Text Books
2. Data Communications and Networking, B Forouzan, 3rd edition.

What is a network?
Set of devices communicating with each other.
- Could be a CPU, monitor and other peripheral devices connected (and exchanging data) to each other.
- Could be a group of people …. A network of friends.
- Or, could be a set of computers communicating with each other.

Classification of Networks
On the basis of
- Applications
- Model
- Size of Geographical Area covered
Uses of Computer Networks

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

Business Applications

- Resources sharing
- Scalability (client-server model)
- High reliability
- Saving money (price/performance ratio)
- A powerful communication media among widely separated employees
- E-commerce / M-commerce

Business Applications of Networks

Client Server Model: A network with two clients and one server: Employees accessing company’s Information System

Business Applications of Networks (2)

The client-server model involves requests and replies.
Home Network Applications

- Access to remote information (WWW etc)
- Person-to-person communication (Email, Instant Messaging etc, Phone)
- Interactive entertainment (Remote operated or online Games)
- Electronic commerce

Peer-to-Peer Model of Communication

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

Some forms of e-commerce

<table>
<thead>
<tr>
<th>Tag</th>
<th>Full name</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>B2C</td>
<td>Business-to-consumer</td>
<td>Ordering books on-line</td>
</tr>
<tr>
<td>B2B</td>
<td>Business-to-business</td>
<td>Car manufacturer ordering tires from supplier</td>
</tr>
<tr>
<td>G2G</td>
<td>Government-to-government</td>
<td>Government distributing tax forms electronically</td>
</tr>
<tr>
<td>C2C</td>
<td>Consumer-to-consumer</td>
<td>Auctioning second-hand products on-line</td>
</tr>
<tr>
<td>P2P</td>
<td>Peer-to-peer</td>
<td>File sharing</td>
</tr>
</tbody>
</table>

Mobile Network Users

<table>
<thead>
<tr>
<th>Wireless</th>
<th>Mobile</th>
<th>Applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>No</td>
<td>No</td>
<td>Desktop computers in offices</td>
</tr>
<tr>
<td>No</td>
<td>Yes</td>
<td>A notebook computer used in a hotel room</td>
</tr>
<tr>
<td>Yes</td>
<td>No</td>
<td>Networks in older, unwired buildings</td>
</tr>
<tr>
<td>Yes</td>
<td>Yes</td>
<td>Portable office; PDA for store inventory</td>
</tr>
</tbody>
</table>

Combinations of wireless networks and mobile computing.
Social Issues

- Social Problems: Youngsters may get exposed to objectionable data
- Ethical Problems: Employers start reading E-mails of employees
- Political Problems: Where a person posts objectionable material about a political leader
- E-business may also result in different types of financial problems

Network Hardware

- Computer networks are classified based on
  - Transmission technology.
  - Scale or size.
- Two types of transmission technology
  - Broadcast links.
  - Point-to-point links.

Broadcast links

- Broadcast networks have a single communication channel or medium which is shared by all the machines on the network.
- Short messages called packets sent by one user are received by all others.
- An address field within the packet specifies the intended recipient who alone will respond to the message.

Broadcast links

- Three modes of transmission: Broadcasting, multicasting and unicasting.
- Broadcasting means sending the same message to all users on a network. This is achieved by using a special type of address called as broadcast address.
- Multicasting is one to many transmission where a message can be transmitted to all users of a group. There may be multiple groups in a network.
- Unicasting is one-to-one transmission with one sender and one receiver.
Point-to-point links

- Two devices are connected together through a dedicated link
- Point-to-point networks consist of many connections, between individual pairs of machines.
- To go from source to destination, packets on this type of network may visit one or more machines.
- As a general rule, smaller, geographically localized networks use broadcast links while larger networks are usually made of point-to-point links.

Network Hardware

Classification of computer networks based on scale or size. Distance is important as a classification metric because different techniques are suitable for different sizes.

- Personal Area Networks (PAN)
- Local Area Networks (LAN)
- Metropolitan Area Networks (MAN)
- Wide Area Networks (WAN)
- Internetworks (Internet)

Broadcast Networks (2)

<table>
<thead>
<tr>
<th>Distance</th>
<th>Processor Distance</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 m</td>
<td>Square meter</td>
</tr>
<tr>
<td>10 m</td>
<td>Room</td>
</tr>
<tr>
<td>1000 m</td>
<td>Building</td>
</tr>
<tr>
<td>1 km</td>
<td>Campus</td>
</tr>
<tr>
<td>10 km</td>
<td>City</td>
</tr>
<tr>
<td>1000 km</td>
<td>Country</td>
</tr>
<tr>
<td>10,000 km</td>
<td>Continent</td>
</tr>
<tr>
<td>16,000 km</td>
<td>Planet</td>
</tr>
</tbody>
</table>

Classification of interconnected processors by scale.

