Introduction to Computer Networks

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- A Comparison of the OSI and TCP/IP Reference Models
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Uses of Computer Networks

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

Business Applications

- Resource Sharing
  - Common Printer
  - Backup Systems
- VPN (Virtual Private Networks)
  - Ending the limitation of geographic disperse working environments.
- Client - Server

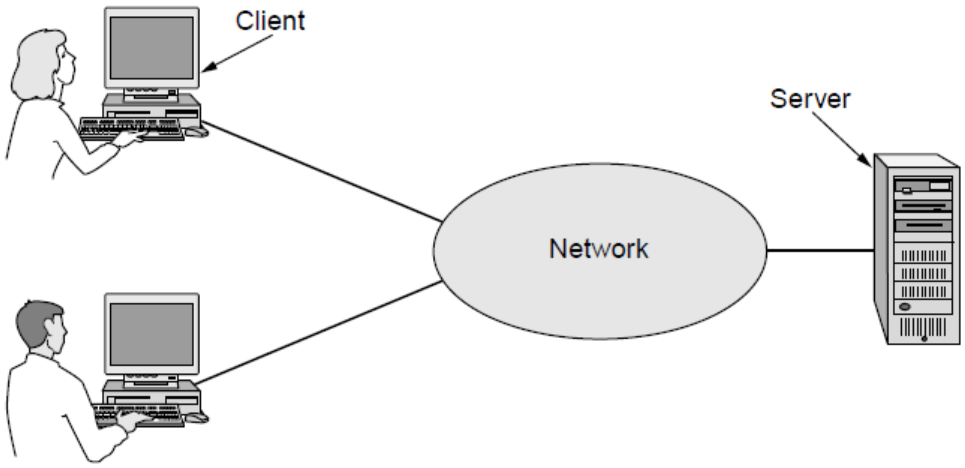


Fig 1.1 Network with Two Clients & One Server

Business Applications

- Client-Server Model
  - Data Sharing
  - Web Application

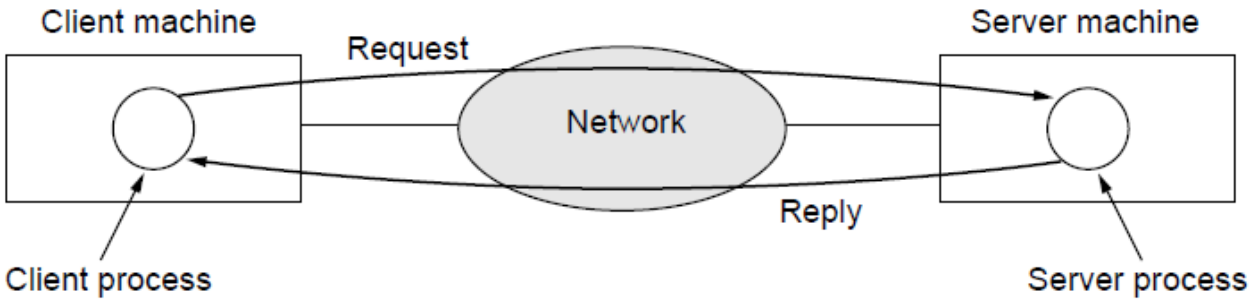


Fig 1.2 Client-Server Model Involves Requests & Replies

- Personal Information Sharing
- Email, VoIP, Video
- Tele-Conferencing
- Desktop Sharing
- Telemedicine
- E-commerce
- Shopping from home

Home Applications

- Peer-to-Peer Applications
  - Torrent
  - Sharing Music and Videos
  - Email, etc.
- Applications that involve interaction between
  - a person and a remote database
  - Person-to-person communication

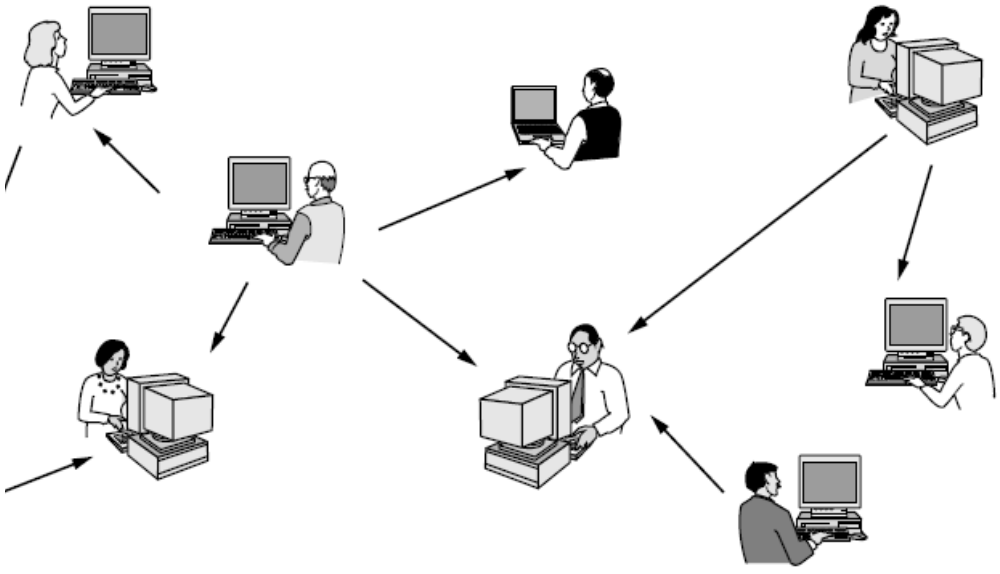


Fig 1.3 Peer-to-Peer System

has no fixed clients and servers.

Home Applications

- Person – to – Person Communication
- Audio + Video
- Instant Messaging (Twitter)
- Online Audio (Radio Channels)
- Online Video (YouTube)
- Tele-learning
- Social Networking
- Facebook, Instagram, Twitter, Whatsapp
- Wiki – Wikipedia
- Home Shopping
- Finances
- Online auctions (eBay)

Home Applications

Tag	Full name	Example
B2C	Business-to-consumer	Ordering books online
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 online
P2P	Peer-to-peer	Music sharing

Home Applications

- Entertainment:
  - MP3 and DVD-quality movies
  - TV shows
  - Interactive Live TV
- Game Playing
  - Multiperson real-time simulation games.
- Ubiquitous Computing
  - Smart Home Monitoring
- RFID (Radio Frequency ID)
  - Replacing Bar Codes with a smart devices that turn the real world to IoT

Mobile Users

- Mobile computers (handheld and laptops)
- Fastest growing segments in computer history.
- Individuals are able to use their mobile devices to:
- Read and send email, Tweet, Watch Movies, Download, Play Games, Surf the Web
- Internet connectivity allows for those applications to be easily built
- Wireless Networks (Cars, Boats, and Airplanes can not have wired Connections)
- Cellular Networks
- Wireless hotspots (802.11 Standard).
- Wireless Networking vs. Mobile Wireless Networks

Mobile Users

Wireless	Mobile	Typical applications
No	No	Desktop computers in offices
No	Yes	A notebook computer used in a hotel room
Yes	No	Networks in unwired buildings
Yes	Yes	Store inventory with a handheld computer

Mobile Users

- Smart Phones – Integration of Internet with Telephony
- Driving the wireless-mobile applications
- 3G & 4G cellular networks provides fast data services
- GPS, m-commerce (mobile commerce), NFC
- Sensor Networks
- Notes that Sense/gather data about state of the physical world.
- Wearable Computers
- Implantable Devices, Pacemakers, Insulin pumps & can be controlled wirelessly

Social Issues

- Network Neutrality
- Digital Millennium Copyright Act
- Profiling Users
- Phishing

Social Issues

- Network Neutrality
- Communications are not to be differentiated by their
  - content, or
  - source, or
  - who is providing the content
- Digital Millennium Copyright Act.
- Warning messages to the operators and the users who are suspect of infringing copyrights

Social Issues

- Profiling Users
- Computer Networks make it very easy to communicate.
- Easy for the people who run the network to snoop on the traffic.
- Sets up a conflict over issues
  - employee rights vs. employer rights.
  - Government vs. Citizens rights.
- Companies collect data to Profile users.

- Phishing
- e-mail messages that masquerade as
- originating from a trustworthy party.
- This is illegal activity
- Encryption

Network Hardware

- Personal area networks
- Local area networks
- Metropolitan area networks
- Wide area networks
- The internet

Network Hardware

- Transmission Technology
- Scale

Network Hardware

- Two types of transmission technologies:
- Broadcast - Communication channel shared by all machines
- Packets send by any machine are received by all the others.
  - An address field within each packed specifies the intended recipient.
  - If packed is intended for some other machine, it is just ignored
  - If packed is indented for the recipient machine then it is processed.
- Wireless network is a common example of a broadcast link
  - Communication is shared over a coverage region that depends on the wireless channel and transmitting machine.
- Broadcast systems usually also allow the possibility of addressing a packet to all destinations.

Network Hardware

- Point-to-point - Connect individual pairs of machines
- Packets (short messages) may have to visit one or more intermediates machines.
- Multiple routes of different lengths are possible.
- Finding good ones is important.
- Unicasting – transmission with exactly one sender and exactly one receiver.

Network Hardware

- Scale
  - Distance is important as a classification metric because different technologies are used at different scales.

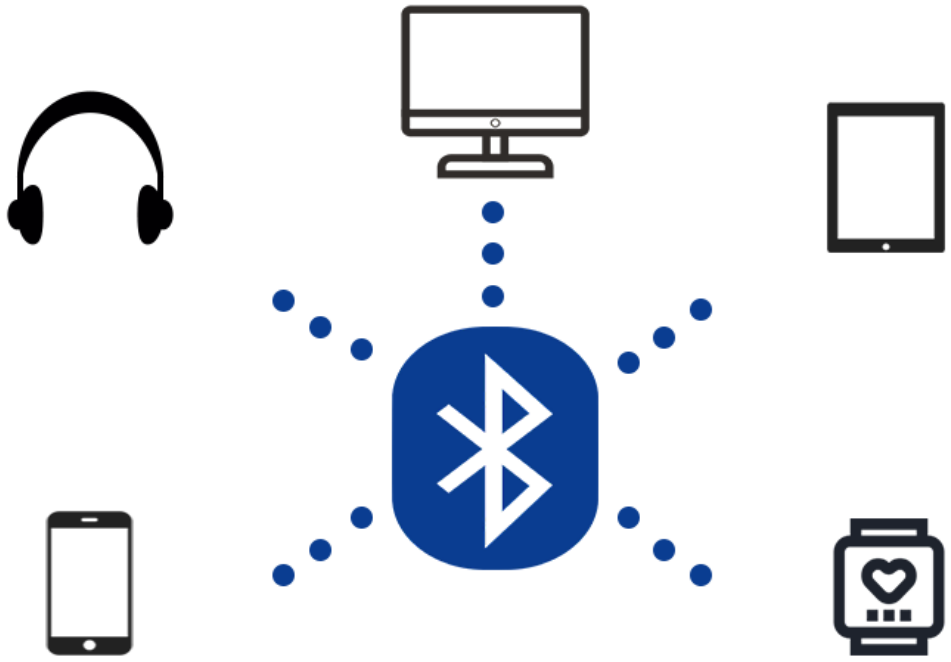
Network Hardware

Classification of Interconnected Processors by 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

Personal Area Network

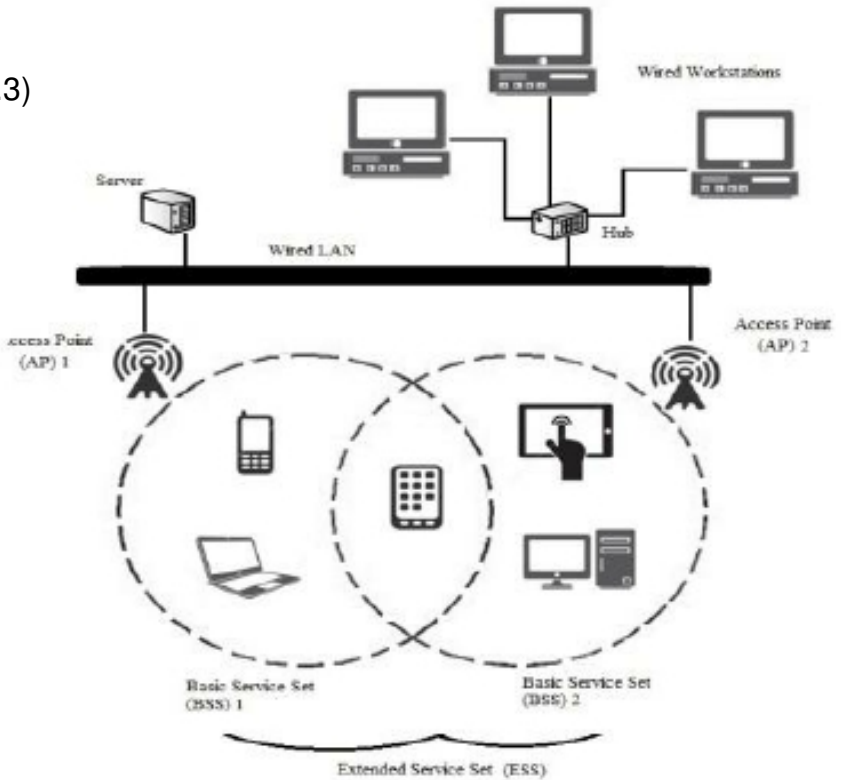
Bluetooth PAN



Local Area Network

Wireless & Wired

Switched Ethernet (802.3)

