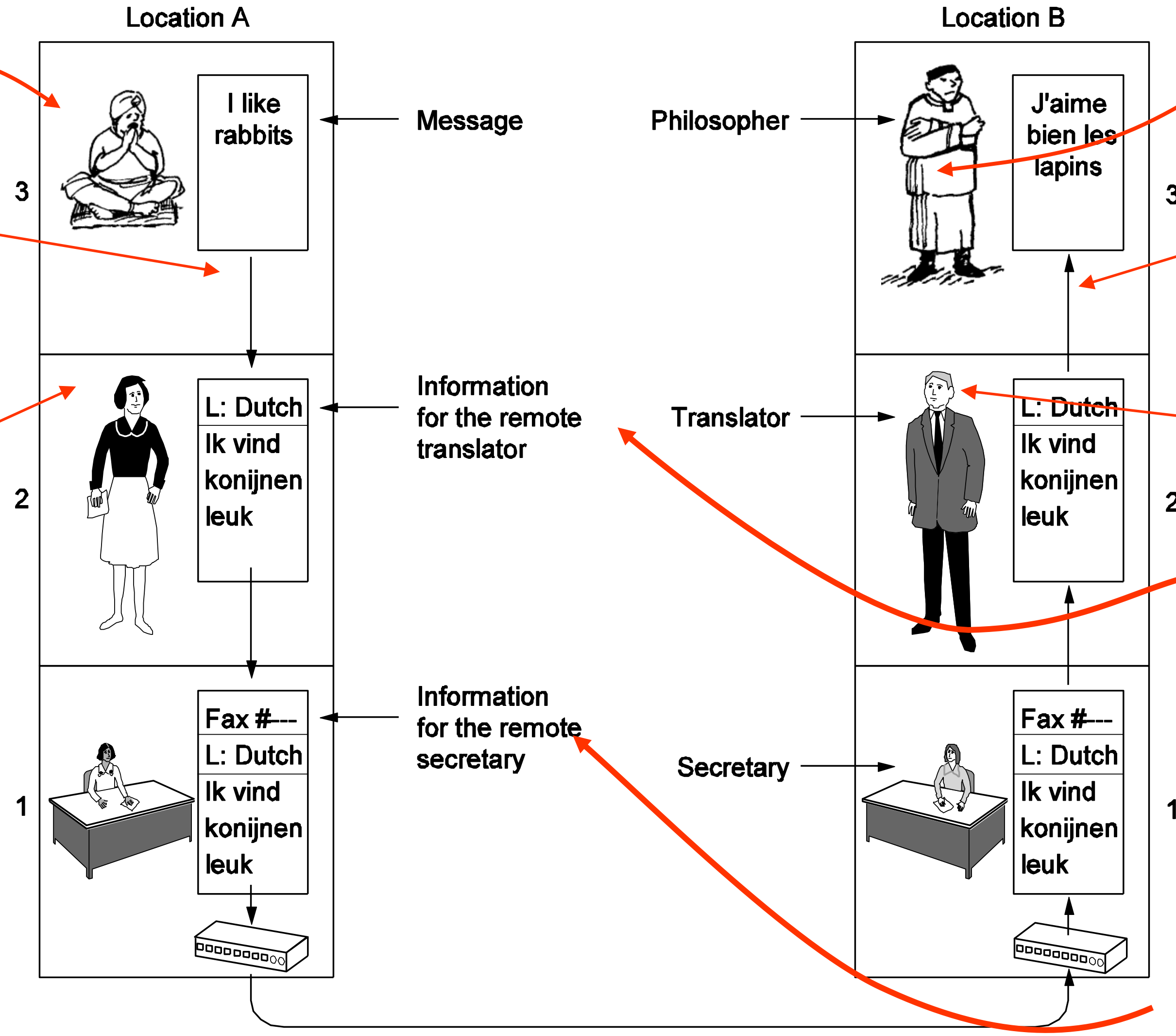
Protocol Hierarchies (2)

Example

Speaks Urdu & English

Passes message down in English

Service=Translate-English-to-Dutch



Speaks French & Chinese

Passes message up in French

Service=Translate-Dutch-to-French

Protocol = Dutch

May change to Africans at will

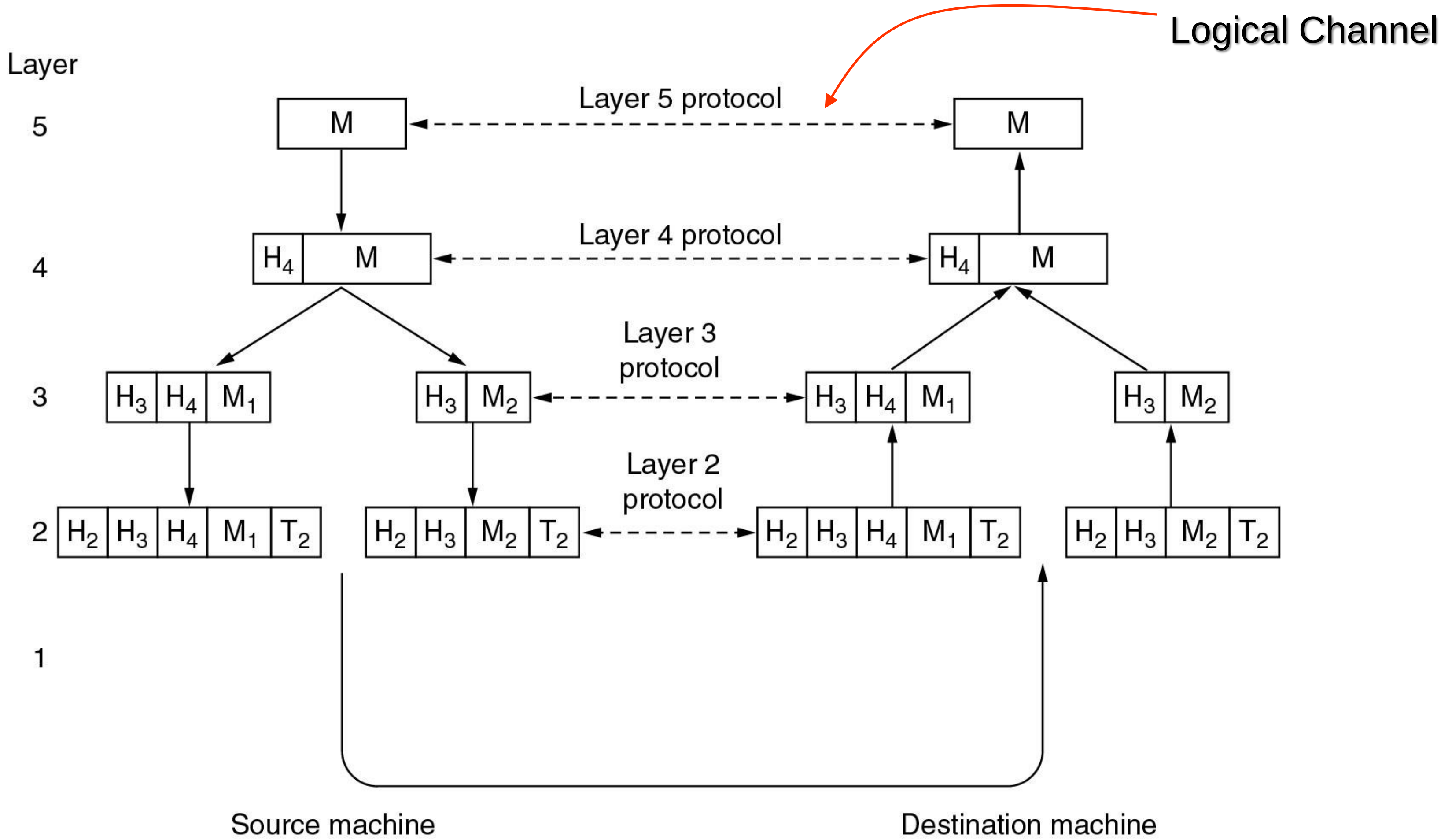
Protocol = Fax

May change to email at will

- The philosopher-translator-secretary architecture.

Protocol Hierarchies (3) Technical Example

- Example information flow supporting virtual communication in layer 5.



Design Issues for the Layers

- Addressing: Each layer needs to ***identify*** and ***locate*** senders and receivers
- Rules for data transfer: e.g. half-duplex vs. full-duplex
- Error Control:
  - Agreement or error detection and correction between peers
  - Message sequence and out-of-order control
  - Fragmentation & Re-assembly
- Flow Control: Fast sender should not overwhelm slow receiver
- Multiplexing/de-multiplexing: Use single channel for multiple communicating parties
- Routing: Find the way between communicating parties

Connection-Oriented and Connectionless Services

- *Six* different types of service.

	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

Continue to work (for a while) and ACK may come later

Block until reply comes

Service and Service Primitives

- A primitive is a **basic operation** available to the upper layers
- A **service is defined** by[*]
  - the **set of primitives** that the service makes available to the upper layers
  - the set of **parameters** of each service primitives
  - the rules that determine the **legal sequences** in which the service primitives can be invoked
- A service provides a level of **abstraction** to the upper layer(s)
- A primitive is available to the upper layer(s) to access the service
- A primitive tells the service to do some functionality or report an action. Example:
  - Connect to a remote host (for connection oriented)
  - Receive a packet from remote peer (connection or connectionless)
- You can think of the set of primitives as user interface to the service
- A primitive may be implemented as system call that may trap into the kernel

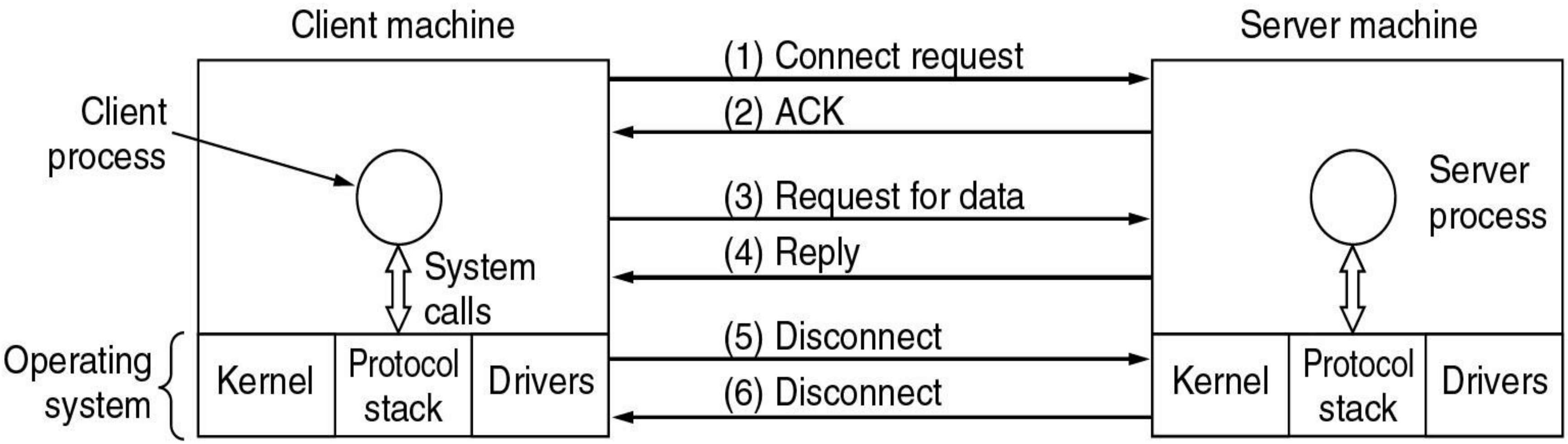
[*] Patterns in Network Architecture: A Return to Fundamentals, by John Day Chapter 1