PAN

- Personal area networks (PAN) : Span a small area where the inter-processor distance is around 1m.
- PAN meant for one person
- Ex: A wireless network connecting a computer with its mouse, keyboard, printer etc.
- Blue tooth technology can be used at these distances.
- Also a Personal Digital Assistant (PDA) that controls the user’s hearing aid or parameters fits in this category.
LAN

- Local Area Network (LAN): Span from a few meters to as much as 1 km.
- They are widely used to connect personal computers and workstations in company offices and factories to share resources (e.g., printers) and exchange information.
- Typical LAN speeds range from 10 mbps to 10 Gbps.
- LANs are distinguished from other kinds of networks by three characteristics:
  - Their size
  - Their transmission technology
  - Their topology.

LAN

- The size of a LAN is known in advance.
- LANs use broadcast links as a transmission technology.
- Commonly used topologies for broadcast LANs are bus and ring networks.
- In a bus network, a linear cable is used to connect all machines.
- This network uses Ethernet protocol which is also called as IEEE 802.3.
- The second type of broadcast LAN is the ring based LAN which uses IBM token ring or IEEE 802.5 protocol. The ring is unidirectional.
- Here a token is circulating round the ring; any station which wants to transmit data must first capture the token and then send the data.
- Ring based LANs operate at the speeds of 4-16 Mbps.

Local Area Networks

Two broadcast networks
(a) Bus
(b) Ring

FDDI (Fiber Distributed Data Interface) is another example of a ring network that uses high speed optical fiber as the transmission medium.

LAN characteristics

- Based on the channel allocation strategy broadcast LANs are further divided into
  - Static allocation
  - Dynamic allocation (i.e., on demand)
- In static channel allocation, divide time into discrete intervals and use a round robin algorithm, allowing each station to broadcast only when its time slot comes up.
- Static allocation wastes channel capacity, when a machine has nothing to say during its allocated slot.
- Dynamic channel allocation methods for a common channel are either centralized or decentralized.
- In the centralized channel allocation method there is a single entity which determines who goes next. It might do this by accepting requests and making a decision according to some internal algorithm.
LAN characteristics

• In the decentralized channel allocation method there is no central entity, each machine must decide for itself whether to transmit or not.
• It must also know what to do in case of conflicts.

Metropolitan Area Network (MAN)

• Covers an entire city, it has multiple ownerships. DQDB (Distributed Queue Dual Bus) is one of the protocols used over a MAN.
• The best example of a MAN is cable television network available in many cities.

Metropolitan Area Networks

A metropolitan area network based on cable TV.

Wide Area Network (WAN)

• It spans a large geographical area often a country or continent.
• In most WANs, the subnet consists of 2 components: transmission lines and switching elements.
• The transmission lines move bits between machines. They can be made of copper wire, optical fiber, or even radio links.
• Switching channels are specialized computers (routers/gateways) that connect three or more transmission lines.
• When data arrive on an incoming line, the switching element must choose an outgoing line on which to forward them.
• This subnet is called as store and forward or packet-switched subnet.
Wide Area Networks

Relation between hosts on LANs and the subnet.

Wireless Networks

Categories of wireless networks:
- System interconnection (Bluetooth)
- Wireless LANs
- Wireless WANs

System interconnection

- System interconnection is all about interconnecting the components of a computer such as keyboard, mouse, monitor, CPU, printer, etc. using short-range wireless radio network called as Bluetooth.

- Blue tooth operates in 2.4GHZ frequency range which is the ISM band (Industrial, Scientific, Medical) for unlicensed usage.

- System interconnection networks use the master-slave paradigm. In which the computer is normally the master, talking to the mouse, keyboard, etc., as slaves.
**Wireless LANs**

- These are the systems in which every computer has a radio modem and antenna with which it can communicate with other systems.
- **There is a standard for wireless LANs called IEEE 802.11**
- Wireless LANs operate at rates up to about 50 Mbps over distances of tens of meters.

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**Wireless WANs**

- The radio network used for cellular telephones is an example of a low-bandwidth wireless WANs or wireless wide area systems.
- Cellular systems operate below 1 Mbps, but distance between base station and the computer or telephone is measured in kilometers rather than in meters.
- **There is a standard for wireless WANs called IEEE 802.16**
- **In addition to low-speed wireless WANs, high-bandwidth wireless WANs are also being developed**
**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, clock, furnace, airco, lights)
- Telemetry (utility meter, smoke/burglar alarm, babycam, thermostat).

