Module 2

Circuit and Packet Switching

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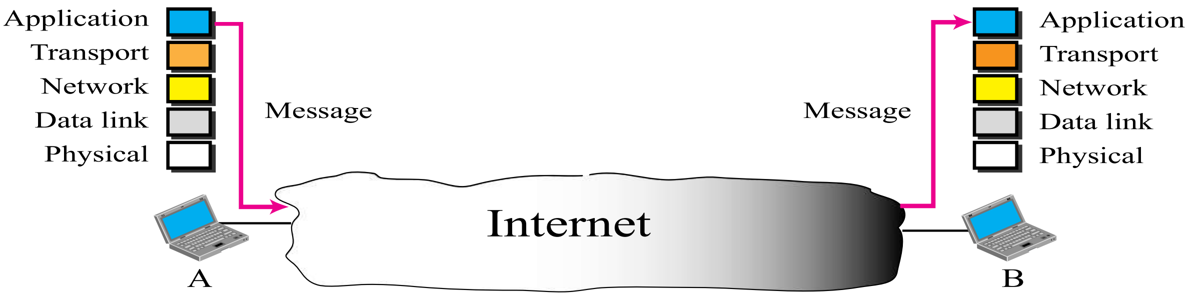
Internet as a black box



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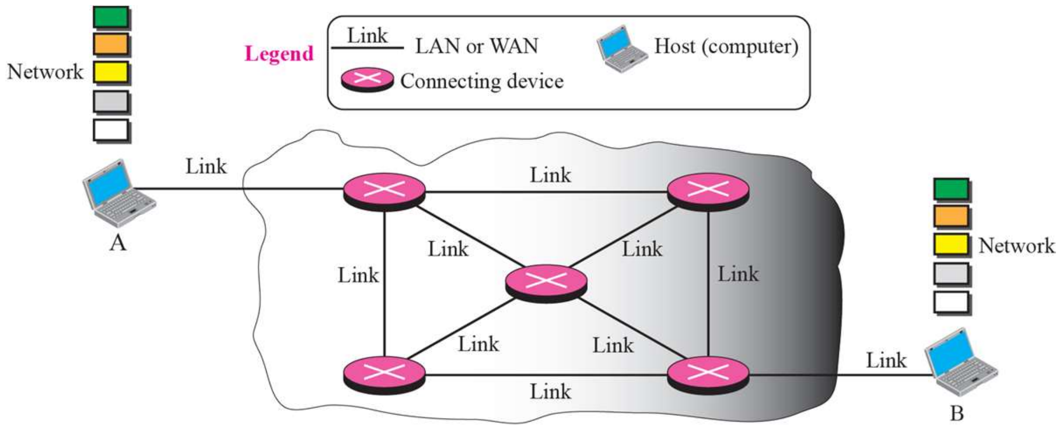
Internet as a combination of LANs and WANs connected together



An internet as a combination of links and connecting devices

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Switched Communications Networks

- the passage of a message from a source to a destination involves many decisions
- When a message reaches a connecting device, a decision needs to be made to select one of the output ports through which the packet needs to be send out.

- Types of switching to be discuss
  - Circuit switching
  - Packet Switching

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Example for Circuit and Packet Switching

- A good example of a circuit-switched network is the early telephone systems in which the path was established between a caller and a callee when the telephone number of the callee was dialed by the caller. When the callee responded to the call, the circuit was established. The voice message could now flow between the two parties, in both directions, while all of the connecting devices maintained the circuit. When the caller or callee hung up, the circuit was disconnected. The telephone network is not totally a circuit-switched network today.

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Example for Circuit and Packet Switching

- The network layer is designed as a packet-switched network.
- Individual datagrams are then transferred from the source to the destination.
- The received datagrams are assembled at the destination before recreating the original message.
- The packet-switched network layer of the Internet was originally designed as a connectionless service, but recently there is a tendency to change this to a connection-oriented service.