Service Primitives Example Connection Oriented

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

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

Service Primitives (3) Client-Server Interaction



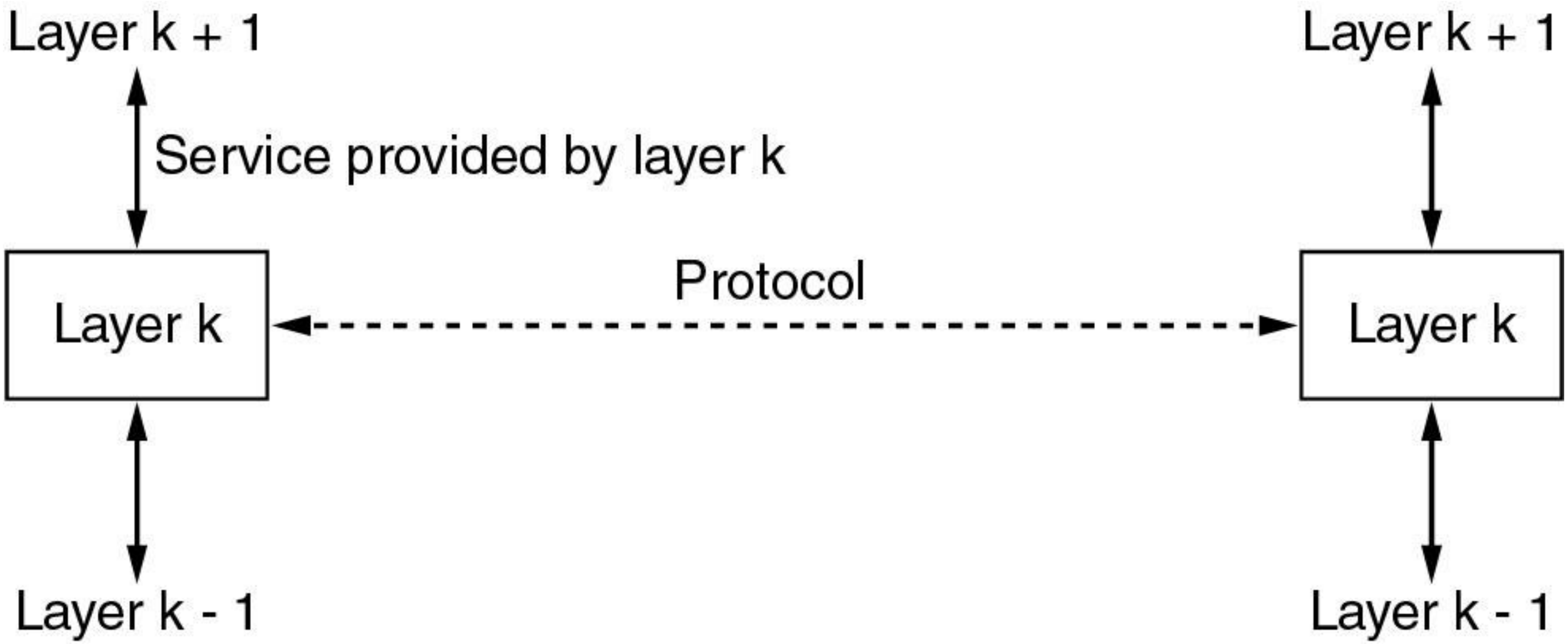
- Packets sent in a simple client-server interaction on a connection-oriented network.

Service vs Protocol

Service	Protocol
Concerned with layers	Concerned with peers within the same layer
Set of operations provided by a layer to upper layer(s)	Set of rules for message exchange between peers within a layer
Define operations, not how an operation is implemented	Related to the way the service is implemented
Example: definition of an object in C++ with its methods	Example: The actual implementation of the methods

Services to Protocols Relationship

- The relationship between a service and a protocol.



Layering Principle

- Layering Principle
  - *Software implementing layer **n** at the destination receives exactly the message sent by software implementing layer **n** at the source.*[*]
- Examples
  - IP is *machine-to-machine because layering principle* only applies across one hop
  - TCP is *end-to-end because layering principle from* original source to ultimate destination

[*]Internetworking with TCP/IP, by Douglas Comer

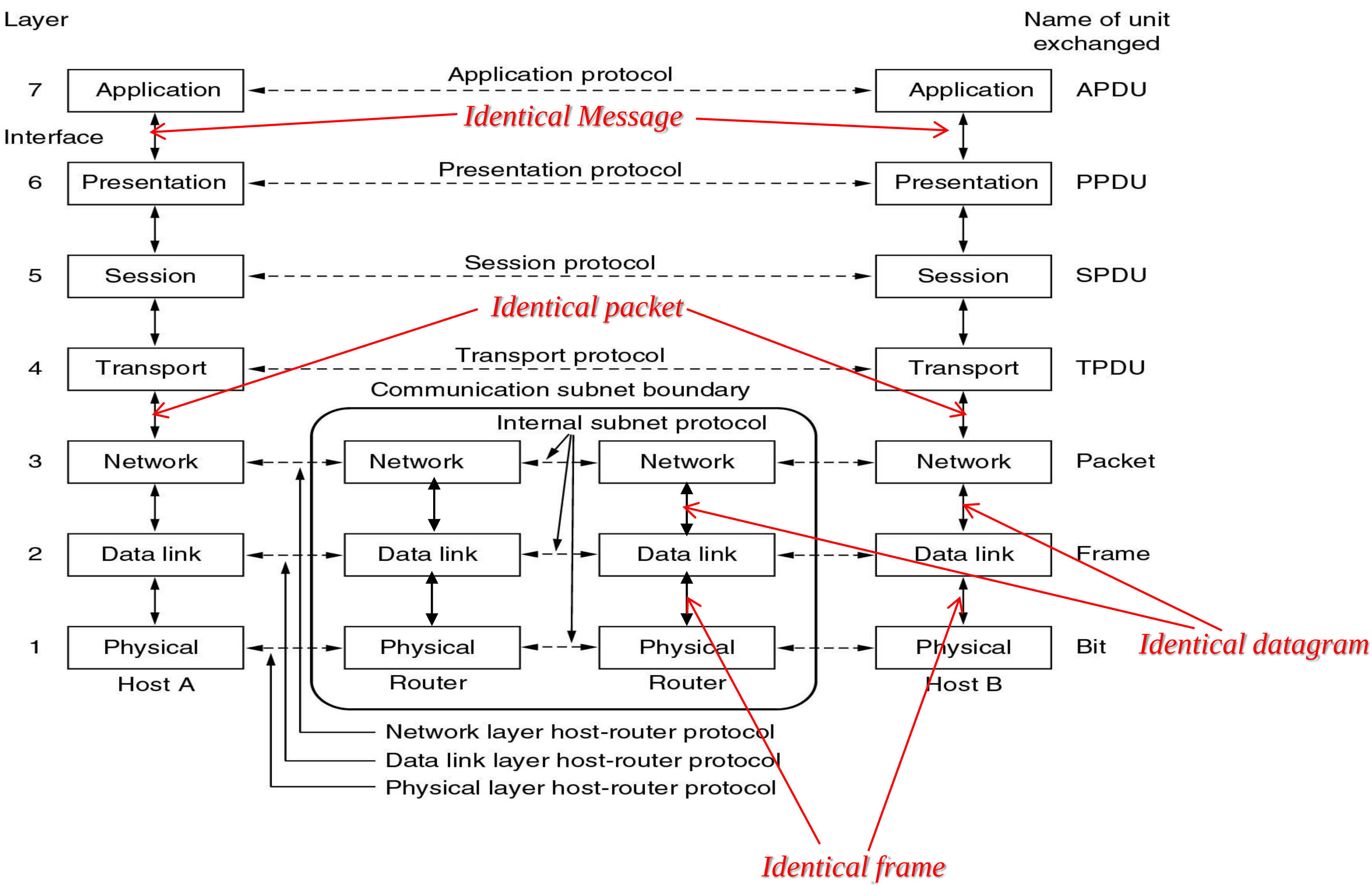
Reference Models

- The OSI Reference Model
- The TCP/IP Reference Model
- A Comparison of OSI and TCP/IP
- A Critique of the OSI Model and Protocols
- A Critique of the TCP/IP Reference Model
- You can learn more from failures
- OSI protocols are rarely used (except ISIS), but model is quite general and partially applied in TCP/IP
- TCP/IP model rarely used, but protocols are widely used

Principles Used to Derive OSI Model

- Each layer provides a level of abstraction (hides details) for upper layer
- Each layer has distinct functionality
- Layer boundaries defined to minimize inter-layer control information flow
- Number of layers should be large enough to avoid collapsing two functions into one layer
- Number of layers should be small enough so that the model becomes manageable

OSI Reference Models



Physical Layer

- Concerned with delivering raw bits across channels
- Mainly worries about physical medium (Wireless, optical,…)
- Typical questions
  – How many pins
  – What are the voltage and power levels
  – Digital modulation techniques (e.g PSK, QAM,…,)
- A typical physical layer devices
  – Digital modulator/demodulator
  – Radio repeater
  – Optical dispersion compensation

Data Link Layer

- Coverts raw transmission service of the wire to a medium that appears **free of <u>undetectable</u>** errors
  - I.e. Provides mechanism to correct or detect error
  - Physical layer alone may deliver data containing errors
- Usually closely tied with the physical layer technology (e.g. PPP for point-to-point, 802.3 for ethernet, 802.16 for fixed wireless,…, etc)
- Deals with
  - Error detection/correction
  - Framing
  - Sometimes provide acknowledgment
- In broadcast networks there are additional problems
  - Co-ordination (e.g. CDMA, token, central arbiter)
  - Local Addressing (within a network)
- Typical layer 2 devices
  - Bridge
  - Switch
  - Libraries that compute header checksum of ethernet frame on your PC

Network Layer

- Concerned with the operation of (sub)-networks
- Abstracts different data link layers into a homogenous network layer
- Independent of the underlying physical and data link layers (e.g. IPv4 and IPv6 works on virtually all networks)
- Deals with
  - Routing packets across networks
    - Routing is most commonly known and applied at the network layer
    - However, routing is a functionality that may exist in all layers*
  - QoS (Delay, BW, Jitter, Congestion control,…,)
  - Global addressing
  - Converting between network layer address space and data link layer address
- Protocol is CLNP (similar to IPv4 and IPv6)
- Examples of network layer devices/software
  - Router
  - Libraries that construct IPv4 packets in your PC

Transport Layer

- Provides **end-to-end** communication to upper layers
  - A service or protocol is said to be **end-to-end** if it provides communication from the source(s) to the sink(s) of information
  - A service or protocol is said to be **end-to-end** if the layering principle applies from one end of the Internet to the other*
- Provides delivery of data from every source on the transmitting node to every receiver at the receiving node
- Hides the dynamics changes in the network layer
- May not provide reliable service
- May not provide in-order delivery
- May be connection oriented or connectionless
- May be byte stream or message oriented
- May provide point-to-point or multi-point-to-multi-point (e.g. PGM, RFC3208, may be considered a network layer or transport layer protocol)
- Examples of transport layer
  - Software that initiates TCP connection to the HTTP server
  - Libraries and functions available to the application on your PC to send and receive streams of data using TCP