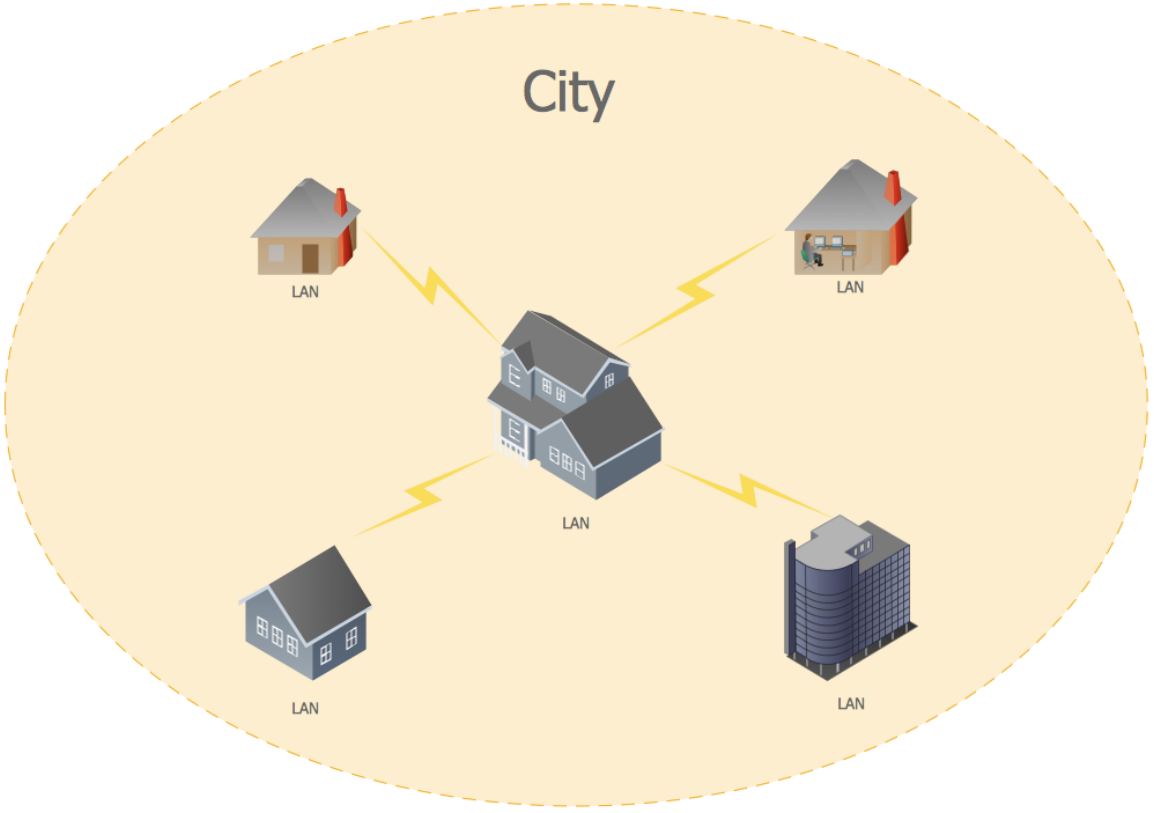


IEEE 802.11 or Wi-Fi

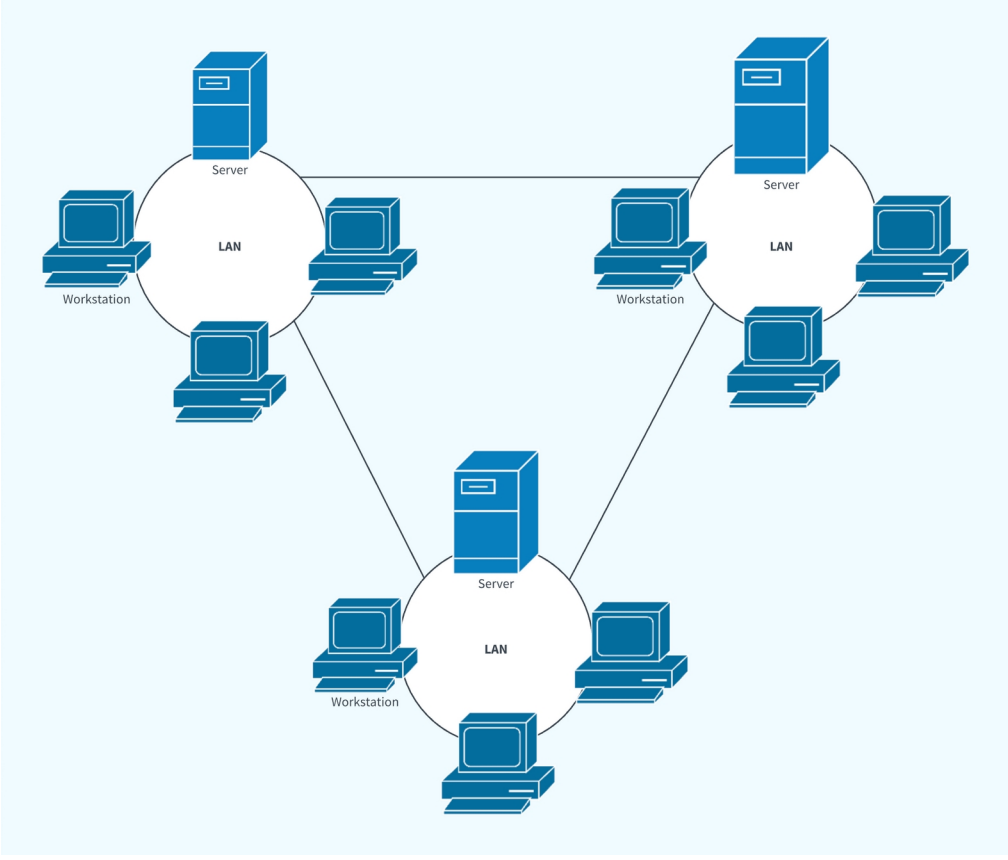
Wireless LAN

- Switched Ethernet
  - Switch - Hardware that connects two devices point-to-point
  - A Switch has multiple ports
- Physical vs. Virtual LAN – VLAN
- Dynamic vs. Static Channel Allocation
  - Static Allocation: Each device is allocated its time slot whether or not it uses it.
  - Dynamic methods allow changing the time allocation scheme.
- Dynamic Allocation
  - Centralized
  - Decentralized

Metropolitan Area Network



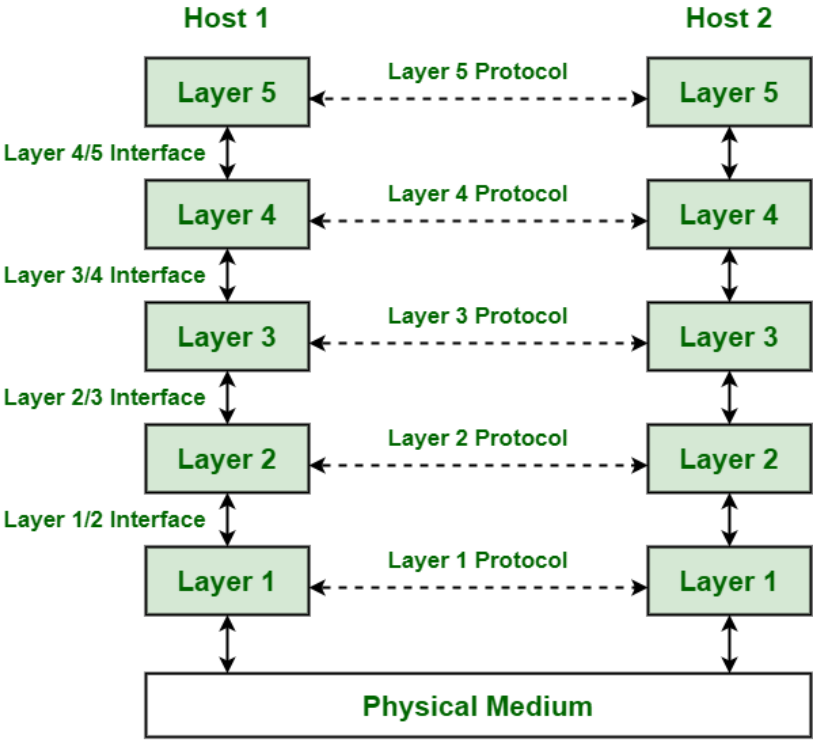
Wide Area Network



Network Software

- Protocol hierarchies
- Design issues for the layers
- Connection-oriented versus connectionless service
- Service primitives
- Relationship of services to protocols

Protocol Hierarchies



Physical Hierarchies

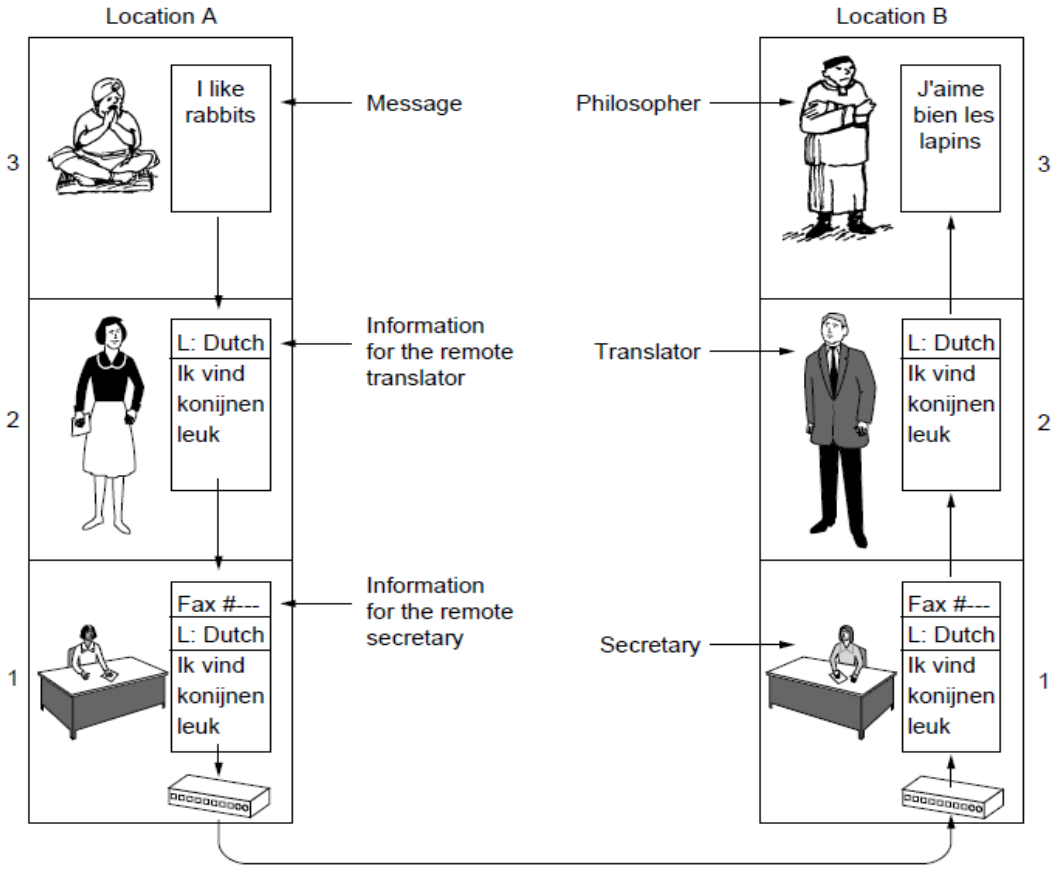
Definitions

- Protocol – is an agreement between the communicating parties.
- Peers – the entities comprising corresponding layers on different machines.
  - Peers use the protocol to communicated with each other.
- No data is directly transferred from layer n on one machine to layer n on another machine.
  - Each Layer passed 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.
  - Virtual communication is shown by dotted lines and physical communication by solid lines the previous figure.