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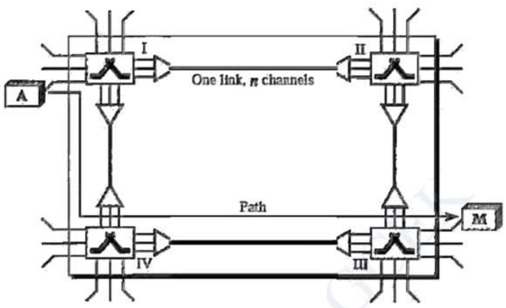
Circuit Switching

- A circuit-switched network consists of a set of switches connected by physical links. A connection between two stations is a dedicated path made of one or more links.
- However, each connection uses only one dedicated channel on each link. Each link is normally divided into n channels by using FDM or TDM.

Circuit Switching



Circuit Switching

- Circuit switching takes place at the physical layer
- Before starting communication, the stations must make a reservation for the resources to be used during the communication.
- Data transferred between the two stations are not packetized (physical layer transfer of the signal). The data are a continuous flow sent by the source station and received by the destination station, although there may be periods of silence.
- There is no addressing involved during data transfer. The switches route the data based on their occupied band (FDM) or time slot (TDM). Of course, there is end-to-end addressing used during the setup phase.

Circuit Switching- Phases

- The actual communication in a circuit-switched network requires three phases: connection setup, data transfer, and connection teardown.
- **Setup Phase**
- **Data transfer Phase**
- **Tear down Phase**

Circuit Switching- Technology in Telephone Networks

- The telephone companies have previously chosen the circuit switched approach to switching in the physical layer; today the tendency is moving toward other switching techniques.

- For example, the telephone number is used as the global address, and a signaling system (called SS7) is used for the setup and teardown phases.

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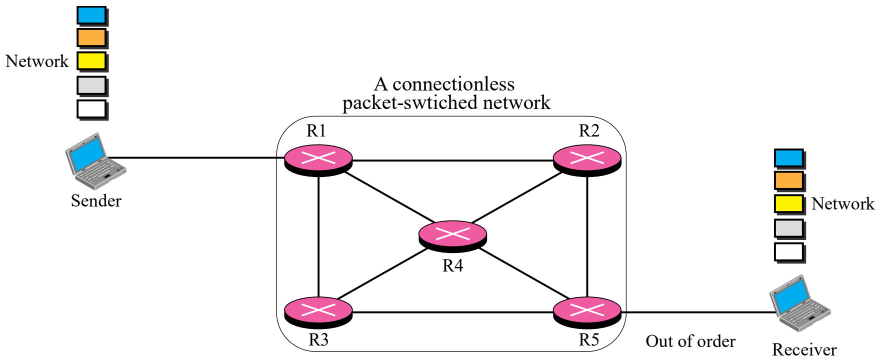
Packet Switching



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Packet Switching

- digital networking communications method that groups all transmitted data – regardless of content, type, or structure – into suitably sized blocks, called packets.
- Packet switching features delivery of variable-bit-rate data streams (sequences of packets) over a shared network.
- When traversing network adapters, switches, routers and other network nodes, packets are buffered and queued, resulting in variable delay and throughput depending on the traffic load in the network.

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Packet Switching

- Packet switching contrasts with another principal networking paradigm, circuit switching, a method which sets up a limited number of dedicated connections of constant bit rate and constant delay between nodes for exclusive use during the communication session.
- In case of traffic fees (as opposed to flat rate), for example in cellular communication services, circuit switching is characterized by a fee per time unit of connection time, even when no data is transferred, while packet switching is characterized by a fee per unit of information.

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Two major packet switching modes exist

1. Connectionless packet switching, also known as datagram switching
2. Connection-oriented packet switching, also known as virtual circuit switching.