See example on how 4 layers are connected in the network

*Internetworking wiith TCP/IP, by Douglas Comer

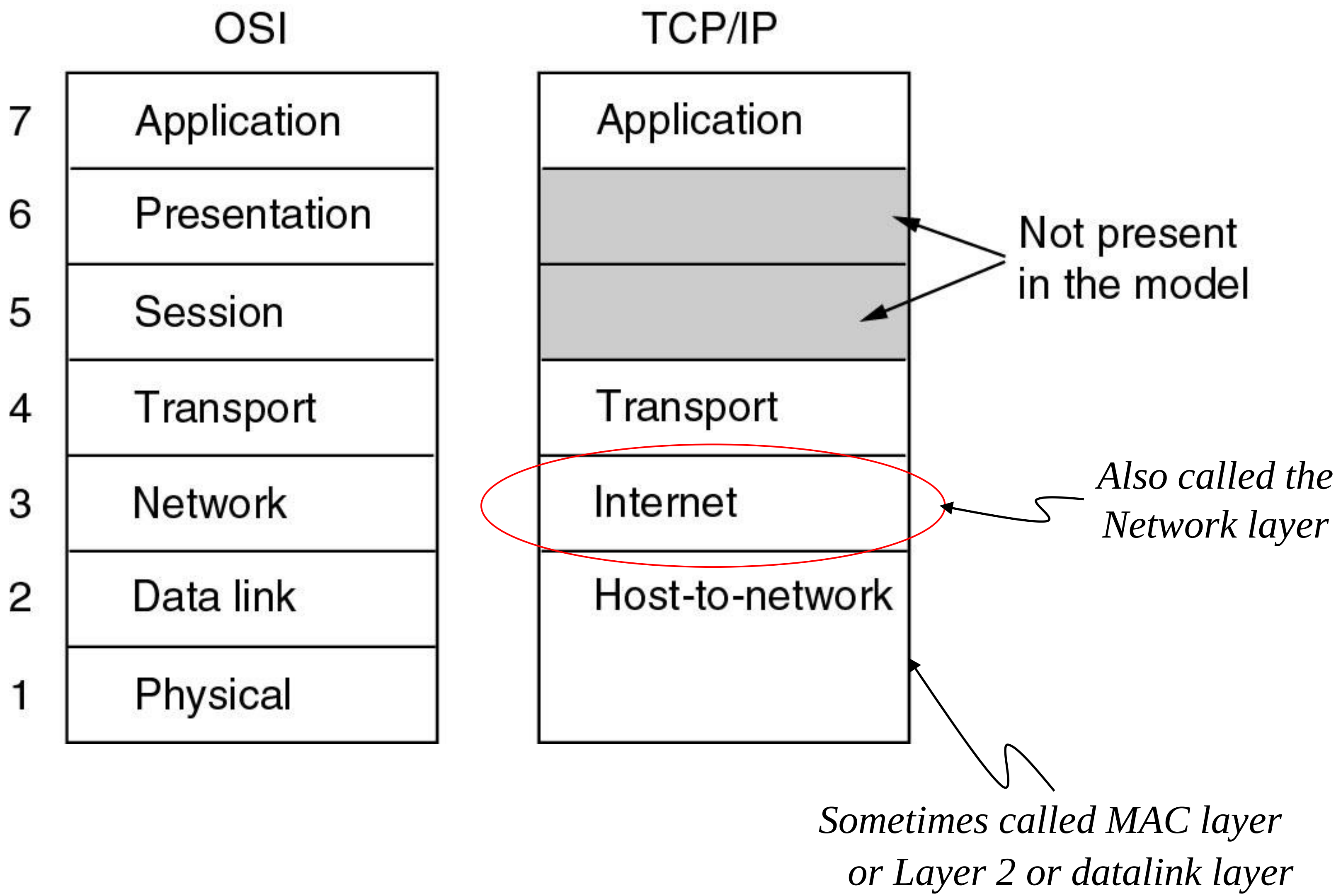
Session, Presentation, Application Layer

- Experience: session and presentation layers are of **little use**
- Session layer provides
  - End-to-end session management (e.g synchronization, floor control)
- Presentation Layer
  - Concerned with syntax and semantics
  - E.g. provides standard encoding of data structures
- Application layer
  - Practically, it is every thing else (including humans)
  - Applications that use the services
  - Top Most layer. Hence there is no well defined service primitives
  - Mail, FTP, http,…, etc

TCP/IP Reference Model

- Initial versions developed by ARPA (a DoD agency)
- Need for flexible architecture to allow for diverse functionality
  - File transfer
  - Speech
- Need resilience under partial network failure
- Need homogeneous communication between heterogeneous networks and end-points

TCP/IP Reference Model



Layer 1+2 (Physical + MAC layer)

- Not well defined in TCP/IP model
- Usually not discussed in details, although recently it is becoming more important, e.g. GMPLS (many RFCs), LAG (802.1ax)
- Unit of data is called "**Frame**"
  - Frame = L2 header + Payload (and, depending on the protocol, "L2 trailer")
- TCP/IP need from layer 2 basic information
  - How to map Layer 2 address to/from internet layer address such as
    - ARP
    - Mapping multicast addresses
  - Know the topology
    - P2P,
    - P2MP (A.K.A multi-access or broadcast)
    - NBMA: Non-Broadcast Multi-Access
- Little layer 2 and layer 3 interaction exists (e.g. IGMP snooping)
- Recently more L2 to L3 interactions such as MPLS labels to wavelengths in DWDM in the GMPLS protocols

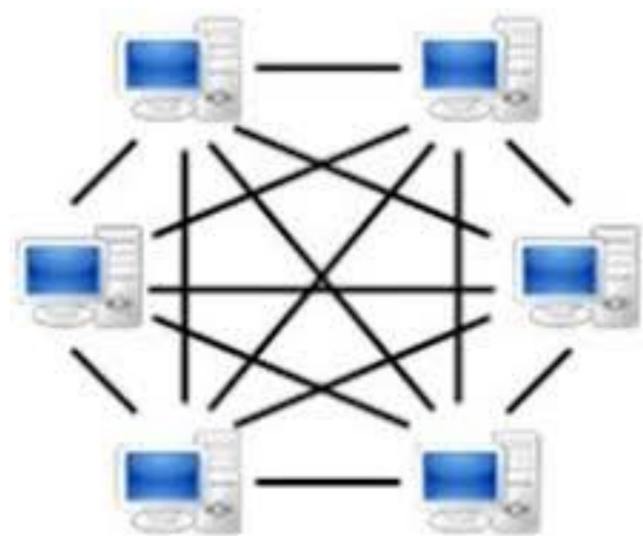
GMPLS / MPLS

- MPLS (Multiprotocol Label Switching) is called *multiprotocol* because it works with the Internet Protocol (IP), Asynchronous Transport Mode (ATM), and frame relay network protocols. In addition to moving traffic faster, MPLS makes it easier to manage a network for quality of service (QoS). The use of MPLS has become widespread as networks carry increasing volumes and varieties of traffic such as Voice over IP (VoIP).

- GMPLS (Generalized Multiprotocol Label Switching), also known as Multiprotocol Lambda Switching, is a technology that provides enhancements to Multiprotocol Label Switching (MPLS) to support network switching for time, wavelength, and space switching as well as for packet switching. In particular, GMPLS will provide support for photonic networking, also known as optical communications.

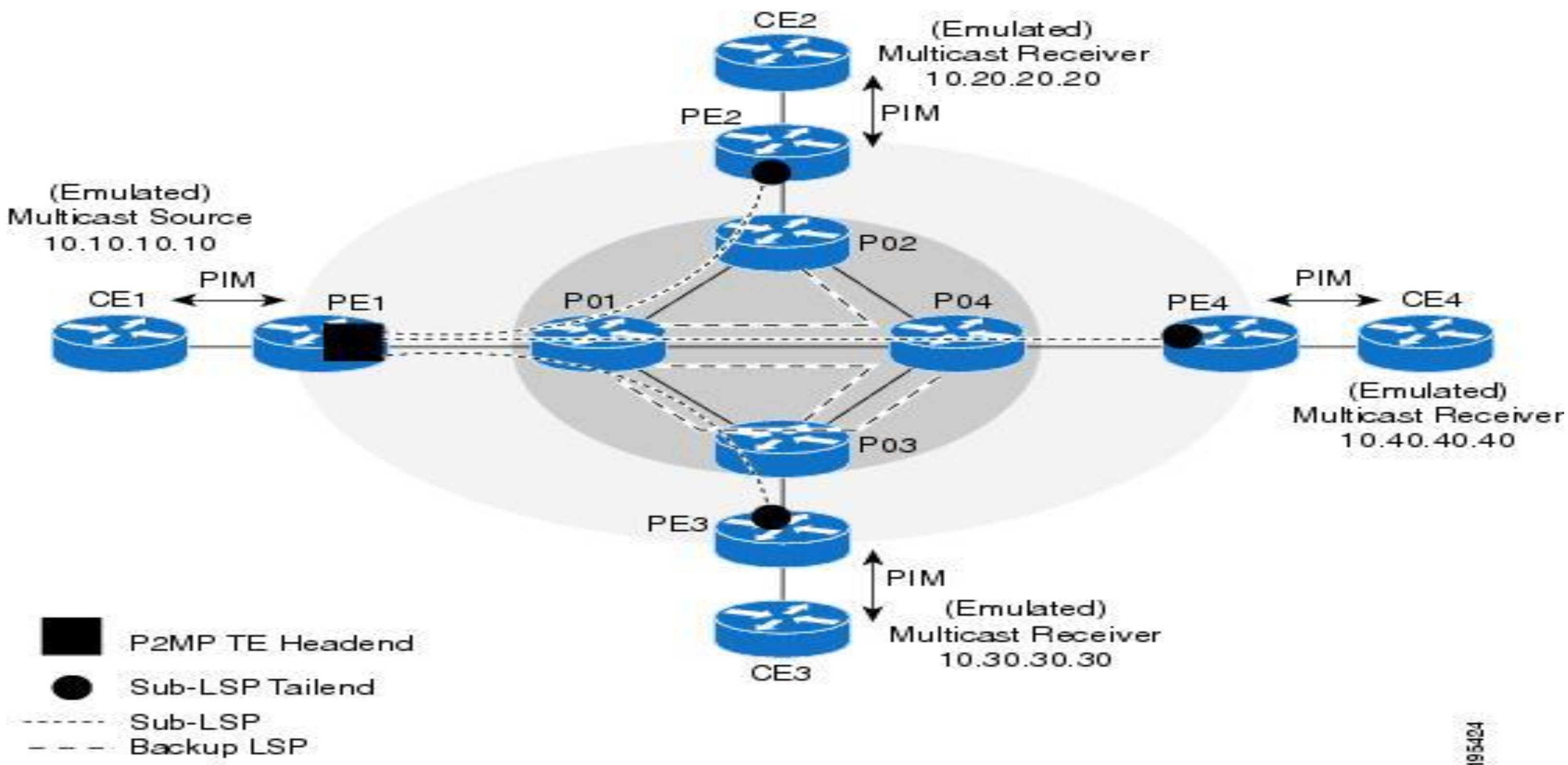
P2P

- Peer-to-peer (**P2P**) computing or networking is a distributed application architecture that partitions tasks or workloads between peers. Peers are equally privileged, equipotent participants in the application. They are said to form a peer-to-peer network of nodes.