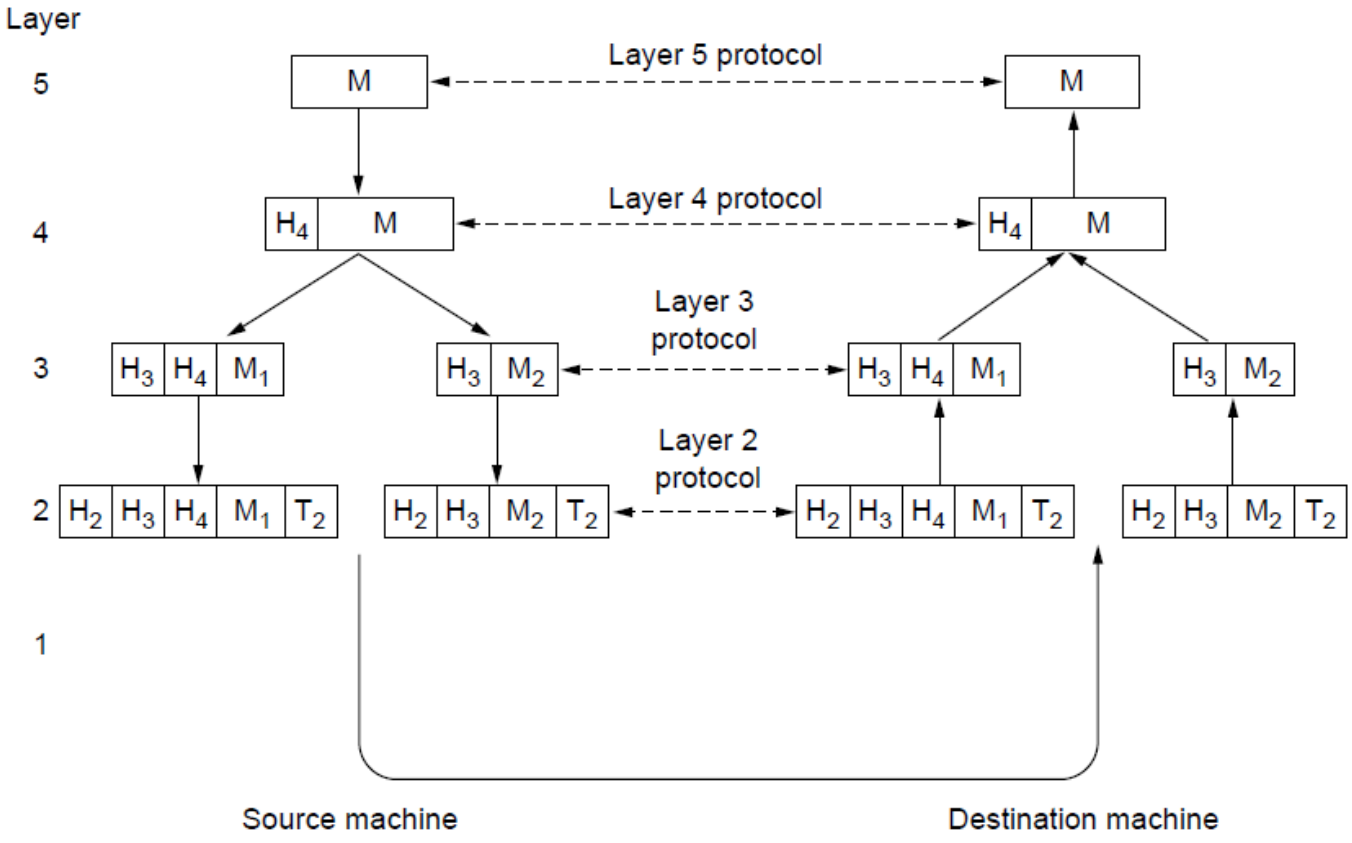
Definitions

- Interface
  - It defines which primitive operations and services the lower layer makes available to the upper one.
- Network Architecture:
  - A set of layers and protocols.
- The specification of the network architecture must contain enough information to allow an implementation of the program or the hardware for each layer so that it will obey appropriately the protocol.
- Protocol Stack:
  - The list of protocols used by a certain system – one protocol per layer

Protocol Hierarchies



Protocol Hierarchies



Design Issues

- Reliability:
  - Network must operate correctly although it is made up of a collection of components that are unreliable.
- Error Detection:
  - It typically uses codes to locate the erroneously transmitted bit(s) and request re-transmission.
- Error Correction:
  - Correct messages is recovered from the possibly incorrect bit(s) that were originally received.
- Routing:
  - Finding a working path through a network.
- Protocol Layering:
  - Networks grow larger over time and new designs emerge that need to connected to the existing networks.

Design Issues

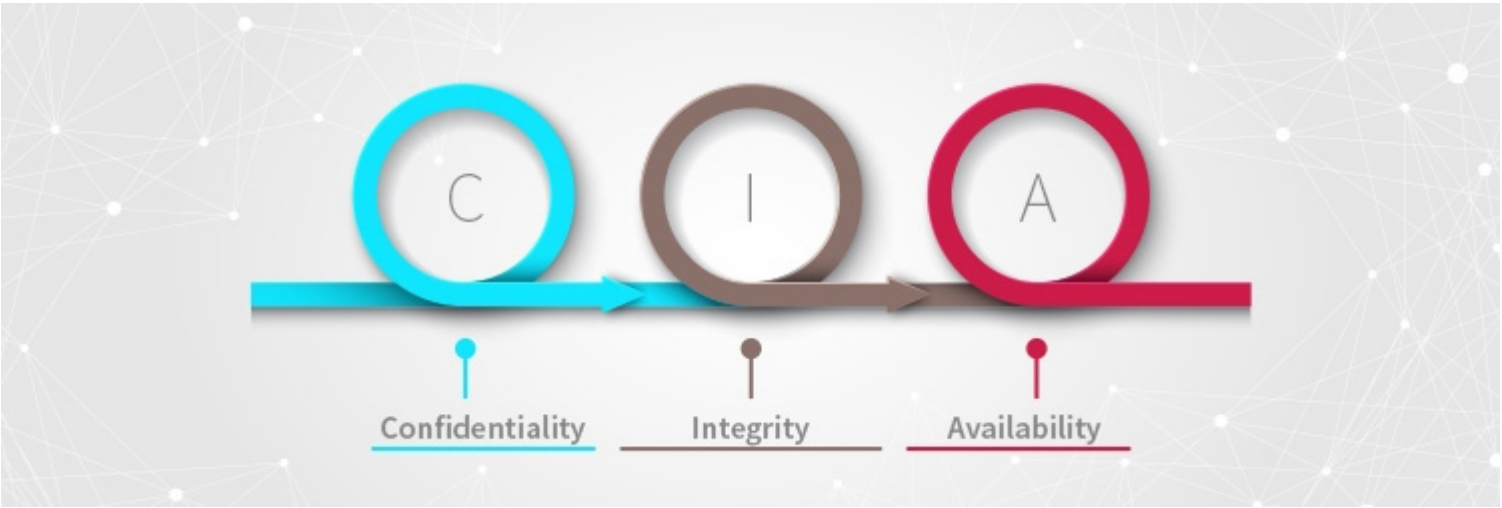
- Addressing and Naming:
  - Every layer needs a mechanism for identifying the senders and receivers that are involved in a particular message.
- Internetworking:
  - Different network technologies often have different limitations:
    - Not all communication channels preserve the order of messages sent on them
    - Differences in the maximum size of a message that the networks can transmit.
- Scalable:
  - Designs that continue to work well when the network gets large.
- Resource Allocation
  - Networks work with their resources to provide services to various hosts. If they are not aware of limitations of the networks resources than the network is providing proper resource allocation.

Design Issues

- Flow Control
  - Feedback from the receiver to the sender is often used to alleviate the problem of the sender swamping the slow receiver with data.
- Congestion:
  - The problem may occur when the network is oversubscribed because to many computers want to send too much traffic and the network will not be able to deliver them all.
  - Overloading problem of the network.
  - One strategy is for each computer to reduce its demand.
- Quality of Service
  - Additional Resources (other then Bandwidth),
  - Real-time delivery (for applications that require high throughput),
  - Live Video

Design Issues

- How good is the network against different kinds of threats
  - Eavesdropping,
  - Confidentiality,
  - Authentication,
  - Integrity, etc.



Connection-Oriented & Connection-less Service

- Layers can offer two different types of service to the layers above them:
- Connection-oriented, and
- Connection less

Connection-Oriented Service

- Modeled after telephone system:
  - Pickup-the-phone
  - Dial the number
  - Talk
  - Hang-up
- Service User:
  - Establishes a connection,
  - Uses a connection (sender pushes objects in at one end and the receiver takes them out at the other end).
  - In some cases when connection is established, the sender, receiver, and a subnet conduct a negotiation about the parameters to be used: Maximum message size, Quality of service required, Other issues

Connection-less Service

- Modeled after a postal system:
- Each message carries the full destination address, and
- Each one is routed through the intermediate nodes inside the system independent of all the subsequent messages.
- Different Names for Messages:
- Store-and-forward switching: Packet, a message, is processed in full before sending it on the next node.
- Cut-through-switching: when the onward transmission of a message at a node start before it is completely received.
- Each kind of the Service can be further characterized by its reliability:
- A reliable service is implemented by having the receiver acknowledge the receipt of each message.
- Acknowledgment service introduces overhead and delays.

Connection-Oriented Versus Connection less Service

	Service	Example
Connection-oriented	Reliable message stream	Sequence of pages
	Reliable byte stream	Movie download
	Unreliable connection	Voice over IP
Connection-less	Unreliable datagram	Electronic junk mail
	Acknowledged datagram	Text messaging
	Request-reply	Database query

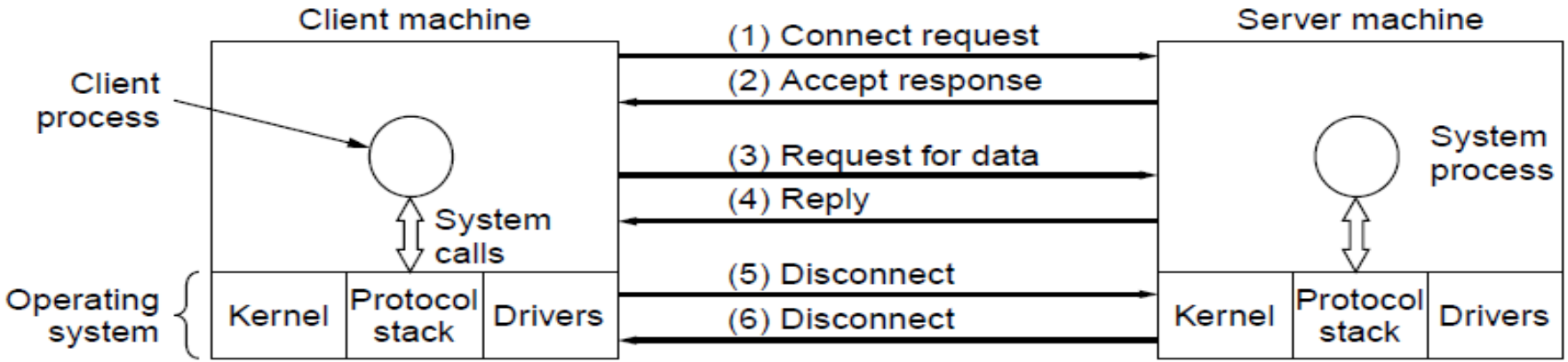
Six Different Types of Service.

Service Primitives

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

Six service primitives that provide a simple connection-oriented service

Service Primitives

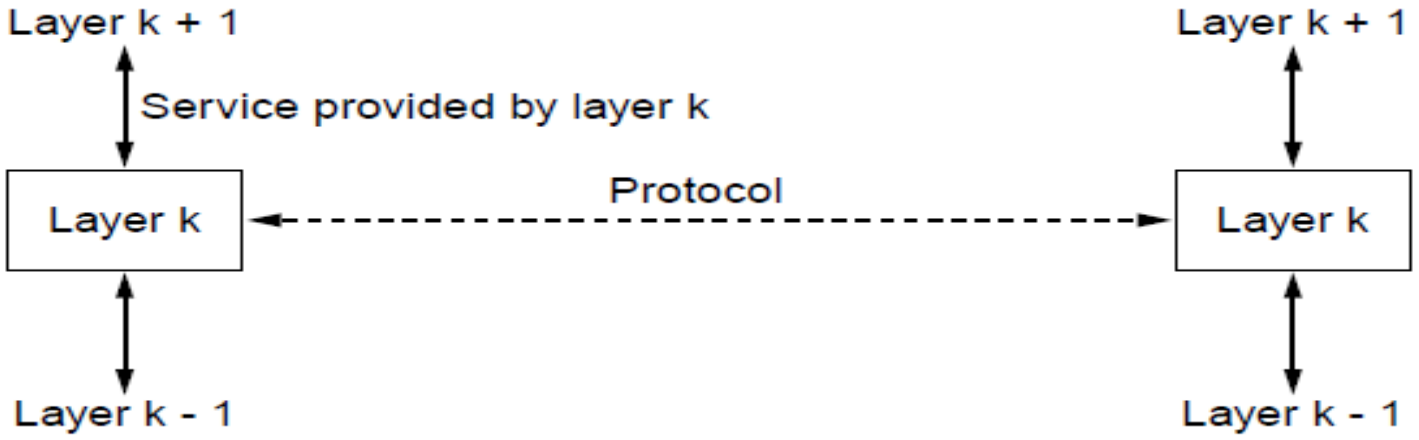


A simple client-server interaction using acknowledged datagrams

Connection-less Service

- A *service* is a set of primitives (operations) that a layer provides to the layer above it.
- The service defines what operations the layer is prepared to perform on behalf of its users, but it does not say anything at all about how these operation are implemented.
- A *protocol* is a set of rules governing the format and meaning of the packets, or messages that are exchanged by the peer entities within a layer.
- Entities use protocols to implement their service definitions.
- They are free to change their protocols at will, provided they do not change the service visible to their users.
- In this way the service and the protocol are completely decoupled.