- In the first case each packet includes complete addressing or routing information. The packets are routed individually, sometimes resulting in different paths and out-of-order delivery. The forwarding decision is based on the destination address of the packet
- In the second case a connection is defined and pre allocated in each involved node during a connection phase before any packet is transferred. The forwarding decision is based on the label of the packet.

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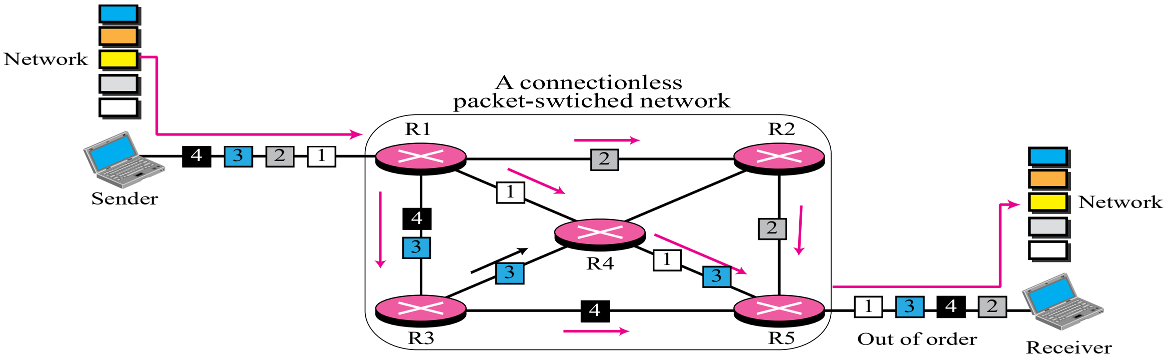
Connectionless Packet Switching Network-Datagram Switching



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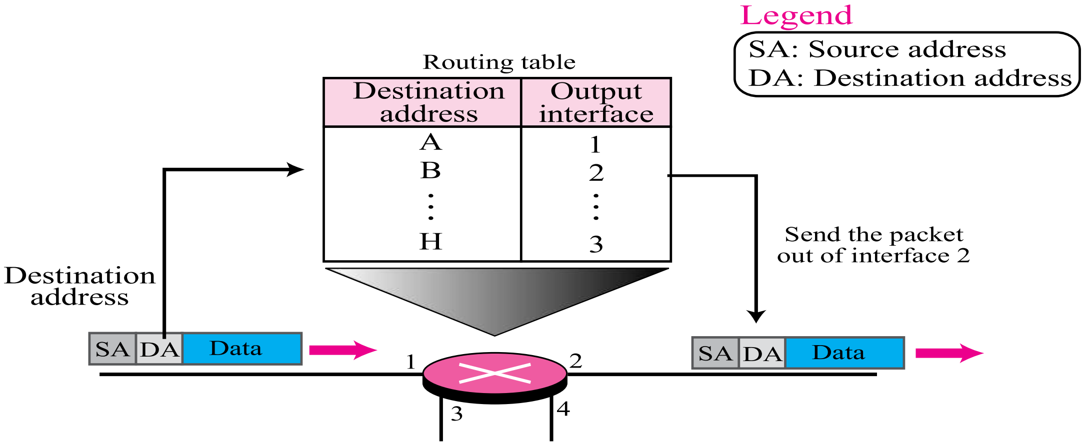
Forwarding Process in Connectionless Network