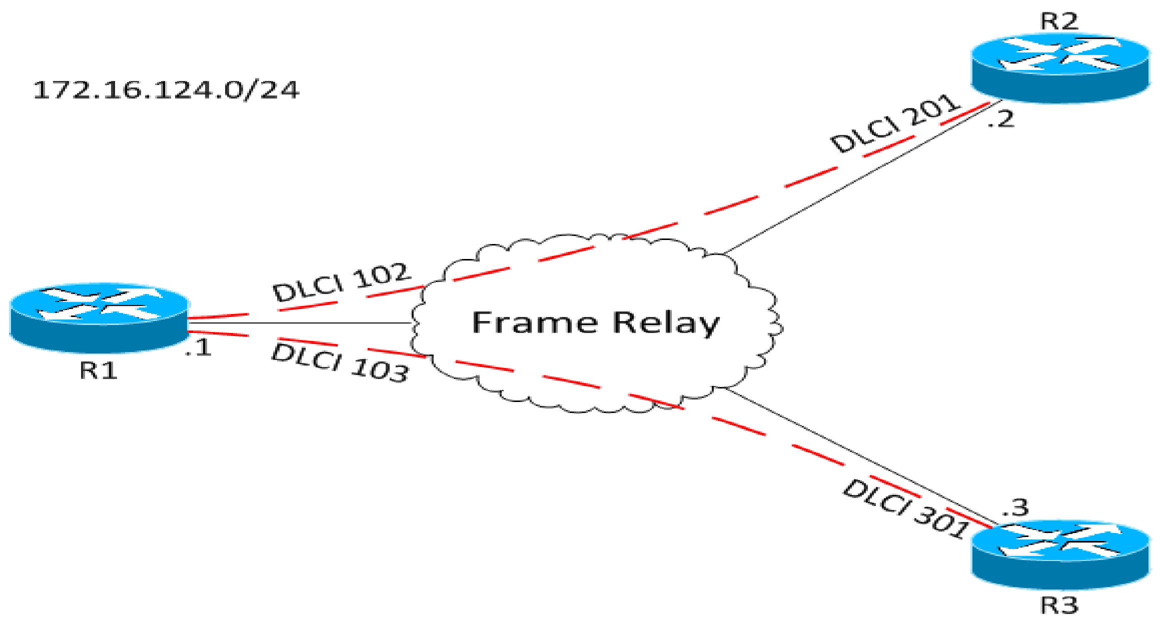
P2MP

- point-to-multipoint communication (**P2MP**, PTMP or PMP) is communication which is accomplished via a distinct type of one-to-many connection, providing multiple paths from a single location to multiple locations.



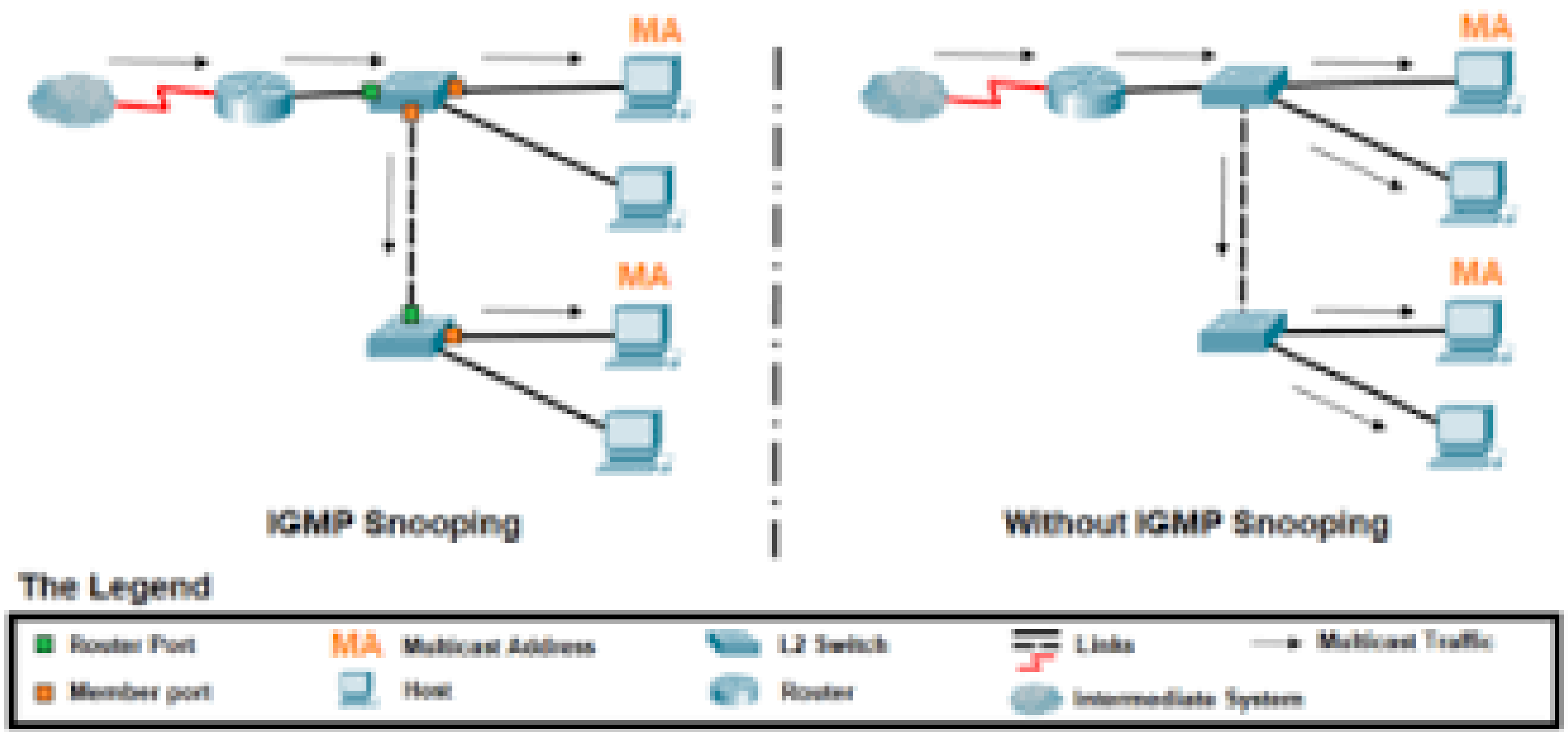
NBMA

- A non-broadcast multiple access network (**NBMA**) is a computer network to which multiple hosts are attached, but data is transmitted only directly from one computer to another single host over a virtual circuit or across a switched fabric.



IGMP snooping

- **IGMP snooping** is the process of listening to Internet Group Management Protocol (**IGMP**) network traffic. The feature allows a network switch to listen in on the **IGMP** conversation between hosts and routers. By listening to these conversations the switch maintains a map of which links need which IP multicast streams.



Layer 3: Network Layer

- Very similar to the network layer in the OSI model
- Concerned with delivery of packets across heterogeneous networks between heterogeneous end-points
- Quality of service (E.g. . Assured forwarding (RFC2597)
- Unreliable: out of order, loss, corruption
- Three major concerns
  - Addressing
  - Routing*
  - QoS
- May provide other services such as security and privacy
  - E.g, Authentication Header (RFC4302)
- The main protocol is IP (corresponding to CLNP in OSI)
  - IP sometimes refers to IPv4 only or to both IPv4 and IPv6
- The unit of data is called "**datagram**"
  - Datagram = IP header + Payload
  - Datagram is the payload of the frame (I.e datagram is the payload for L2)
  - Sometimes the payload is called ***packet***
  - Packet and datagram are frequently used *interchangeably*

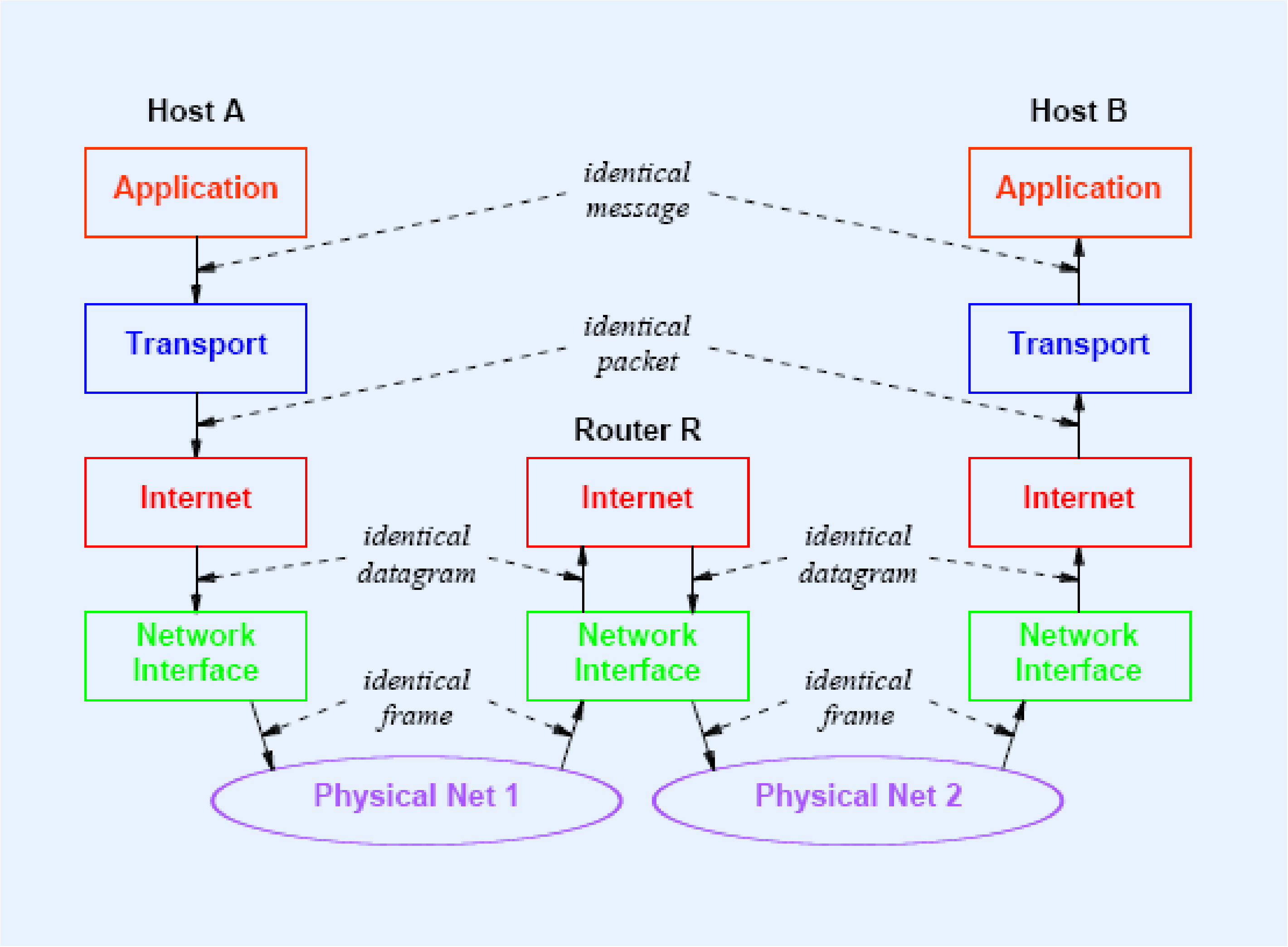
Layer 4: Transport Layer

- Very similar to the transport layer in the OSI model
- End-to-End communication service
- TCP (Main rfc 793 and some others)
  - Stream of bytes
  - Connection oriented
  - Reliable
  - Point-to-point
- UDP (rfc768)
  - Datagram (message oriented)
  - Connectionless
  - Unreliable
  - May be used for point-to-multipoint
- Other protocols also exist
  - SCTP (rfc4960) provides multi-stream connection
  - RTP (rfc3559) Provides real-time reliable connection. Supports mcast
  - PGM (RFC3208) may be considered a transport layer protocol. Provides reliable multicast communication

Layer 5: Application Layer

- No session or presentation layers
- Layer 5 includes all other protocols and services
- All protocols that use the services of the network or the transport layer
- Examples
  - FTP
  - HTTP
  - RTSP
  - NTP
  - Email, SMTP, IMAP, POP3