Relationship of Services to Protocols



Relationship between a Service and a Protocol

Reference Models

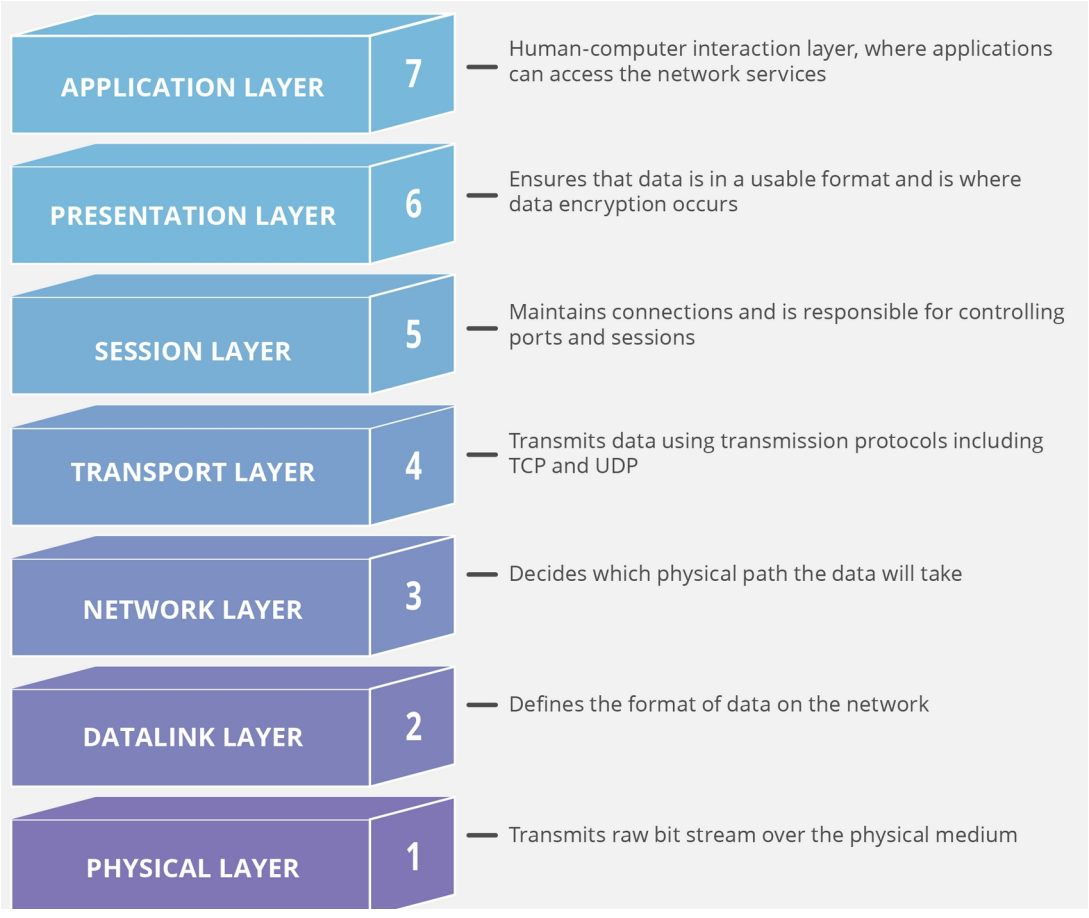
- OSI reference model
- TCP/IP reference model
- Model used for this text
- Comparison of OSI and TCP/IP
- Critique of OSI model and protocols
- Critique of TCP/IP model

OSI Reference Model

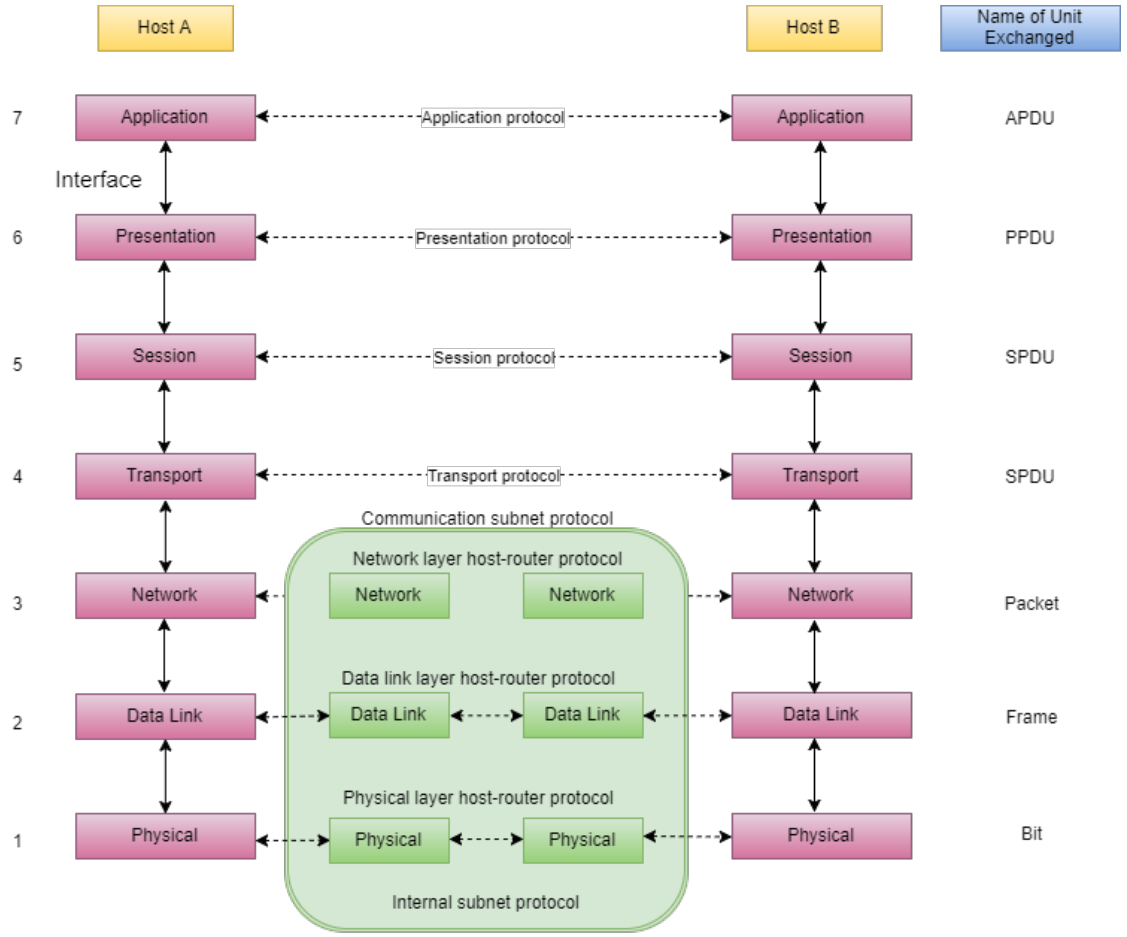
Principles for the seven layers

- Layers created for different abstractions
- Each layer performs well-defined function
- Function of layer chosen with definition of international standard protocols in mind
- Minimize information flow across interfaces between boundaries
- Number of layers optimum

7 Layers of the OSI



OSI Reference Model



The TCP/IP Reference Model

- Initiation of wide area computer networks *ARPANET*
- Successor Internet
- ARPANET research network sponsored by the DoD.
- Used initially leased telephone lines
- When satellite and radio networks were included the new reference architecture was needed
- Hence the ability to connect to multiple networks in a seamless way was one of the major design goals.
- This architecture latter became known as the *TCP/IP Reference Model*.
- Design criteria:

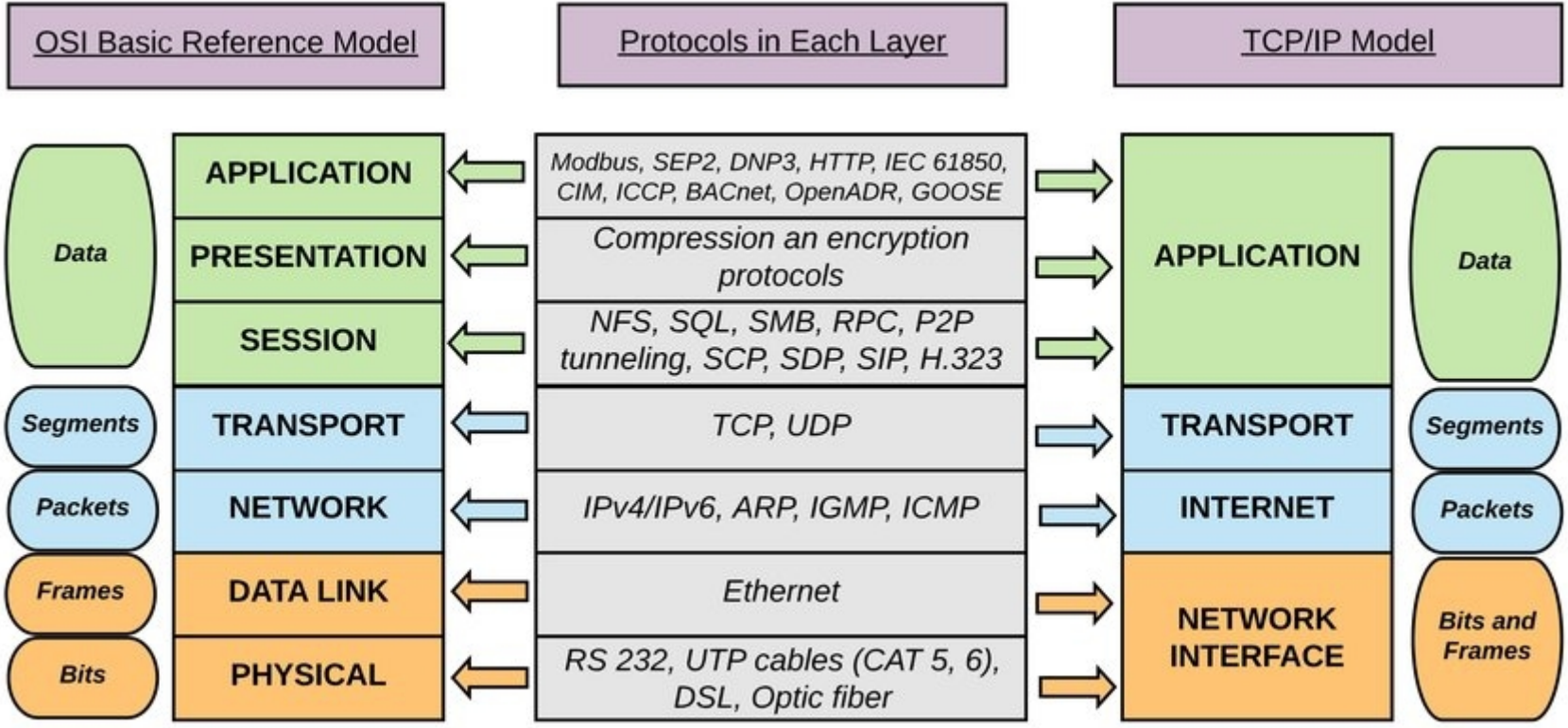
→ Applications with divergent requirements were supported ranging from file transfer to real-time speech transmission.

→ Network be able to survive loss of subnet hardware without existing conversations being broken off

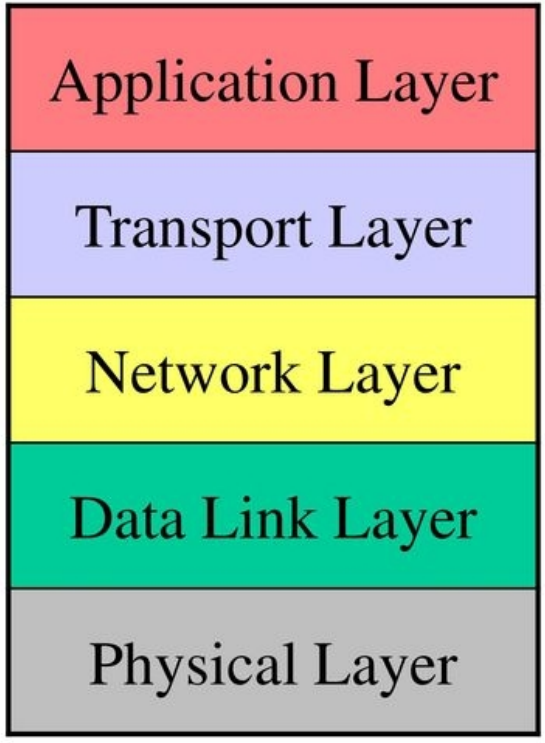
The TCP/IP Reference Model

OSI Model	TCP/IP Model
Application Layer	Application layer
Presentation Layer	
Session Layer	
Transport Layer	Transport Layer
Network Layer	Internet Layer
Data link layer	Link Layer
Physical layer	

The TCP/IP Reference Model



Model Used in the 1st Book



Comparison of OSI & TCP/IP Layers

Concepts central to OSI model

- Services
- Interfaces
- Protocols

Service

- Each layer provides a service to the layer above it.
- The service definition tells what the layer does, not how entities above it access it or how the layer works.
- It defines the layer's semantics.