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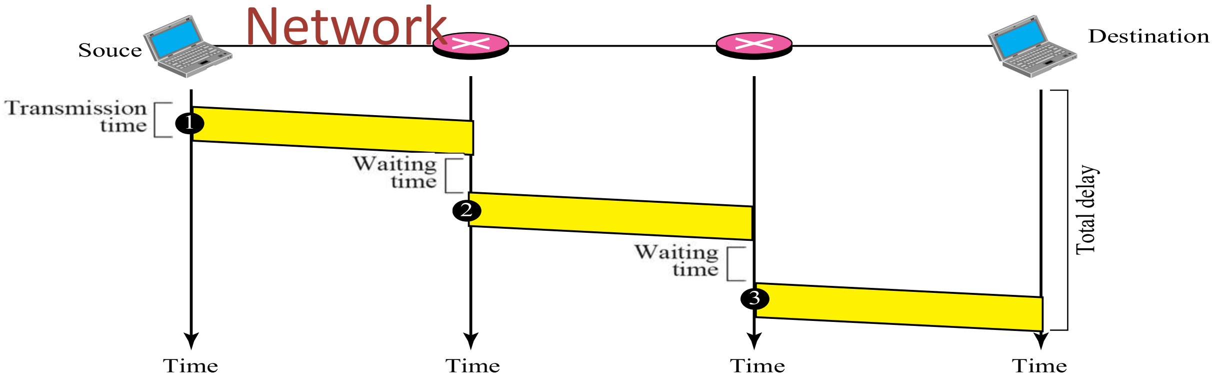
Delay in Connectionless Network



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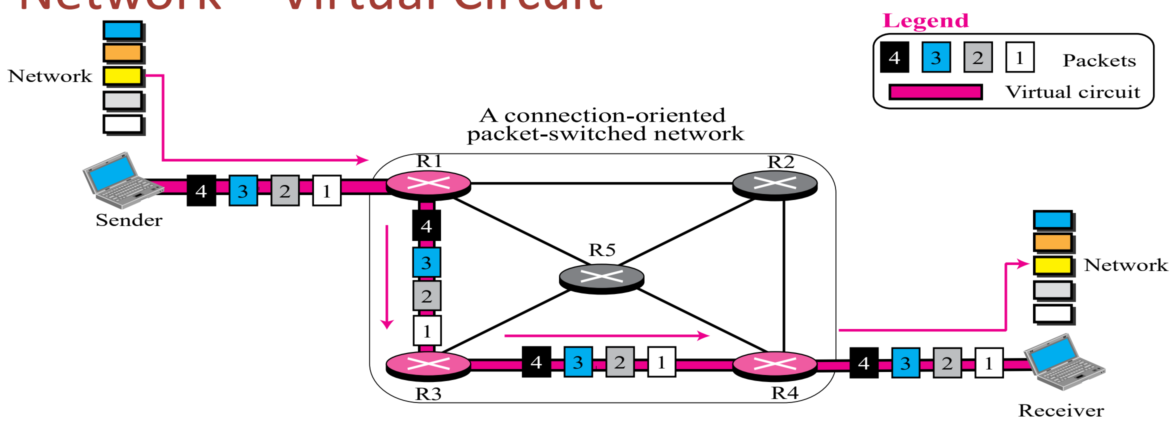
A Connection Oriented Packet Switched Network – Virtual Circuit



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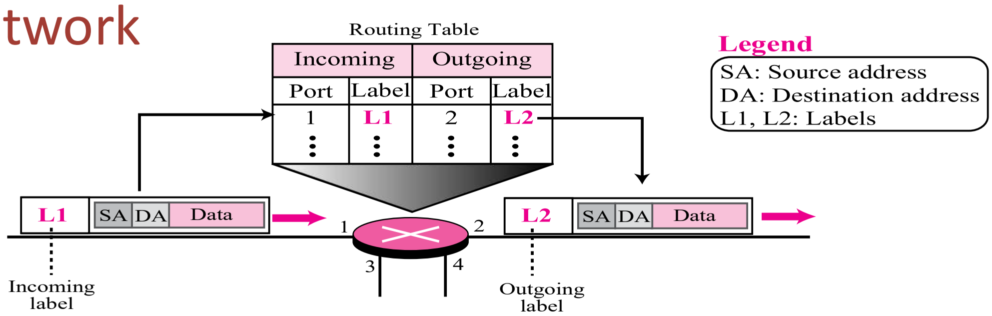
Forwarding Process in a Connection oriented Network