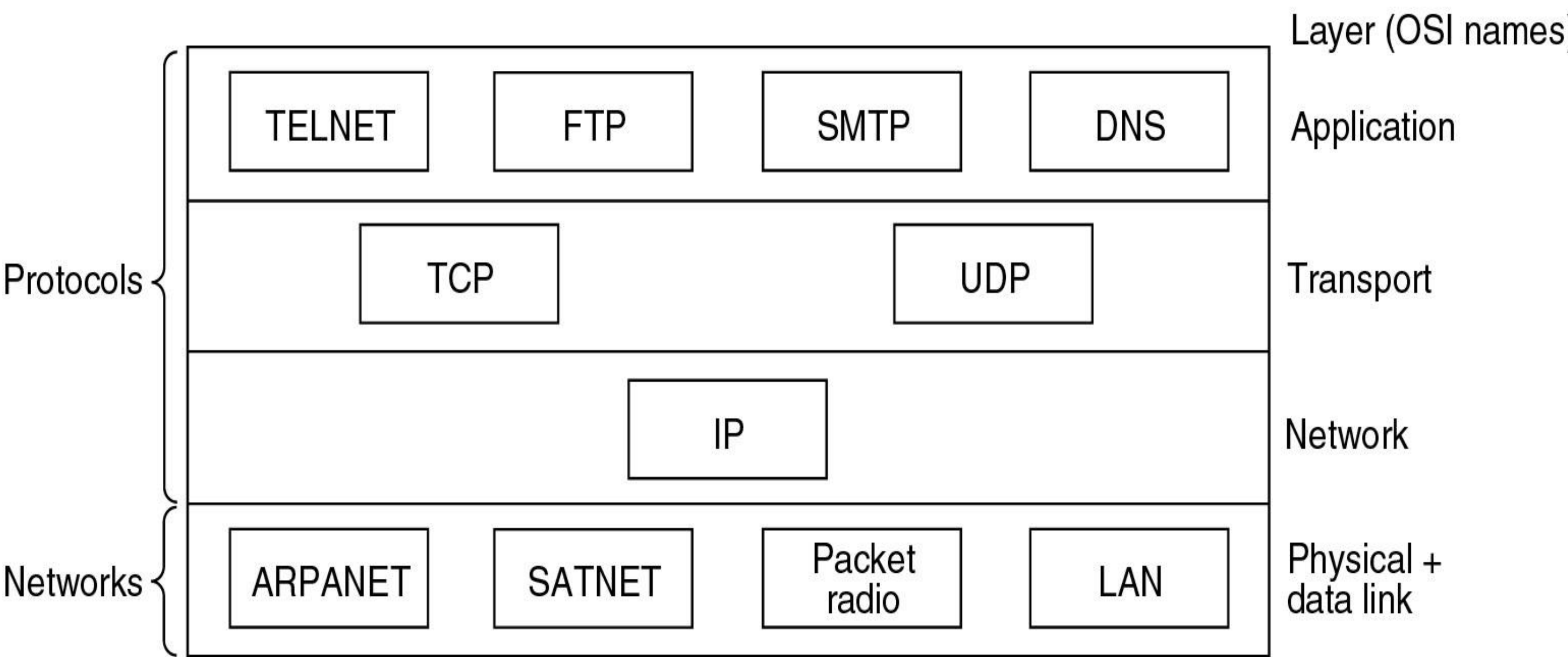
Illustration Of Layering In An Internet



*Internetworking wiith TCP/IP, by Douglas Comer

Relation between IP, TCP, UDP

- Protocols and networks in the TCP/IP model initially.



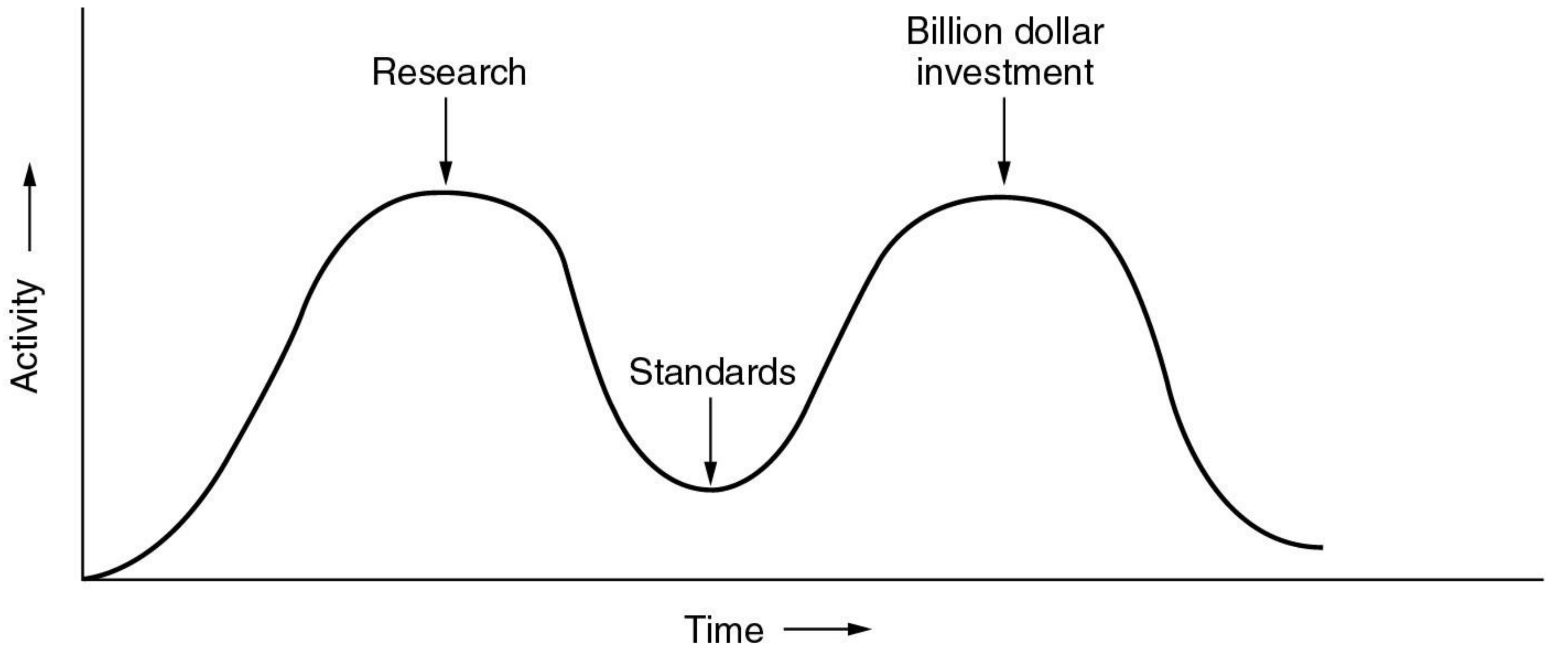
Comparing OSI and TCP/IP Models

- Concepts central to the OSI model
  - Services
  - Interfaces
  - Protocols
- OSI Provides clear distinction between service and protocol
  - Model developed first then protocols
  - Model fits any protocol stack
  - Model provides connectionless and connection-oriented
  - People did not have experience with real world ⇒ problems at implementation. E.g.
    - Originally for P2P. Broadcast retrofitted later
    - Assume single network per country ⇒ No thought of internetworking
- TCP/IP
  - Cowboy mentality
  - Protocols developed first in then model later
    - Model fits nicely to protocols
    - Model only works for TCP/IP protocol stack

A Critique of the OSI Model and Protocols

- Why OSI did not take over the world
  - Bad timing
  - Bad technology
  - Bad implementations
  - Bad politics

Bad Timing



- The apocalypse of the two elephants.
- If the period between the two humps is too small, standards people may be crushed
- OSI came when TCP/IP was widespread in academia and industry has started to invest. OSI was *crushed*

Bad Technology

- Too complex and lengthy
- Same functions appeared in multiple layers
  - Flow control
  - Congestion control
  - Error control
  - addressing

Bad Implementation and politics

- Complex standard ⇒ Bad implementation
  - Inefficient implementation
  - Complex and cumbersome to produce

- Bad politics
  - TCP/IP viewed as part of academia and research
  - OSI part of politicians and government
  - Researchers developing TCP/IP on Unix assumed that government bureaucrats are trying to shove inferior standard down their throat
  - Example: U.K. delegation insisted that any "tutorial material" should not be included[*]
  - The term "*entity*" is used very frequently instead of common terms such as *procedure*, *program*, *task*, for fear that the standard would dictate implementation[*]

[*] Patterns in Network Architecture: A Return to Fundamentals, by John Day, chapter 5

A Critique of the TCP/IP Reference Model

- Problems:
  - Service, interface, and protocol not distinguished
    - Model is not useful for designing new networks
  - Not a general model.
    - E.g Hard to describe bluetooth in TCP/IP model
  - MAC layer (Host-to-network) not really a layer
  - No mention of physical and data link layers
  - Minor protocols deeply entrenched in products, hard to replace
    - This is because TCP/IP protocols was initially developed by few graduate students and distributed for free

Hybrid Model

- The hybrid reference model to be used in this book*.

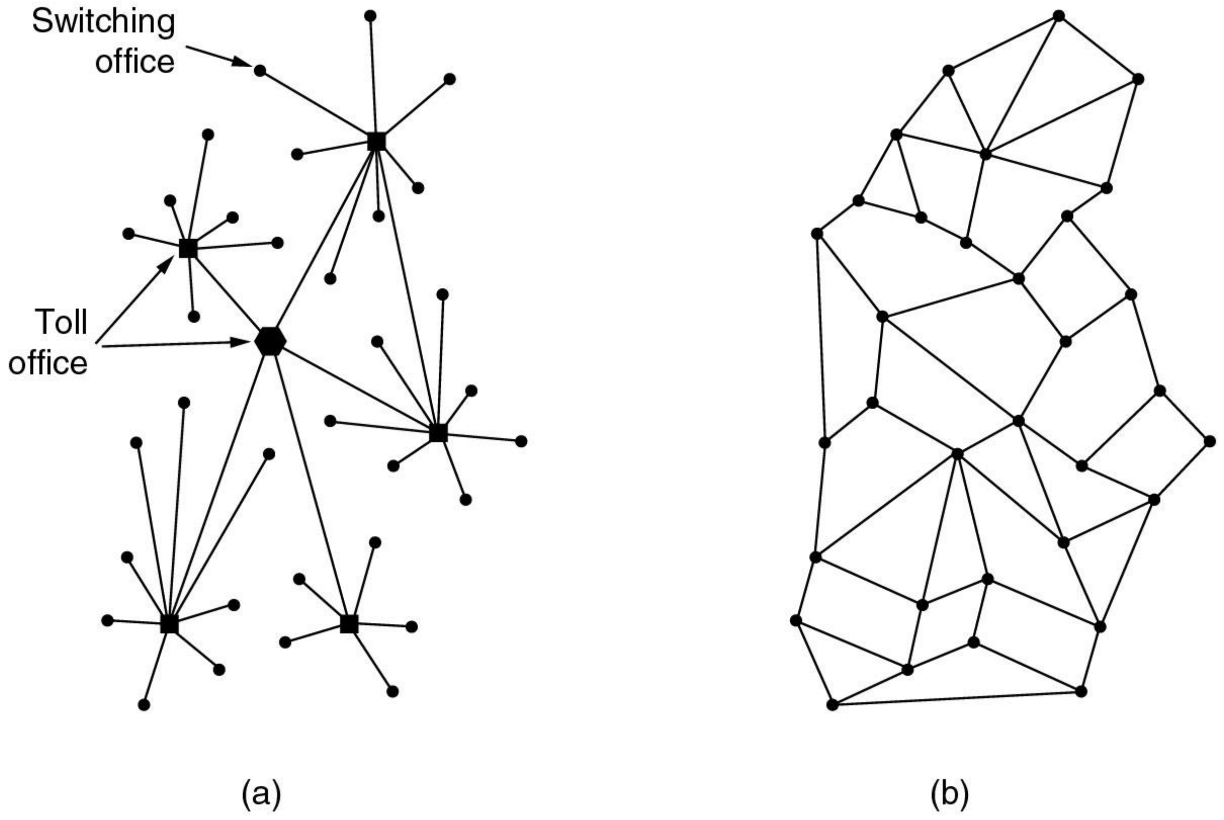
5	Application layer
4	Transport layer
3	Network layer
2	Data link layer
1	Physical layer