Interface

- A layer's interface tells the processes above it how to access it.
- It specifies what the parameters are and what results to expect.
- The layer also says nothing about how the layer works inside.

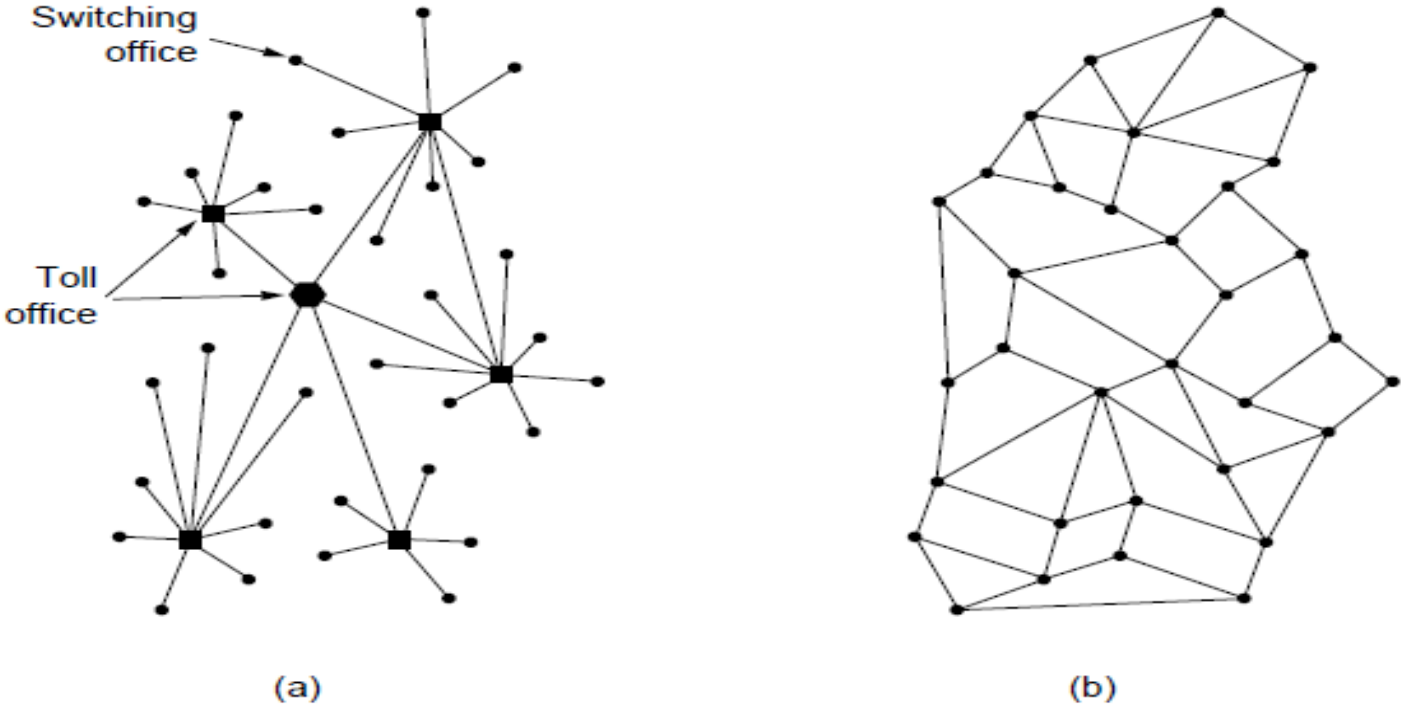
Protocol

- A layer's protocol its is own business: it can use any protocols it wants to as long as it gets the job done (i.e. provides the offered services).
- A layer is allowed to change the protocol with the condition that it will not affect the software in higher layers.

Example Networks

- Internet
  - ARPANET (Advanced Research Project Agency Networks)

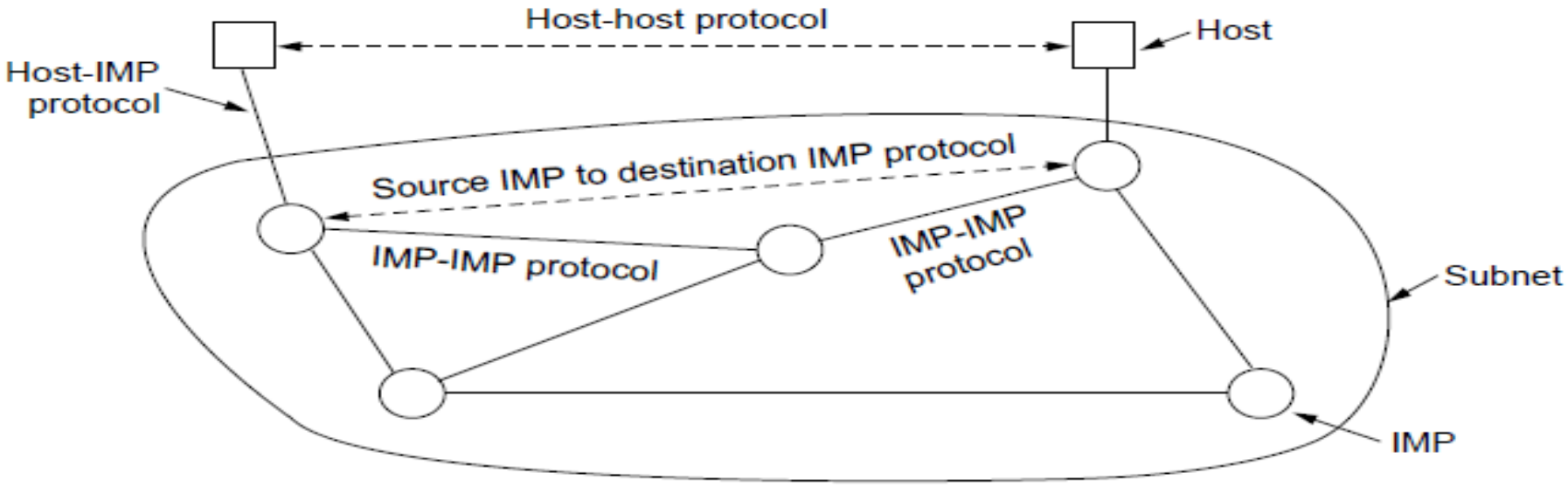
The ARPANET



(a) Structure of the telephone system.

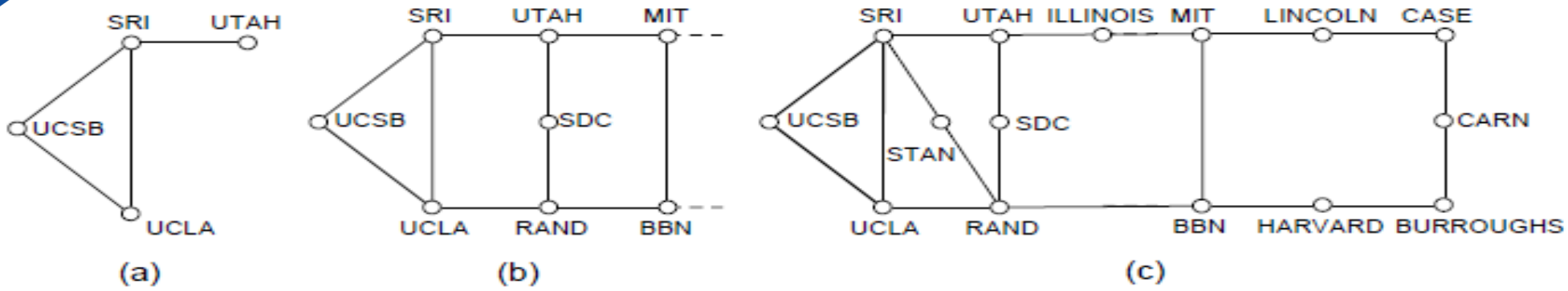
(b) Baran's proposed distributed switching system.

The ARPANET



Original ARPANET Design

The ARPANET



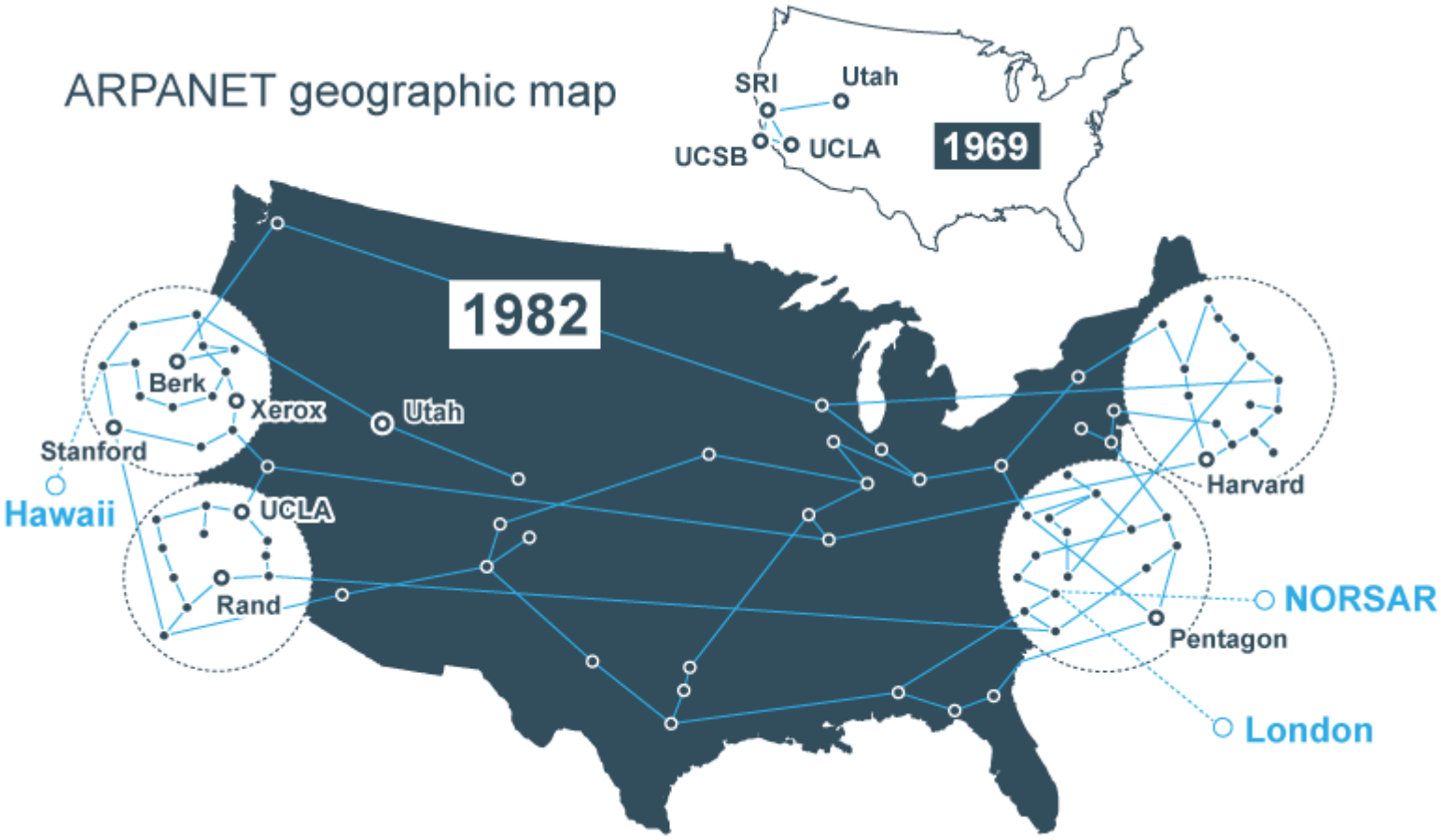
Growth of the ARPANET.

(a) December 1969.