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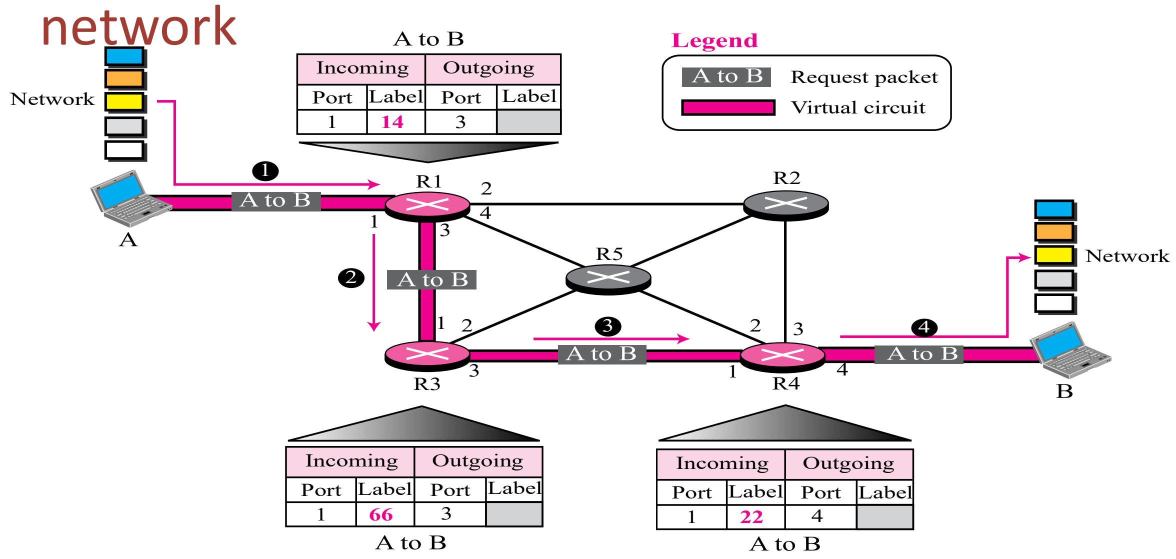
Sending request packet in a virtual-circuit network



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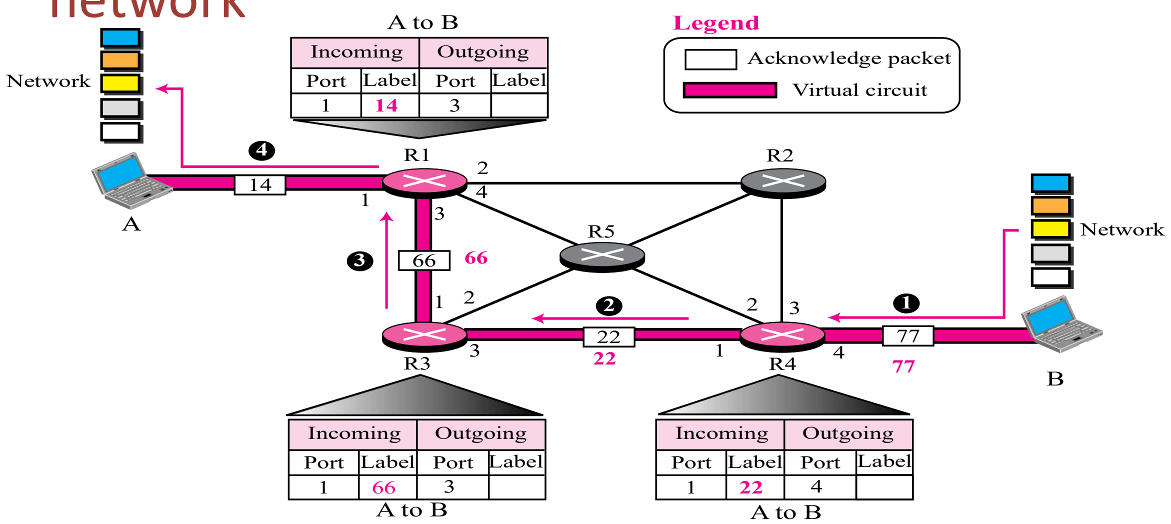
Setup acknowledgement in a virtual-circuit network