- Most of the industry adopt and follow this model, in many cases unintentionally and without explicitly mentioning it
  - E.g. there are transport protocols developed for wireless even though the datalink layer for wireless and wired Ethernet are almost identical

Example Networks

- The Internet
- Connection-Oriented Networks:
  X.25, Frame Relay, and ATM
- Ethernet
- Wireless LANs: 802:11

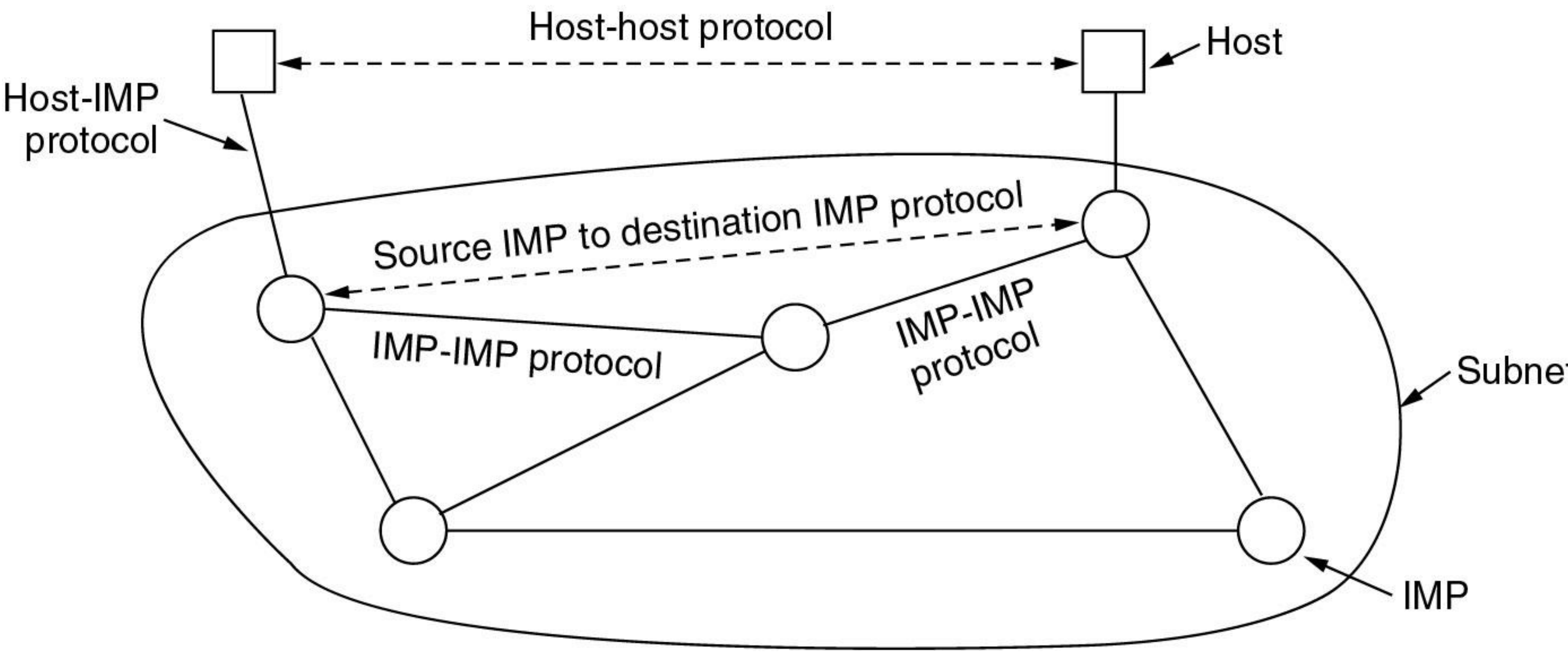
The ARPANET



- (a) Structure of the telephone system.
- (b) Baran's proposed distributed switching system.

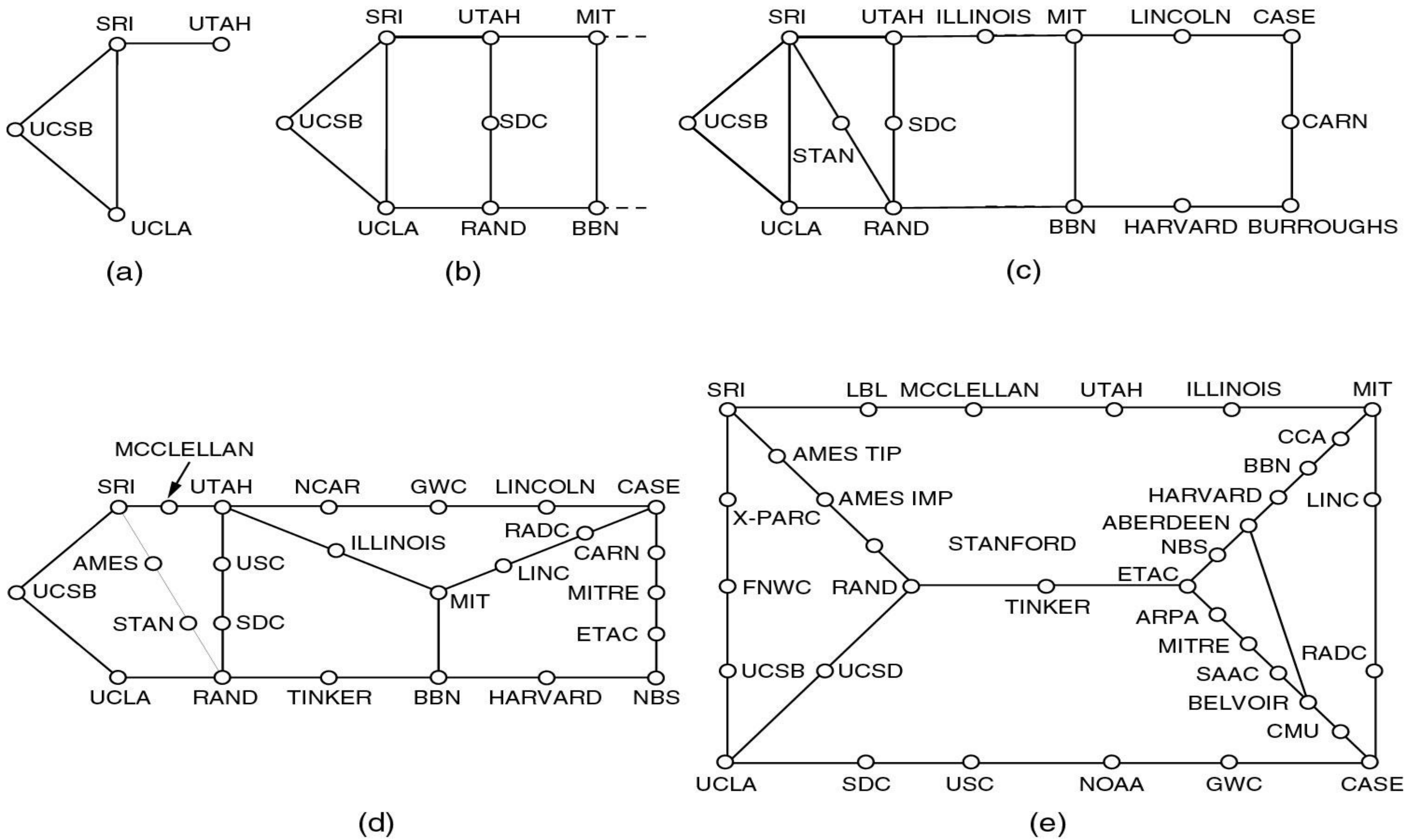
The ARPANET (2)

- The original ARPANET design.



IMP: Interface Message Processor , 1st Router

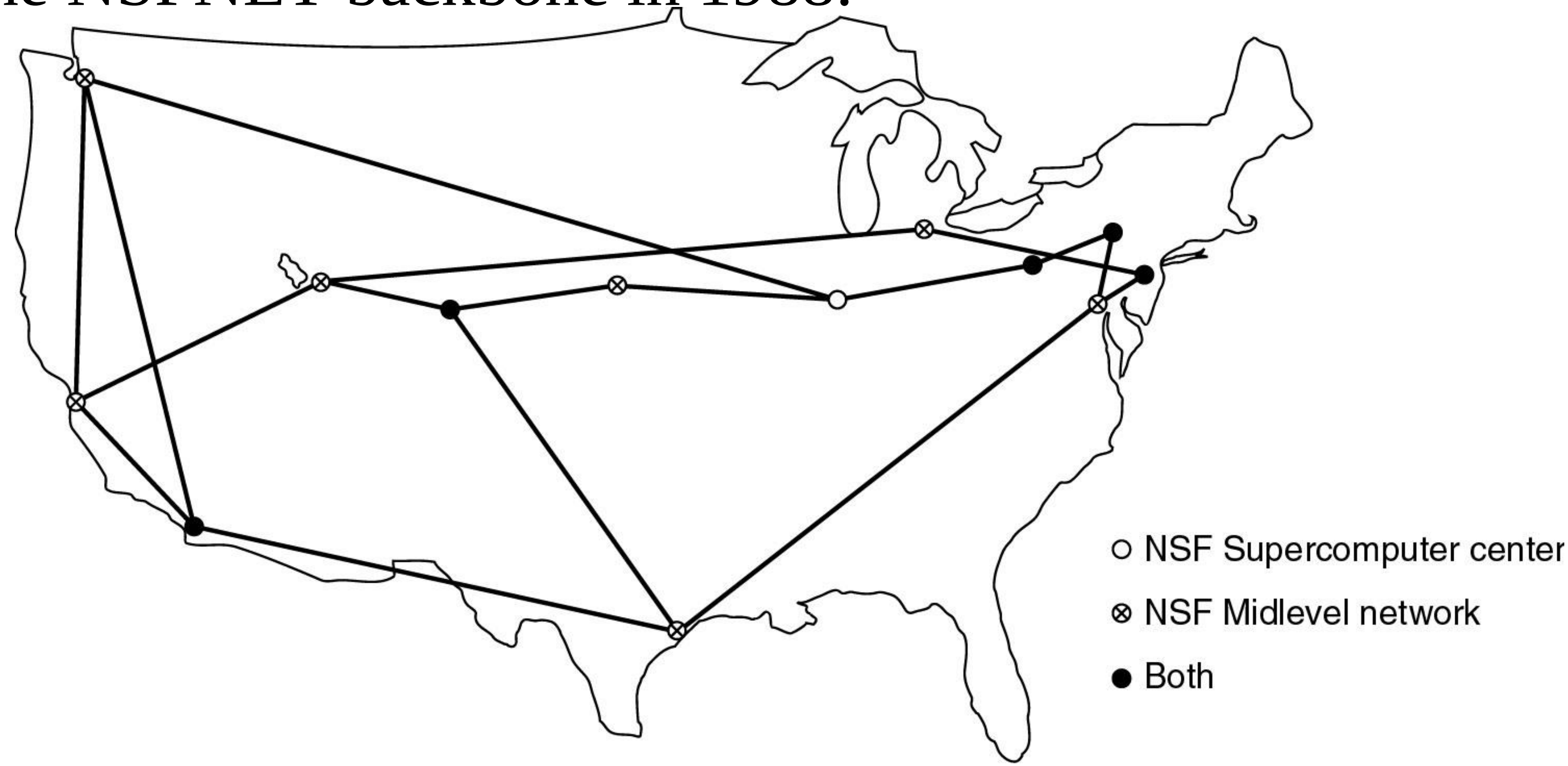
The ARPANET (3)



- Growth of the ARPANET (a) December 1969. (b) July 1970.
- (c) March 1971. (d) April 1972. (e) September 1972.

NSFNET

- The NSFNET backbone in 1988.