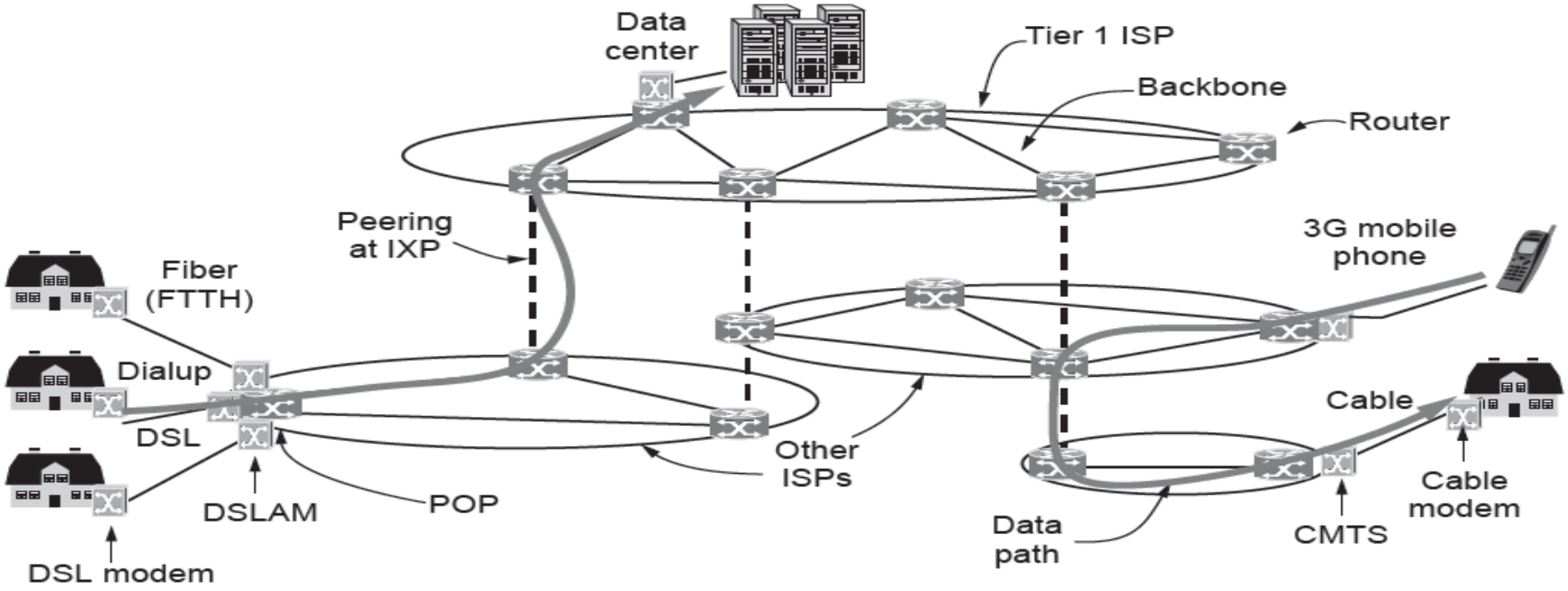
(b) July 1970.

(c) March 1971.

The ARPANET


ARPANET geographic map
SRI
Utah
UCSB
UCLA
1969
1982
Berk
Xerox
Utah
Stanford
Hawaii
UCLA
Rand
Harvard
NORSAR
Pentagon
London

The Architecture of the Internet



Overview of the Internet architecture

Network Standardization

- Who's Who in telecommunications
- Who's Who in international standards
- Who's Who in internet standards

Who's Who in International 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 (WiFi)
802.12 ↓	Demand priority (Hewlett-Packard's AnyLAN)

The 802 working groups. The important ones are marked with *.

The ones marked with ↓ are hibernating. The one marked with † gave up and disbanded itself.

Who's Who in International Standards

802.13	Unlucky number; nobody wanted it
802.14 ↓	Cable modems (defunct: an industry consortium got there first)
802.15 *	Personal area networks (Bluetooth, Zigbee)
802.16 *	Broadband wireless (WiMAX)
802.17	Resilient packet ring
802.18	Technical advisory group on radio regulatory issues
802.19	Technical advisory group on coexistence of all these standards
802.20	Mobile broadband wireless (similar to 802.16e)
802.21	Media independent handoff (for roaming over technologies)
802.22	Wireless regional area network

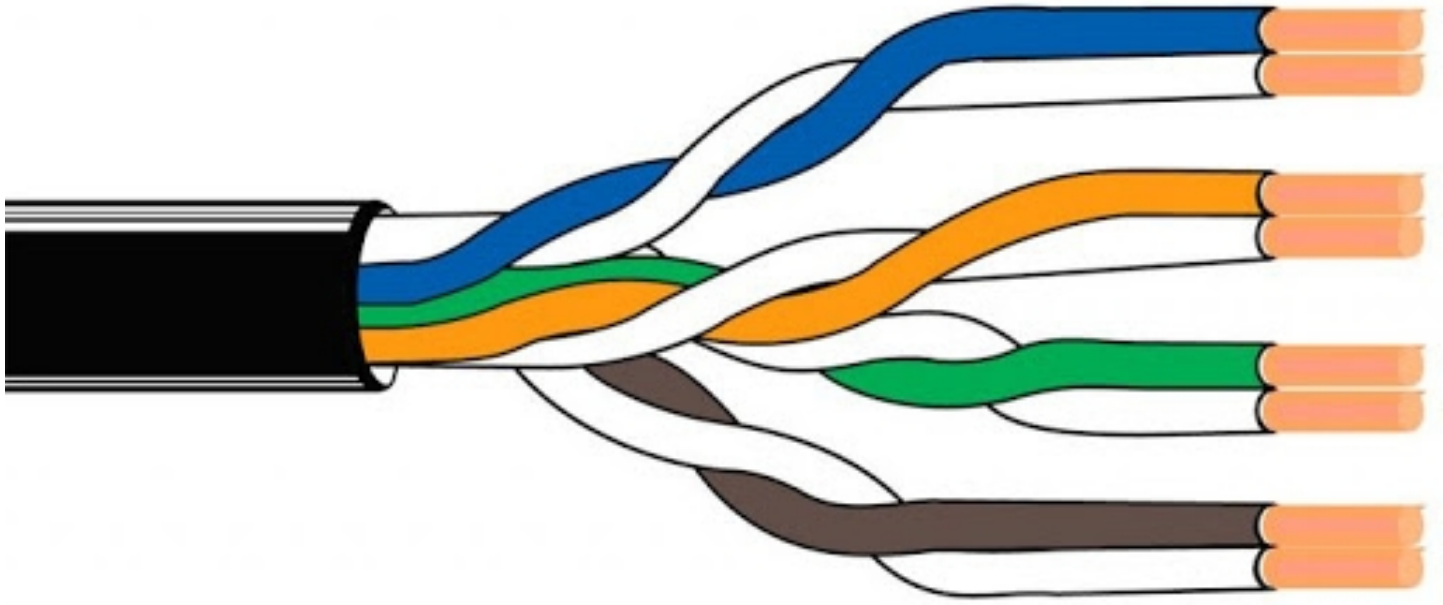
Guided Transmission Media

- Magnetic media
- Twisted pairs
- Coaxial cable
- Power lines
- Fiber optics

Magnetic Media

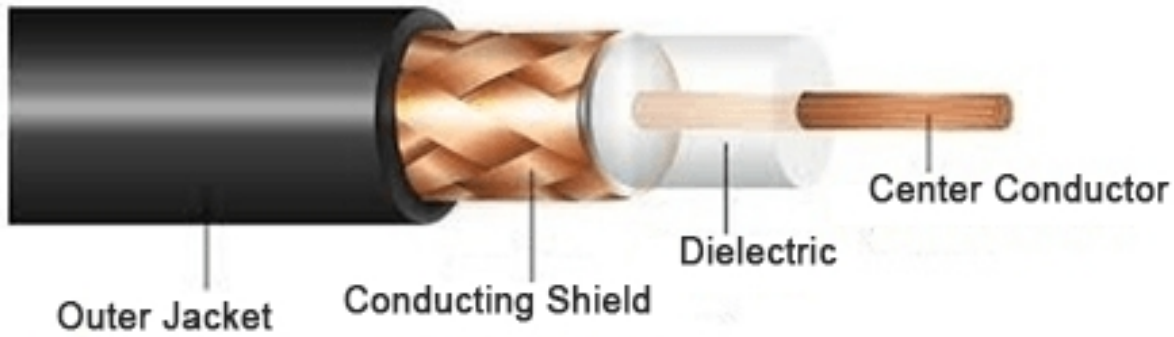
- Write data onto magnetic media
  - Disks
  - Tapes
- Data transmission speed

Twisted Pair

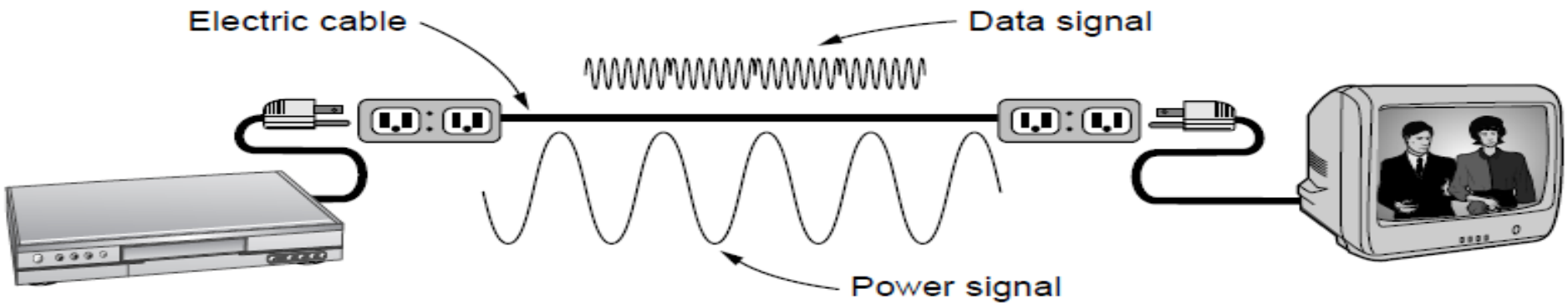


Category 5 UTP cable with four twisted pairs

Coaxial Cable

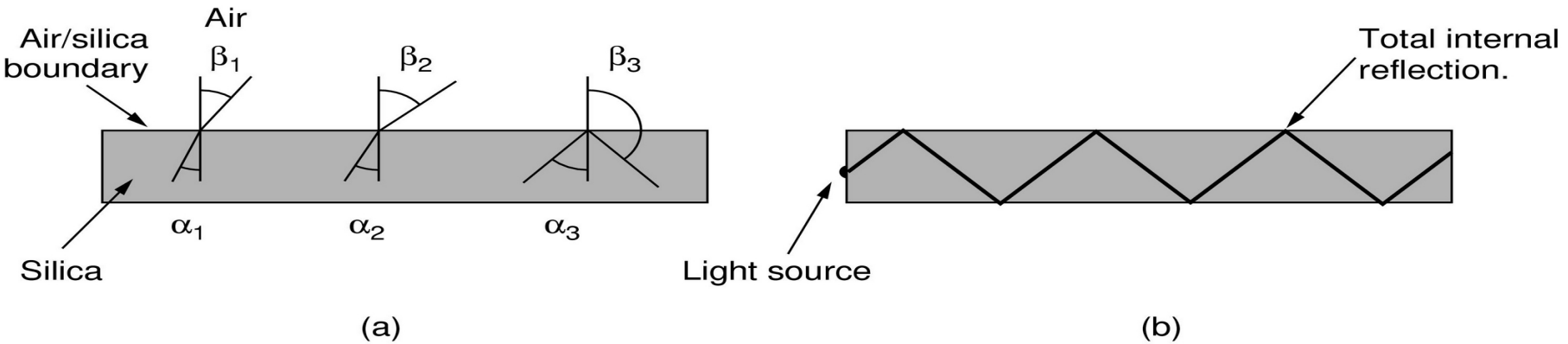


Power Lines



A network that uses household electrical wiring.

Fiber Optics



Light trapped by total internal reflection.