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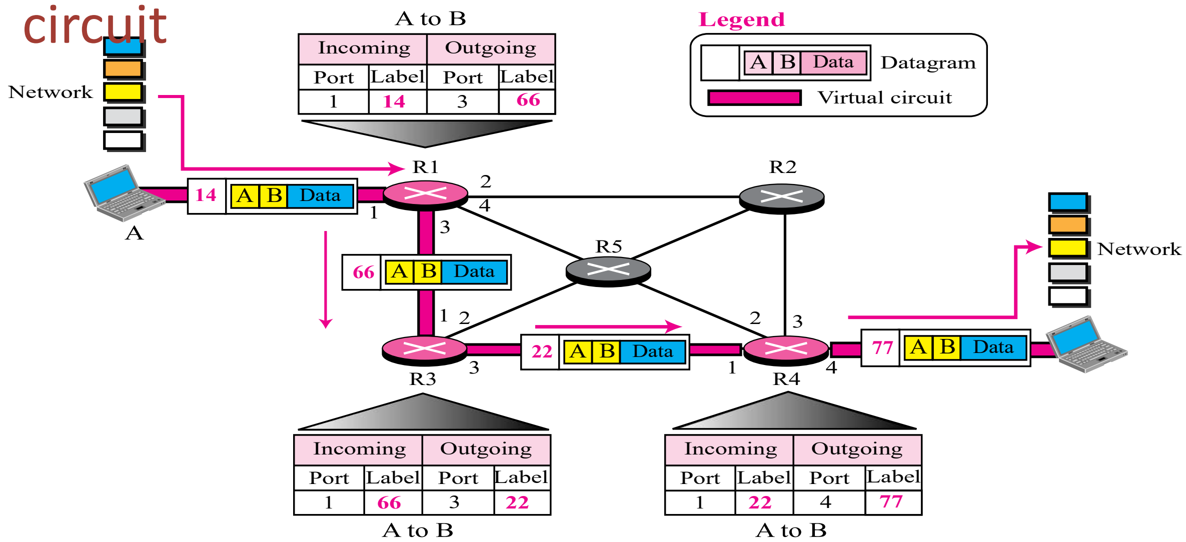
Flow of one packet in an established virtual circuit



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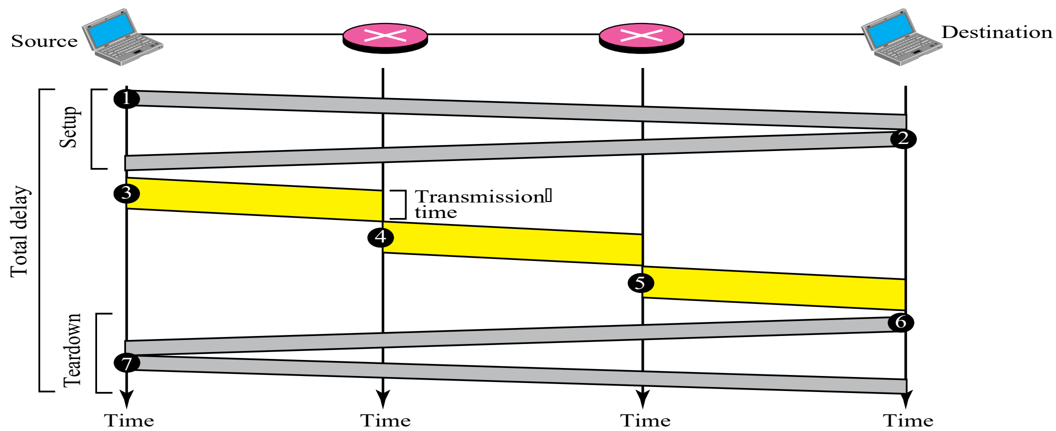
Delay in a connection-oriented network