**Internetworks**

- When two or more networks are connected, they make an Internetwork or Internet
- Internetwork is formed when distinct networks are interconnected
- An internet may consist of several LANs, or MANs connected together by a WAN.
- A common form Internet is a collection of LANs connected by a WAN or connecting two LANs.

**Network Software**

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

**Protocol Hierarchies**

- Most networks are organized as a stack of layers or levels, each one built upon the one below it.
- The number of layers, the name of each layer, the contents of each layer, and the function of each layer differ from network to network.
- The purpose of each layer is to offer certain services to the higher layers, shielding those layers from the implementation details of the offered services.
Protocol Hierarchies

- **Protocol** is an agreement between the communicating parties on how communication is to proceed.
- The entities comprising the corresponding layers on different machines are called **peers**.
- 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**.
- The interface defines which primitive operations and services the lower layer makes available to the upper one.

Protocol Hierarchies (2)

A set of layers and protocols is called a network architecture.
A list of protocols used by certain system, one protocol per layer, is called protocol stack.

The philosopher-translator-secretary architecture.
**Design Issues for the Layers**

- **Addressing**: Every layer needs a mechanism for identifying senders and receivers. Therefore some form of addressing is needed in order to specify a specific destination.

- **Rules for data transfer**: In some systems, data only travel in one direction; in others, data can go both ways. Many networks provide at least two logical channels per connection, one for normal data and one for urgent data.

- **Error Control**: Many error-detecting and error-correcting codes are known, but both ends of the connection must agree on which one is being used.

**Multiplexing and Demultiplexing**

- Sequencing: Must preserve order of message sent on communication channels. The receiver must have some way of telling the sender which messages have been correctly received and which have not.

- Flow Control: How to keep a fast sender from swamping a slow receiver with data.

- Another problem that must be solved at several levels is the inability of all processes to accept arbitrarily long messages. This property leads to mechanisms for disassembling, transmitting, and then reassembling messages.

- Multiplexing: It is the set of techniques that allows the combined transmission of multiple data across a single data link.

- Demultiplexing: Performs reverse process of multiplexing.

- Routing: When there are multiple paths between source and destination, a route must be chosen.
Connection-Oriented & Connectionless Services

- **Connection-oriented (CO-mode) communication**: In this mode, user first establishes connection, uses the connection and then releases the connection.
- The data stream is delivered in the same order as it was sent.
- **Ex: Just like Telephone call**
- **Connectionless communication** is just packet switching where no call establishment and release occur. A message is broken into packets, and each packet is transferred separately. Moreover, the packets can travel different route to the destination since there is no connection.
- The message may be delivered out of order.
- Connectionless service is typically provided by the UDP (User Datagram Protocol) and hence it is also called datagram service.
- **Ex: The postal system**
- Each service can be characterized by a quality of service.

Connection-Oriented and Connectionless Services

<table>
<thead>
<tr>
<th>Service</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reliable message stream</td>
<td>Sequence of pages</td>
</tr>
<tr>
<td>Reliable byte streams</td>
<td>Remote login</td>
</tr>
<tr>
<td>Unreliable connection</td>
<td>Unicast video</td>
</tr>
<tr>
<td>Unreliable datagram</td>
<td>Electronic junk mail</td>
</tr>
<tr>
<td>Acknowledged datagram</td>
<td>Registered mail</td>
</tr>
<tr>
<td>Request reply</td>
<td>Database query</td>
</tr>
</tbody>
</table>

Six different types of service.

**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
The OSI Reference Model

- The Physical Layer is concerned with transmitting a bit stream over a communication channel (physical medium).
  - Representation of bits
  - Transmission rate
  - Synchronization of bits
  - Topology
  - Line configuration: point-to-point, multipoint
  - Transmission mode: simplex, half-duplex, or full-duplex
    - Simplex: only one device can send; the other can only receive
    - Half-duplex: two devices can send & receive, but not at the same time
    - Full-duplex: two devices can send & receive at the same time

- The data link layer transforms the physical layer into a reliable link. It makes the physical layer appear error free to the upper layer
  - Framing: Divide the data stream into manageable data units called frames or packets
  - Flow control
  - Error control
  - Addressing
  - Broadcast networks have additional issue in the data link layer: how to control access to shared channel. A special sublayer of the data link layer, the medium access control sublayer, deals with this problem

- The network layer is responsible for the source-to-destination (end-to-end) delivery of the entire message. Whereas the network layer oversees end-to-end delivery of individual packets
  - Disassembling and reassembling
  - Sequencing
  - Flow control
  - Error control
The OSI Reference Model

- The session layer: The services provided by the first three layers (physical, data link and network) are not sufficient for some purpose.
- The session layer is to establish, manage, and terminate the session between communicating parties.
- The session layer is the network dialog controller (keeping track of whose turn it is to transmit).
  - Token management (preventing 2 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)
- The presentation layer is concerned with syntax and semantics of the information exchanged between two systems.
  - Translation
  - Encryption
  - Compression

The application layer enables the user or software to access the network resources.
- It provides user interfaces and support for services such as E-mail, remote file access and transfer, shared database management, and other types of distributed information services.