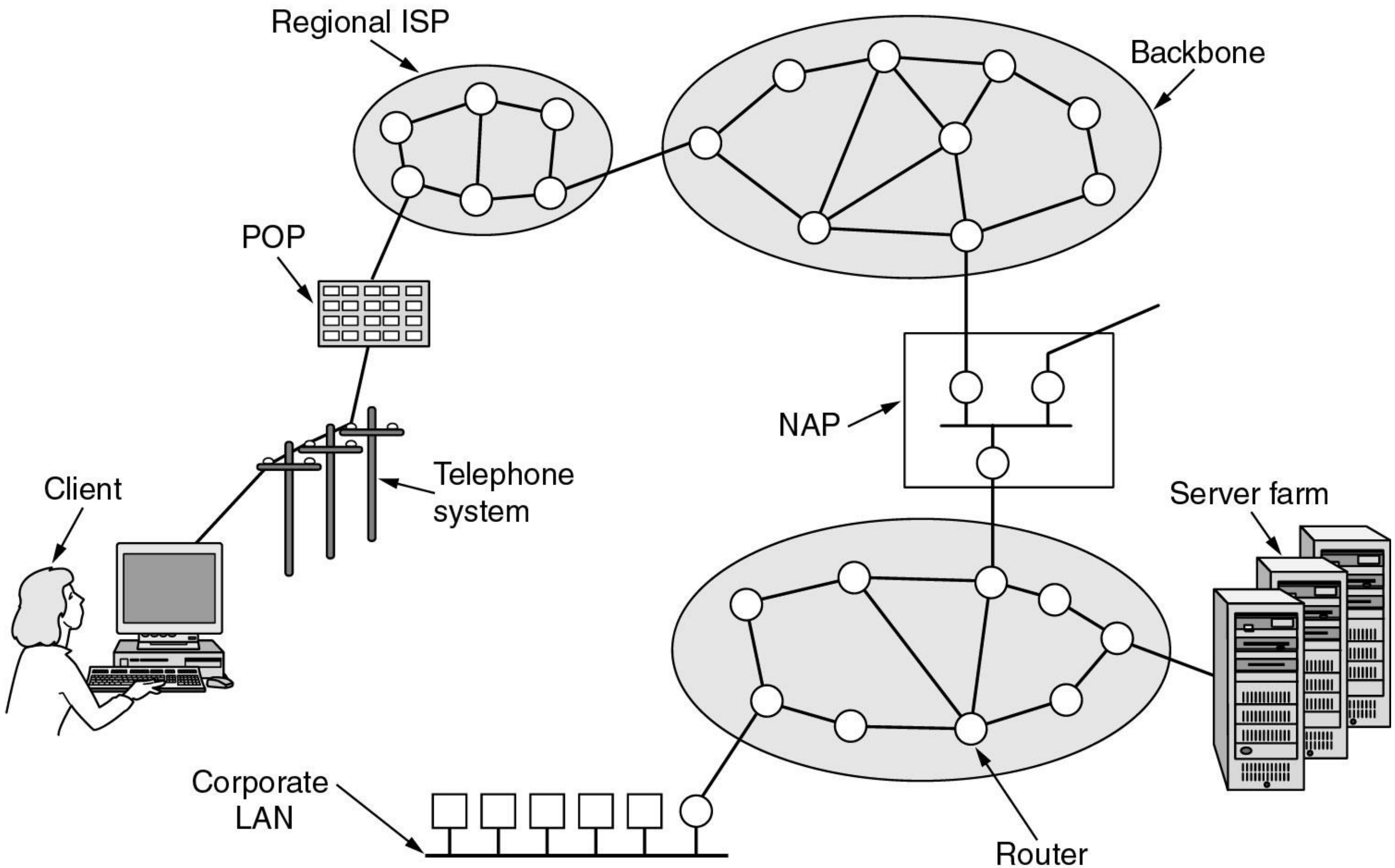
NSFNET was a backbone **network** for research computing deployed in the mid-1980s

Internet Usage

- Traditional applications (1970 – 1990)
- E-mail
- News
- Remote login
- File transfer

Architecture of the Internet

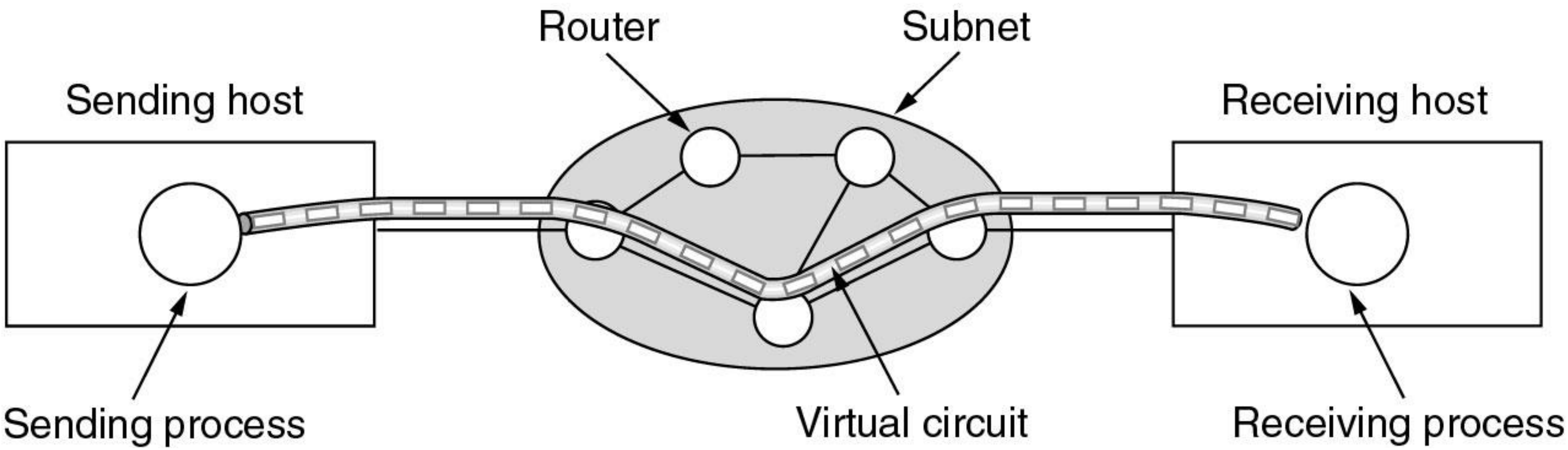
- Overview of the Internet.



POP: Point of Presence
NAP: Network Access Point

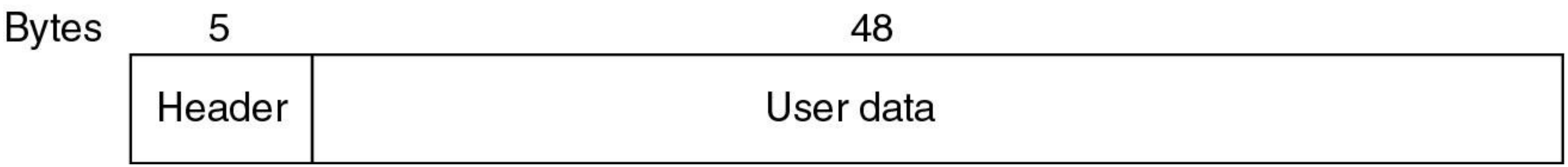
ATM Virtual Circuits

- A virtual circuit.



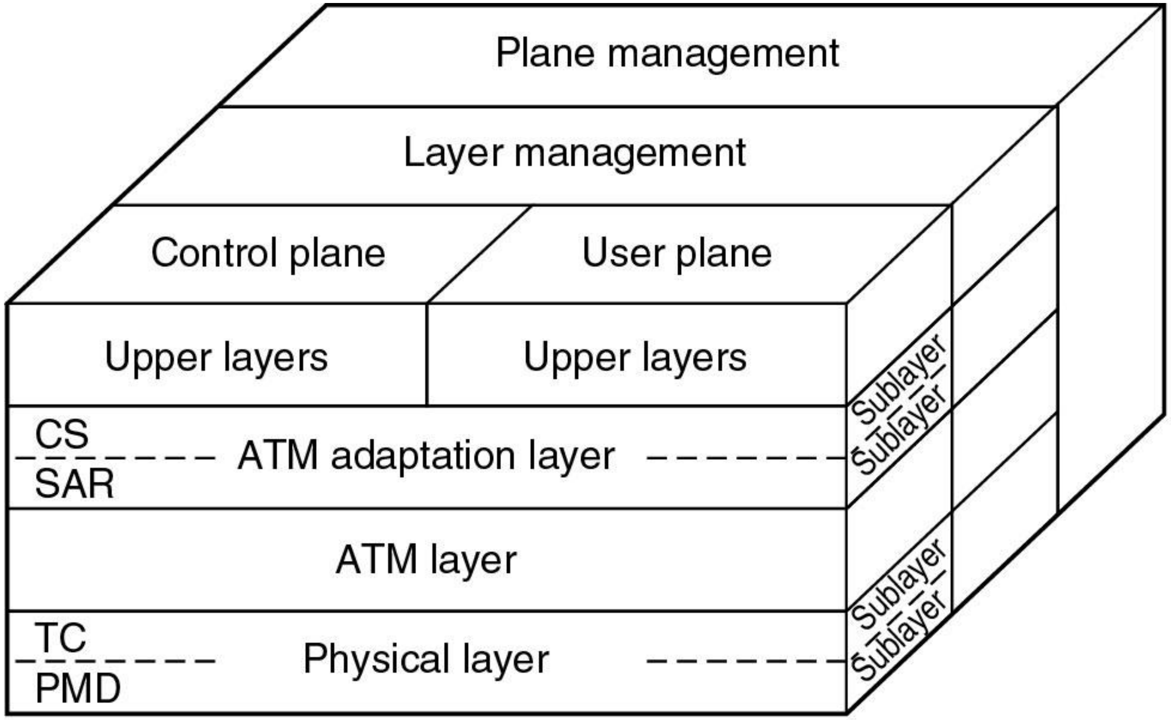
ATM Virtual Circuits (2)

- An ATM cell.



The ATM Reference Model

- The ATM reference model.



CS: Convergence sublayer
SAR: Segmentation and reassembly sublayer
TC: Transmission convergence sublayer
PMD: Physical medium dependent sublayer

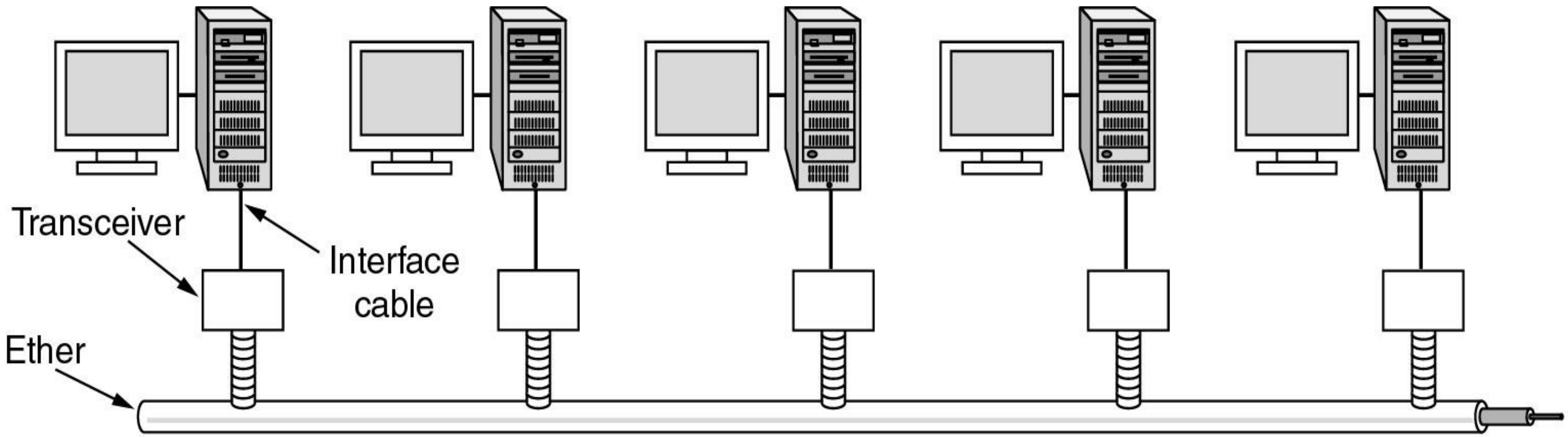
The ATM Reference Model (2)