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Comparison of Circuit Switching and Packet Switching

Parameter	Circuit Switching	Packet Switching
Routing scheme	Route selected during call setup	Each packet routed independently
Multiplexing scheme	Circuit multiplexing	Packet multiplexing shared media access networks
Addressing scheme	Hierarchical numbering plan	Hierarchical address space
Information representation	Analog voice or PCM coded voice	Binary information
End terminal	Telephone, modem	Computer
Transmission system	Analog and digital data over different transmission media	Digital data over different transmission media
Traffic	Real time interactive	Heavy traffic
Application	Telephone network for bi-directional, real time transfer of voice signals	Internet for datagram and reliable stream service between computers

Implementing Network Software

- Network architectures and protocol specifications are essential things, but a good blueprint is not enough to explain the phenomenal success of the Internet:
- some of the issues involved in implementing a network application on top of the Internet , such programs are simultaneously an application (i.e., designed to interact with users) and a protocol (i.e., communicates with peers across the network).

Implementing Network Software- Application Programming Interface (Sockets)

- The place to start when implementing a network application is the interface exported by the network.
- Since most network protocols are implemented in software (especially those high in the protocol stack), and nearly all computer systems implement their network protocols as part of the operating system, when we refer to the interface "exported by the network," we are generally referring to the interface that the OS provides to its networking subsystem. This interface is often called the network application programming interface (API).

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Implementing Network Software- Application Programming Interface (Sockets)

- The main abstraction of the socket interface, not surprisingly, is the socket. A good way to think of a socket is as the point where a local application process attaches to the network.
- The interface defines operations for creating a socket, attaching the socket to the network, sending/ receiving messages through the socket, and closing the socket.

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Implementing Network Software- Application Programming Interface (Sockets)

- Socket creation Steps
- Step 1: create a socket, which is done with the following operation:

  int socket(int domain, int type, int protocol)
- Step 2 : depends on whether you are a client or a server. On a server machine, the application process performs a passive open the server says that it is prepared to accept connections, but it does not actually establish a connection

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Implementing Network Software- Application Programming Interface (Sockets)

The server does this by invoking the following three operations:

- int bind(int socket, struct sockaddr *address, int addr len)
- int listen(int socket, int backlog)
- int accept(int socket, struct sockaddr *address, int *addr len)

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Implementing Network Software- Application Programming Interface (Sockets)

On the client machine, the application process performs an active open; that is, it says who it wants to communicate with by invoking the following single operation:

int connect(int socket, struct sockaddr *address, int addr len)

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Implementing Network Software- Application Programming Interface (Sockets)

Once a connection is established, the application processes invoke the following two operations to send and receive data:

int send(int socket, char *message, int msg len, int flags)

int recv(int socket, char *buffer, int buf len, int flags)

The first operation sends the given message over the specified socket, while the second operation receives a message from the specified socket into the given buffer. Both operations take a set of flags that control certain details of the operation

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Networking Parameters(Transmission Impairment, Data Rate and Performance)

Transmission Impairment

Signals travel through transmission media, which are not perfect. The imperfection causes signal impairment. This means that the signal at the beginning of the medium is not the same as the signal at the end of the medium. What is sent is not what is received. Three causes of impairment are attenuation, distortion, and noise

Transmission Impairment - Attenuation

Attenuation means a loss of energy. When a signal, simple or composite, travels through a medium, it loses some of its energy in overcoming the resistance of the medium. That is why a wire carrying electric signals gets warm, if not hot, after a while. Some of the electrical energy in the signal is converted to heat. To compensate for this loss, amplifiers are used to amplify the signal.