Fiber Cables

Views of a fiber cable

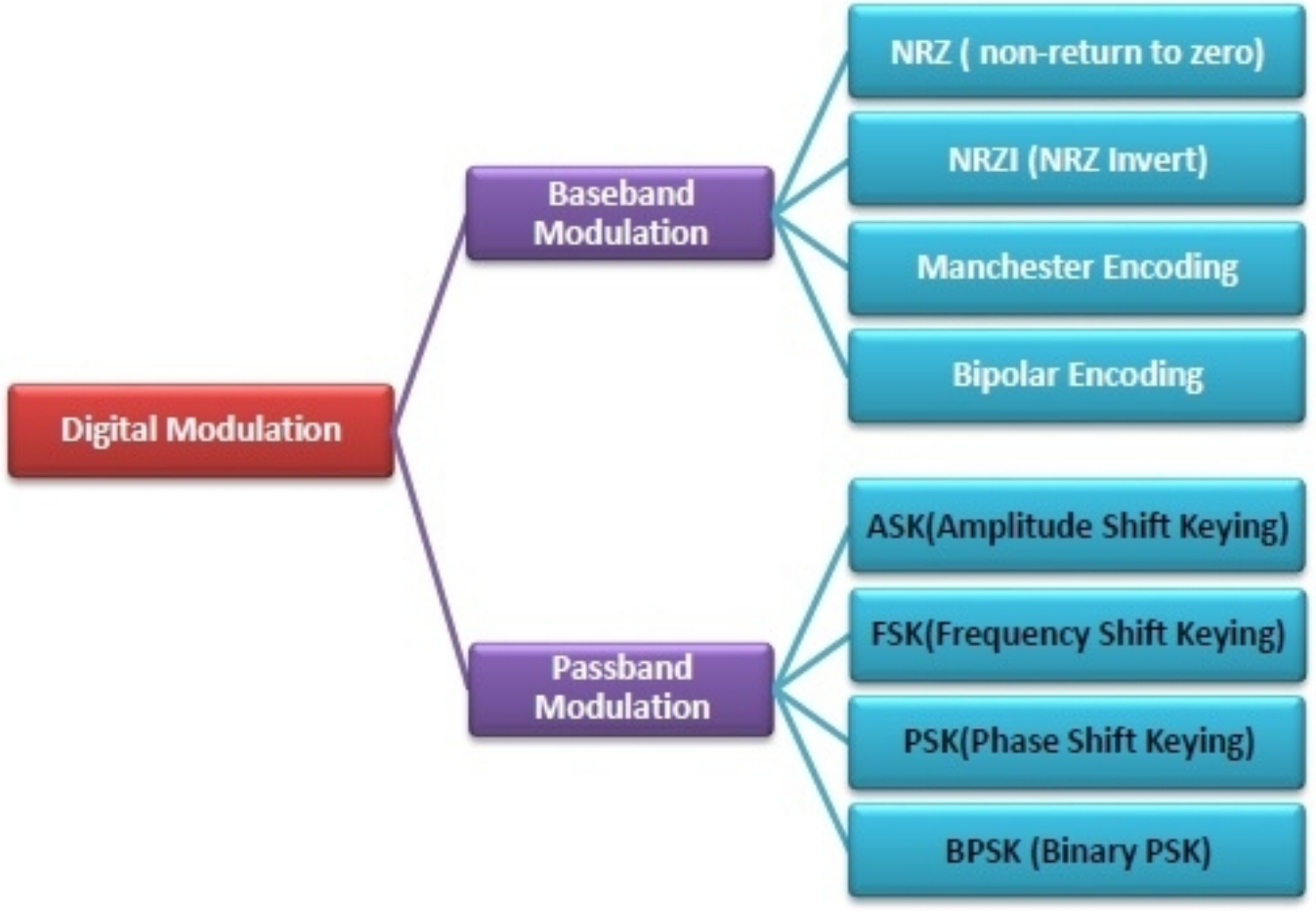
Fiber Cables

Digital Modulation

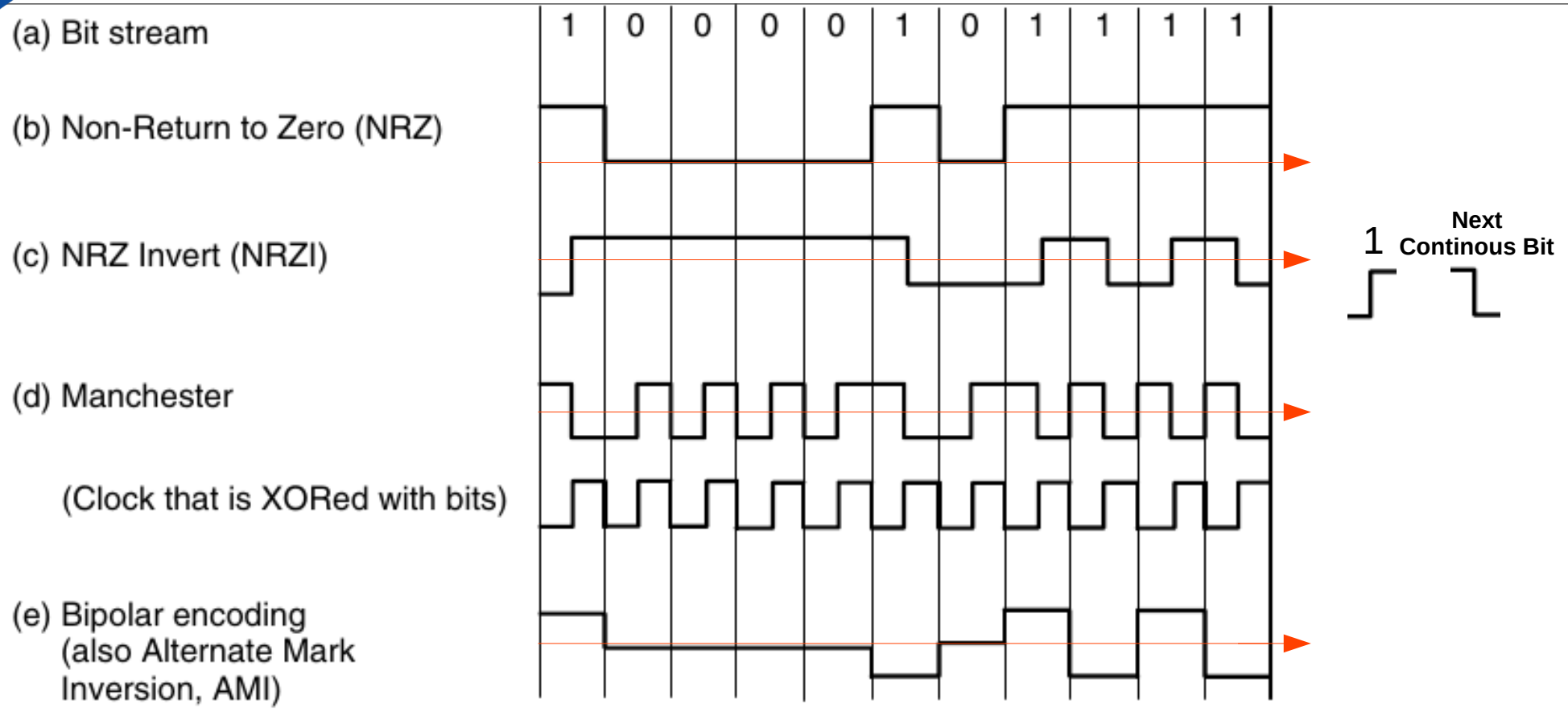
- The process of conversion between bits and signals that represent them is called digital modulation.

- Digital Modulation
  - Passband Modulation
  - Broadband Modulation

Digital Modulation



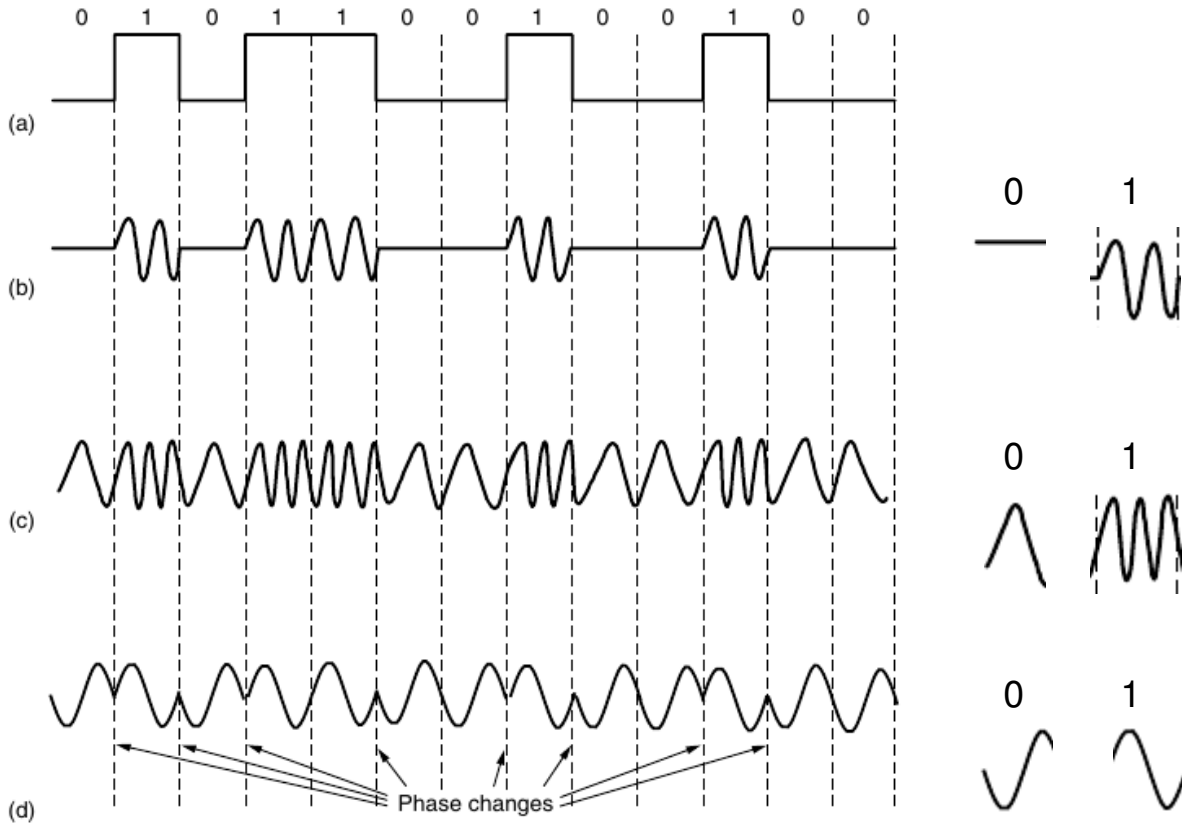
Passband Modulation



4B/5B Mapping

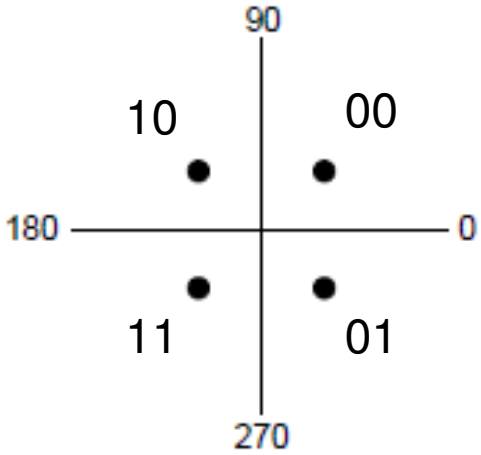
Data (4B)	Codeword (5B)	Data (4B)	Codeword (5B)
0000	11110	1000	10010
0001	01001	1001	10011
0010	10100	1010	10110
0011	10101	1011	10111
0100	01010	1100	11010
0101	01011	1101	11011
0110	01110	1110	11100
0111	01111	1111	11101

Broadband Modulation



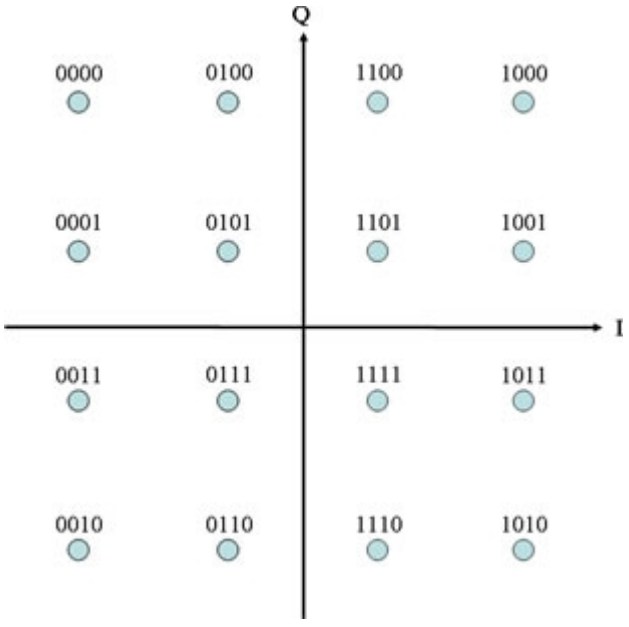
(a) A binary signal. (b) Amplitude shift keying. (c) Frequency shift keying. (d) Phase shift keying.