Reference Models (2)

<table>
<thead>
<tr>
<th>OSI</th>
<th>TCP/IP</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>Application</td>
</tr>
<tr>
<td>6</td>
<td>Presentation</td>
</tr>
<tr>
<td>5</td>
<td>Session</td>
</tr>
<tr>
<td>4</td>
<td>Transport</td>
</tr>
<tr>
<td>3</td>
<td>Network</td>
</tr>
<tr>
<td>2</td>
<td>Data link</td>
</tr>
<tr>
<td>1</td>
<td>Physical</td>
</tr>
</tbody>
</table>

The TCP/IP reference model.

TCP/IP Reference Model

- The TCP/IP model does not have session or presentation layers.
- The Internet Layer:
  - Its job is to permit hosts to inject packets into any network and have them travel independently to the destination (potentially on a different network).
  - They may even arrive in a different order than they were sent, in which case it is the job of higher layers to rearrange them, if in-order delivery is desired.
  - The internet layer defines an official packet format and protocol called IP (Internet Protocol).
  - Routing
  - Congestion control
TCP/IP Reference Model

- The Transport Layer:
  - Allows peer entities on the source and destination hosts to carry on a conversation, just as in the OSI transport layer.
  - Two end-to-end transport protocols are defined:
    - Transmission Control Protocol (TCP): Provides full transport layer services to applications. TCP is a reliable connection-oriented protocol
      - Flow control
      - Disassembling and reassembling
      - Error control
      - Sequencing
    - User datagram protocol (UDP): Is an unreliable, connection less protocol
      - Sequencing
      - Flow control

TCP/IP Reference Model

- The application layer in TCP/IP is equivalent to the combined session, presentation and application layers in the OSI model
- The Host-to-Network Layer:
  - The TCP/IP reference model does not really say much about what happens here
  - Except to point out that the host has to connect to the network using some protocol so it can send IP packets to it.
  - This protocol is not defined and varies from host to host and network to network.

Reference Models (3)

<table>
<thead>
<tr>
<th>Layer</th>
<th>OSI Names</th>
<th>Protocols</th>
</tr>
</thead>
<tbody>
<tr>
<td>Application</td>
<td>TCP</td>
<td>RTP/RTSP</td>
</tr>
<tr>
<td>Transport</td>
<td>IP</td>
<td>UDP</td>
</tr>
<tr>
<td>Network</td>
<td>Physical layer</td>
<td>IP, TCP, UDP</td>
</tr>
</tbody>
</table>

Comparing OSI and TCP/IP Models

- The OSI & TCP/IP reference models have much in common
- The functionality of the layer is roughly similar
- OSI has 7 layers and TCP/IP has 4 layers

Concepts central to the OSI model

- Services
- Interfaces
- Protocols

TCP/IP model did not distinguish between service, interface, & protocol

The protocols in OSI model are better hidden than in the TCP/IP

The OSI model was devised before the corresponding protocols were invented

In TCP/IP model reverse was true: protocols came first, and the model was description of the protocols.
Comparing OSI and TCP/IP Models

• The OSI supports both connectionless and connection-oriented communication in the network layer, but only connection-oriented communication in the transport layer.
• The TCP/IP supports only one mode (connectionless) in the network layer, but supports both modes in the transport layer.

A Critique of the OSI Model and Protocols

Why OSI did not take over the world

• Bad timing: The time at which a standard is established is absolutely critical to its success.
• Bad technology: The choice of seven layers was more political than technical, and two of the layers (session and presentation) are nearly empty, whereas two other ones (data link and network) are overfull.
• Bad implementations
• Bad politics

Bad Timing

The apocalypse of the two elephants.

A Critique of the TCP/IP Reference Model

Problems:

• Service, interface, and protocol not distinguished
• Not a general model
• Host-to-network “layer” not really a layer
• No mention of physical and data link layers
• Minor protocols deeply entrenched, hard to replace
Hybrid Model

<table>
<thead>
<tr>
<th>Layer</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 Application layer</td>
</tr>
<tr>
<td>4 Transport layer</td>
</tr>
<tr>
<td>3 Network layer</td>
</tr>
<tr>
<td>2 Data link layer</td>
</tr>
<tr>
<td>1 Physical layer</td>
</tr>
</tbody>
</table>

The hybrid reference model to be used in this book.

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