Decibel

To show that a signal has lost or gained strength, engineers use the unit of the decibel. The decibel (dB) measures the relative strengths of two signals or one signal at two different points. Note that the decibel is negative if a signal is attenuated and positive if a signal is amplified.

Transmission Impairment - Attenuation

$$dB = 10\log_{10}\frac{P2}{P1}$$

Variables PI and P2 are the powers of a signal at points 1 and 2, respectively.

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Transmission Impairment - Attenuation

Example: Suppose a signal travels through a transmission medium and its power is reduced to one-half. Find the attenuation (loss of power).

Solution: dB=10 log (P/2P)= -3 dB

Example: A signal travels through an amplifier, and its power is increased 10 times Find the amplification (gain of power).

Solution: dB=10 log (10P/P)= 10 dB

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Transmission Impairment - Distortion

- Distortion means that the signal changes its form or shape.
- Distortion can occur in a composite signal made of different frequencies. Each signal component has its own propagation speed (see the next section) through a medium and, therefore, its own delay in arriving at the final destination. Differences in delay may create a difference in phase if the delay is not exactly the same as the period duration.
- In other words, signal components at the receiver have phases different from what they had at the sender. The shape of the composite signal is therefore not the same

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Transmission Impairment - Noise

- Noise is another cause of impairment. Several types of noise, such as thermal noise, induced noise, crosstalk, and impulse noise, may corrupt the signal. Thermal noise is the random motion of electrons in a wire which creates an extra signal not originally sent by the transmitter. Induced noise comes from sources such as motors and appliances.
- To find the theoretical bit rate limit, we need to know the ratio of the signal power to the noise power. The signal-to-noise ratio is defined as:

SNR = average signal power/ average noise power

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Data Rate

A very important consideration in data communications is how fast we can send data, in bits per second over a channel. Data rate depends on three factors:

1. The bandwidth available
2. The level of the signals we use
3. The quality of the channel (the level of noise) Two theoretical formulas were developed to calculate the data rate: one by Nyquist for a noiseless channel, another by Shannon for a noisy channel.

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Data Rate - Noiseless Channel: Nyquist Bit Rate

For a noiseless channel, the Nyquist bit rate formula defines the theoretical maximum bit rate

$$\text{BitRate} = 2 \text{ x bandwidth x } \log_2 L$$

In this formula, bandwidth is the bandwidth of the channel, L is the number of signal levels used to represent data, and Bit Rate is the bit rate in bits per second.

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Data Rate - Noiseless Channel: Nyquist Bit Rate

Example:

Consider a noiseless channel with a bandwidth of 3000 Hz transmitting a signal with two signal levels. The maximum bit rate can be calculated as

BitRate =2 x 3000 x log2 2 =6000 bps

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Data Rate - Noisy Channel: Shannon Capacity

In reality, we cannot have a noiseless channel; the channel is always noisy. In 1944, Claude Shannon introduced a formula, called the Shannon capacity, to determine the theoretical highest data rate for a noisy channel:

$$\text{Capacity} = \text{bandwidth} \times \log_2 (1 + \text{SNR})$$

In this formula, bandwidth is the bandwidth of the channel, SNR is the signal-to-noise ratio, and capacity is the capacity of the channel in bits per second. Note that in the Shannon formula there is no indication of the signal level, which means that no matter how many levels we have, we cannot achieve a data rate higher than the capacity of the channel. In other words, the formula defines a characteristic of the channel, not the method of transmission.

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Data Rate - Noisy Channel: Shannon Capacity

Example:

Consider an extremely noisy channel in which the value of the signal-to-noise ratio is almost zero. In other words, the noise is so strong that the signal is faint. For this channel the capacity C is calculated as

C=B $\log_2$ (1 + SNR) =B $\log_2$ (1 + 0) = B $\log_2$ (1) = B x 0 =0

This means that the capacity of this channel is zero regardless of the bandwidth. In other words, we cannot receive any data through this channel.

Thank You