Quadrature Phase Shift Keying



(a)

Quadrature Amplitude Modulation



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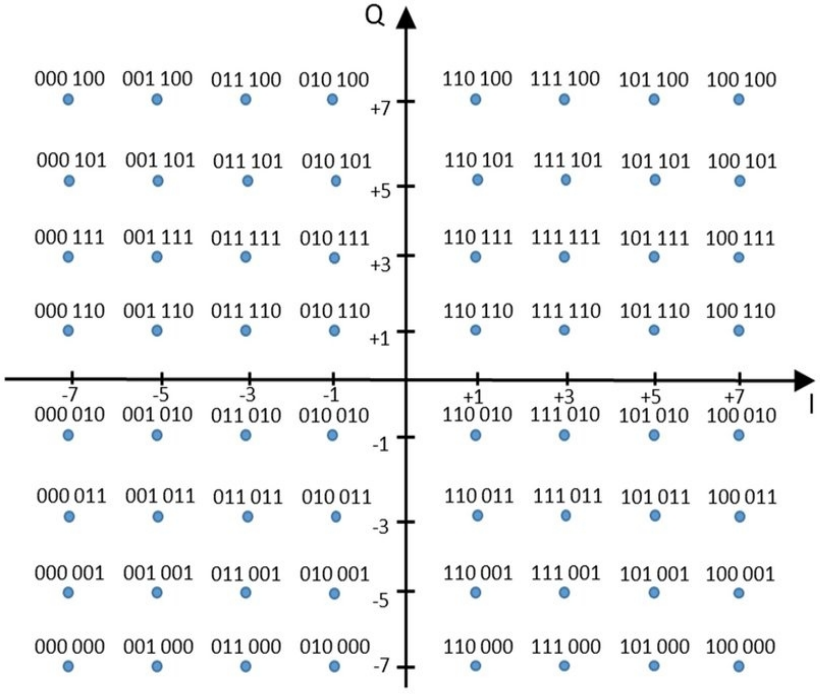
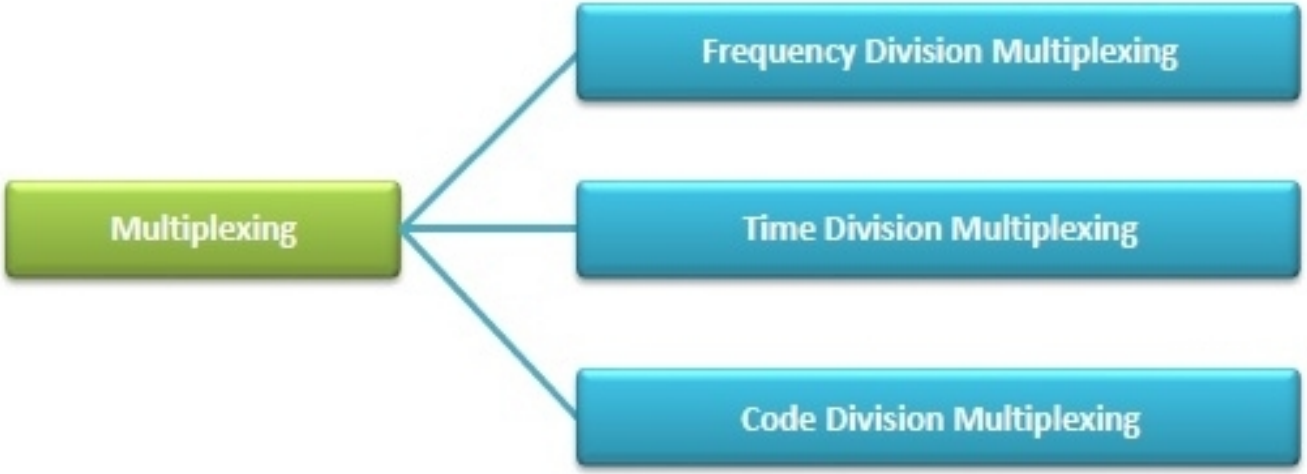


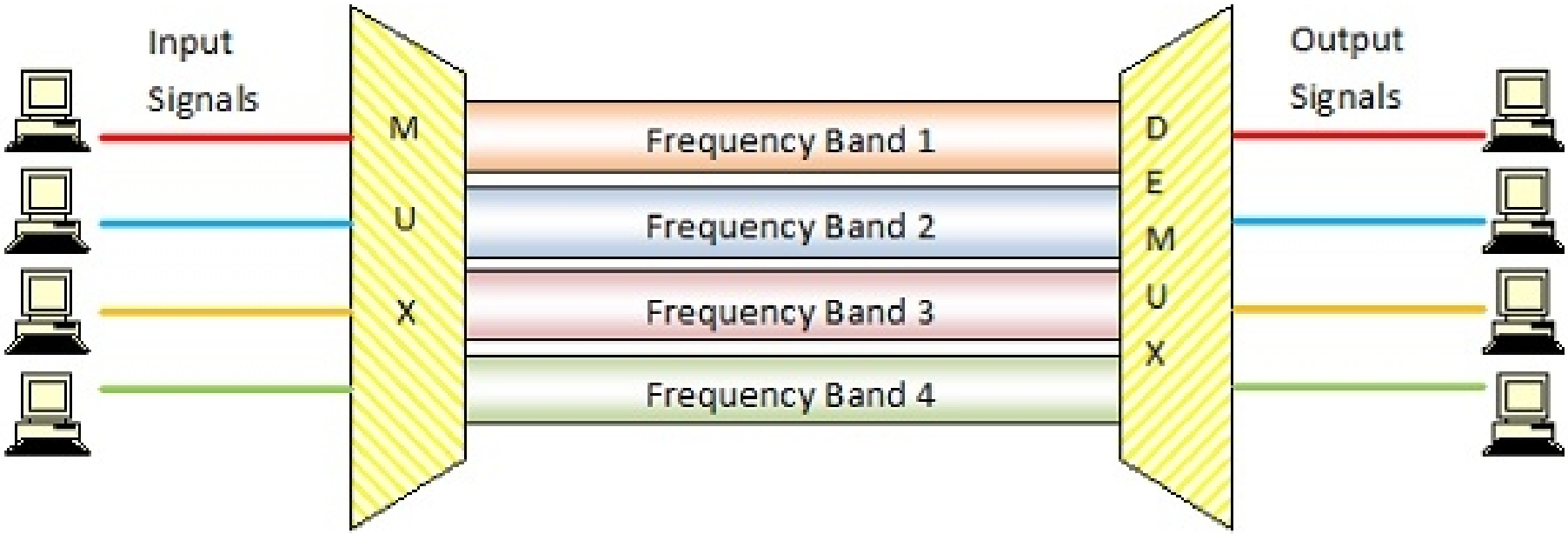
QAM-64

Multiplexing

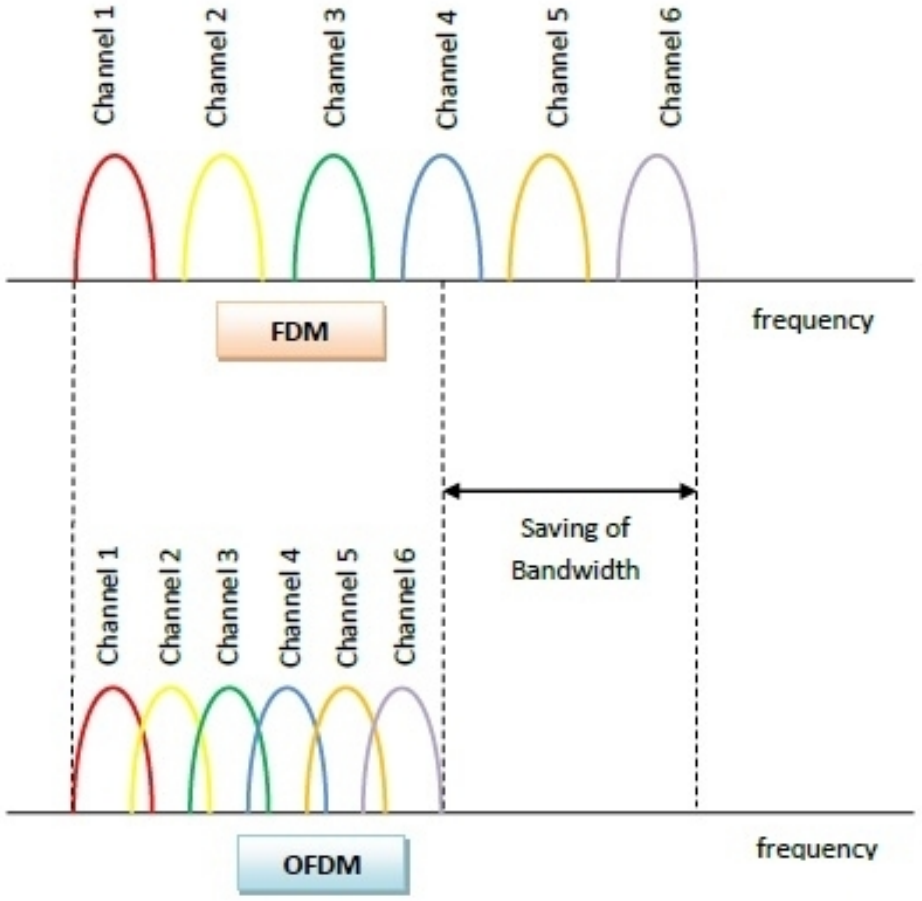
- Channels are often shared by multiple signals.
- More convenient to use a single wire to carry several signals than to install a wire for every signal. This kind of sharing is called **Multiplexing**



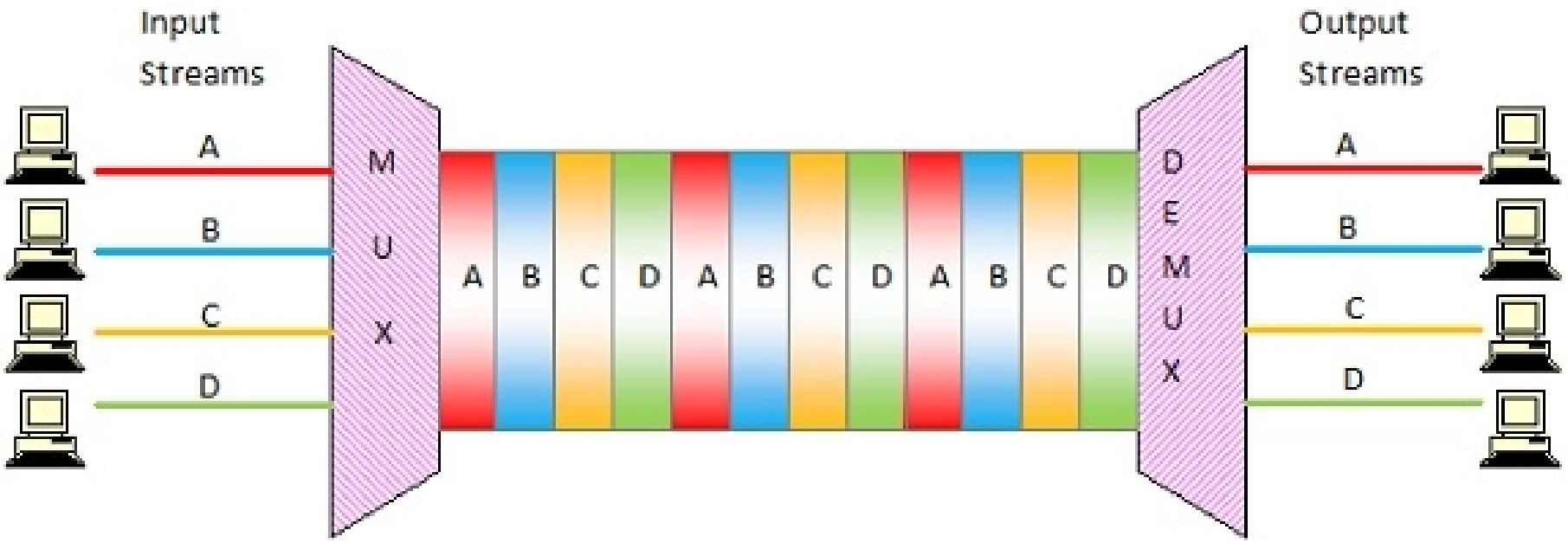
Frequency Division Multiplexing



Orthogonal Frequency Division Multiplexing



Time Division Multiplexing



Code Division Multiplexing

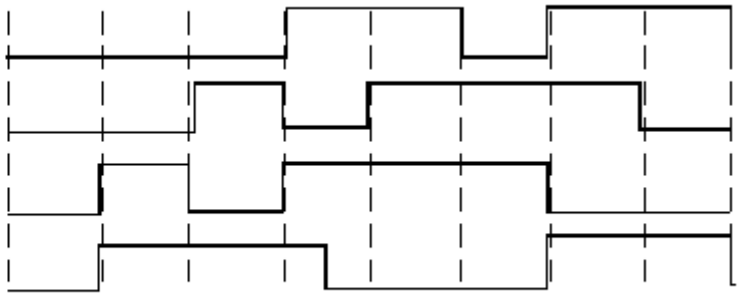
$A = (-1\ -1\ -1\ +1\ +1\ -1\ +1\ +1)$

$B = (-1\ -1\ +1\ -1\ +1\ +1\ +1\ -1)$

$C = (-1\ +1\ -1\ +1\ +1\ +1\ -1\ -1)$

$D = (-1\ +1\ -1\ -1\ -1\ -1\ +1\ -1)$

(a)



(b)

$S_1 = C$

$S_2 = B+C$

$S_3 = A+\overline{B}$

End of

Unit 1