OSI layer	ATM layer	ATM sublayer	Functionality
3/4	AAL	CS	Providing the standard interface (convergence)
		SAR	Segmentation and reassembly
2/3	ATM		Flow control Cell header generation/extraction Virtual circuit/path management Cell multiplexing/demultiplexing
2	Physical	TC	Cell rate decoupling Header checksum generation and verification Cell generation Packing/unpacking cells from the enclosing envelope Frame generation
1		PMD	Bit timing Physical network access

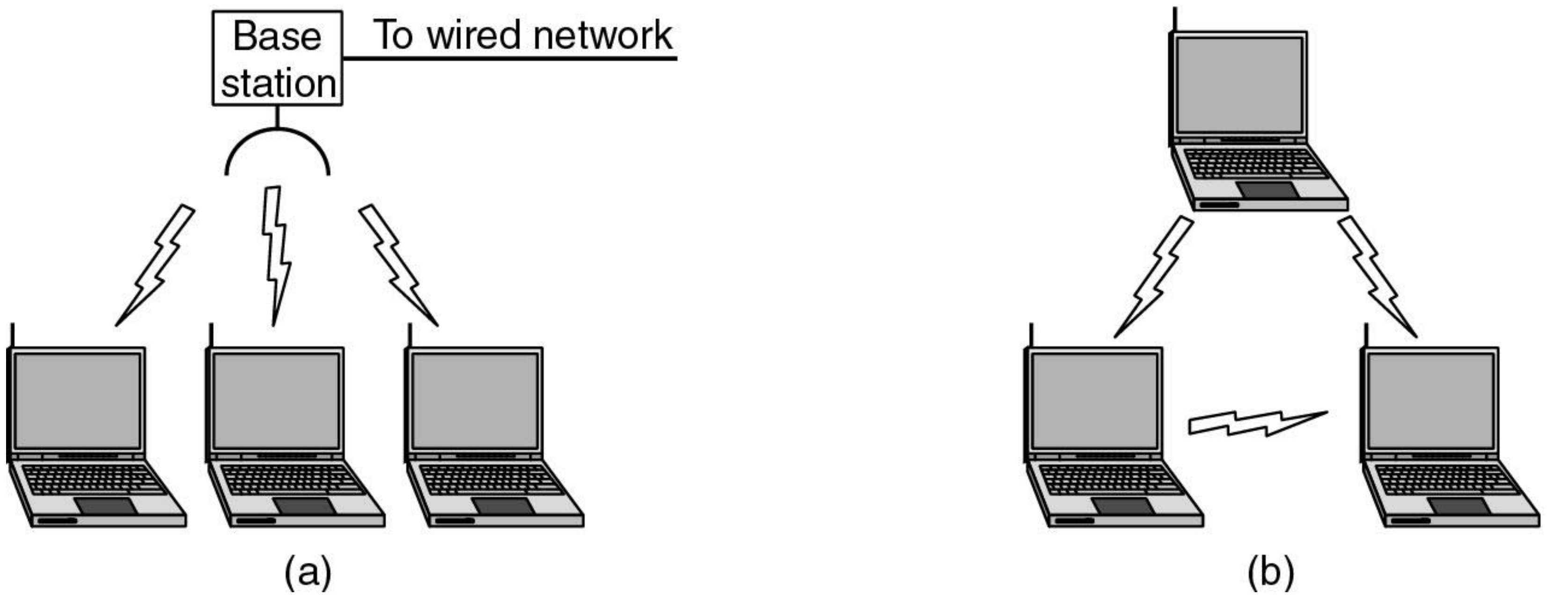
- The ATM layers and sublayers and their functions.

Ethernet

- Architecture of the original Ethernet.



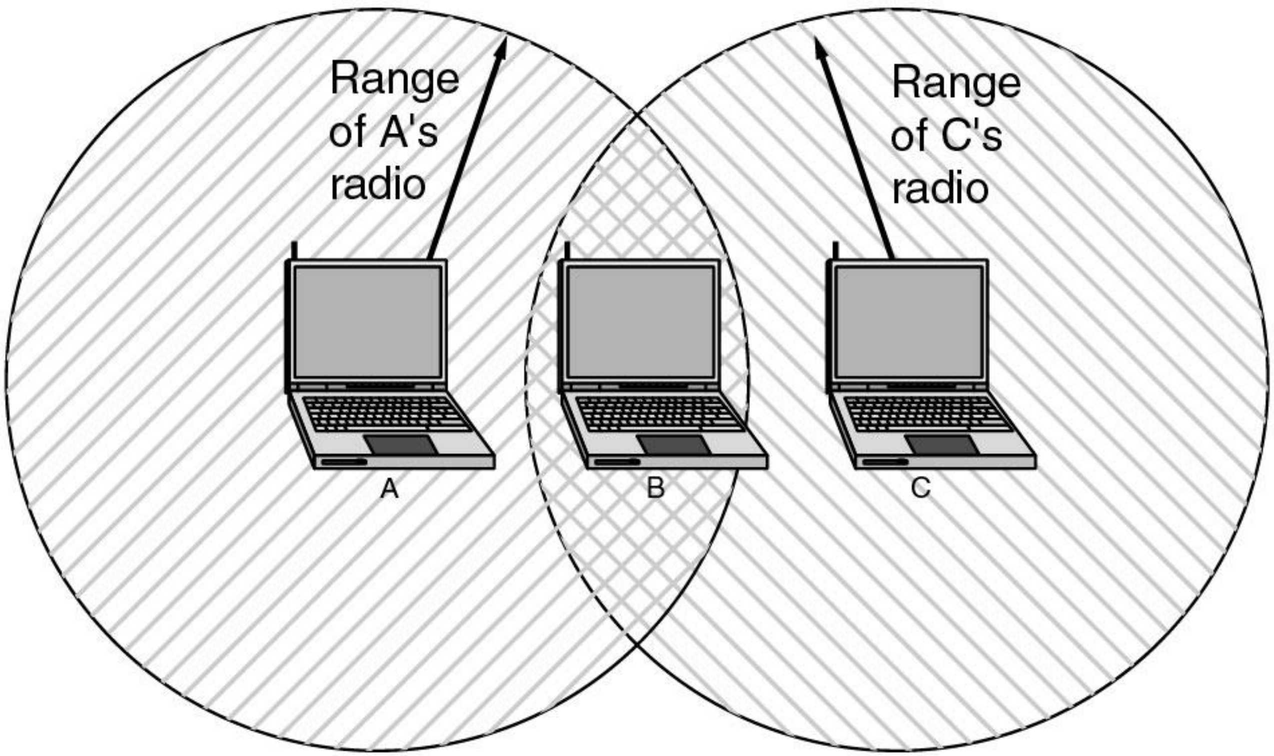
Wireless LANs



- (a) Wireless networking with a base station.
- (b) Ad hoc networking.

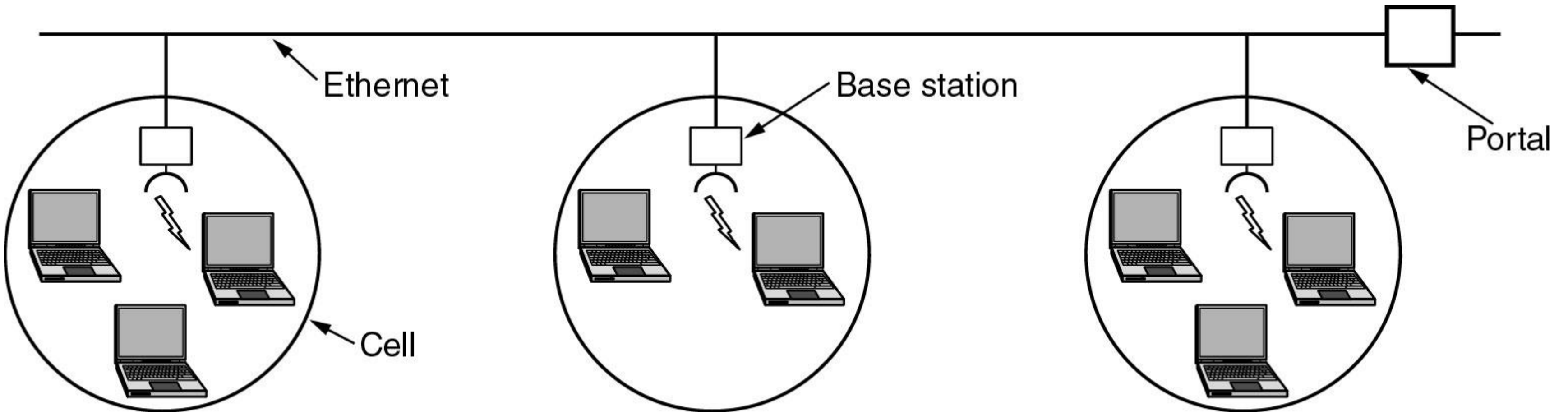
Wireless LANs (2)

- The range of a single radio may not cover the entire system.



Wireless LANs (3)

- A multicell 802.11 network.



Network Standardization

- Who’s Who in the Telecommunications World
- Who’s Who in the International Standards World
- Who’s Who in the Internet Standards World

ITU

- Main sectors
  - Radiocommunications
  - Telecommunications Standardization
  - Development
- Classes of Members
  - National governments
  - Sector members
  - Associate members
  - Regulatory agencies

IEEE 802 Standards

Number	Topic
802.1	Overview and architecture of LANs
802.2 ↓	Logical link control
802.3 *	Ethernet
802.4 ↓	Token bus (was briefly used in manufacturing plants)
802.5	Token ring (IBM's entry into the LAN world)
802.6 ↓	Dual queue dual bus (early metropolitan area network)
802.7 ↓	Technical advisory group on broadband technologies
802.8 †	Technical advisory group on fiber optic technologies
802.9 ↓	Isochronous LANs (for real-time applications)
802.10 ↓	Virtual LANs and security
802.11 *	Wireless LANs
802.12 ↓	Demand priority (Hewlett-Packard's AnyLAN)
802.13	Unlucky number. Nobody wanted it
802.14 ↓	Cable modems (defunct: an industry consortium got there first)
802.15 *	Personal area networks (Bluetooth)
802.16 *	Broadband wireless
802.17	Resilient packet ring

The 802 working groups. The important ones are marked with *. The ones marked with ↓ are hibernating. The one marked with † gave up.

Metric Units

Exp.	Explicit	Prefix	Exp.	Explicit	Prefix
10^{-3}	0.001	milli	10^{3}	1,000	Kilo
10^{-6}	0.000001	micro	10^{6}	1,000,000	Mega
10^{-9}	0.000000001	nano	10^{9}	1,000,000,000	Giga
10^{-12}	0.000000000001	pico	10^{12}	1,000,000,000,000	Tera
10^{-15}	0.000000000000001	femto	10^{15}	1,000,000,000,000,000	Peta
10^{-18}	0.000000000000000001	atto	10^{18}	1,000,000,000,000,000,000	Exa
10^{-21}	0.000000000000000000001	zepto	10^{21}	1,000,000,000,000,000,000,000	Zetta
10^{-24}	0.000000000000000000000001	yocto	10^{24}	1,000,000,000,000,000,000,000,000	Yotta

- The principal metric prefixes.