UNIT-I

Network architecture:

Network architecture is the design of a communication networks. It is a framework for the specification of a network's physical components and their functional organization and configuration, its operational principles and procedures, as well as data formats used in its operation.

In computing, the network architecture is a characteristics of a computer networks. The most prominent architecture today is evident in the framework of the Internet, which is based on the Internet protocol suite.

In telecommunication, the specification of a network architecture may also include a detailed description of products and services delivered via a communications network, as well as detailed rate and billing structures under which services are compensated.

In distinct usage in distributed computing, network architecture is also sometimes used as a synonym for the structure and classification of distributed application architecture, as the participating nodes in a distributed application are often referred to as a *network*. For example, the applications architecture of the public switched telephone networks (PSTN) has been termed the Advanced Intelligent Networks. There are any number of specific classifications but all lie on a continuum between the Dumb Network (e.gInternet) and the intelligent computer networks (e.g., the telephone network). Other networks contain various elements of these two classical types to make them suitable for various types of applications. Recently the context networks, which is a synthesis of the two, has gained much interest with its ability to combine the best elements of both.

Computer networks are designed in a highly structured way to reduce their design complexity.Most networks are organised as a series of *layers* or levels. The number of layers, the name of each layer, and the function of each layer differs from network to network. However, in all networks, each layer clearly defines various data communication functions and logical operations. Each level is functionally independent of the others, but builds on its predecessor. In order to function, higher levels depend on correct operation of the lower levels. Figure 1.2 illustrates a 7-layer network architecture. Layer (level) *n* on one computer carries
on communication with layer *n* on another computer. The set of rules and conventions that encompasses electrical, mechanical and functional characteristics of a data link, as well as the control procedures for such communication is called the *layer n protocol.* The communication between two layers at the same level (layer *n*, *n* ¡¡= 1) of two different computers is called *virtual communication*. Here, each layer passes data and control information to the layer immediately below it, until the lowest layer (layer 1). At layer 1, information from one computer is physically transferred to layer 1 of the other *(physical communication)*.
The *interface* between each pair of adjacent layers defines which operations and services the lower layer offers to the upper one. The *network architecture* thus can be defined as the set of layers and protocols.
1.2. The ISO and other models
Figure 1.2 shows the reference model of the Open Systems Interconnection (OSI), which has been developed by the International Standards Organisation

(ISO). We will briefly define thefunctions and operation of each layer of this architecture in turn.

1.2.1. Layer 1: the physical layer

This layer is concerned with transmitting an electrical signal representation of data over a communication link. Typical conventions would be: voltage levels used to represent a “1” and a “0”, duration of each bit, transmission rate, mode of transmission, and functions of pins in a connector.An example of a physical layer protocol is the RS-232 standard.

1.2.2. Layer 2: the data link layer

This layer is concerned with error-free transmission of data units.The data unit is an abbreviation of the official name of *data-link-service-data-units;* it is sometimes called the *data f rame*. The function of the data link layer is to break the input data stream into data frames, transmit the frames sequentially, and process the *acknowledgement frame* sent back by the receiver. Data frames from this level when transferred to layer 3 are assumed to be error free.

1.2.3. Layer 3: the network layer

This layer is the *network control* layer, and is sometimes called the *communication subnet layer*.It is concerned with intra-network operation such as addressing and routing within the subnet. Basically, messages from the source host are converted to *packets*. The packets are then routed to their proper destinations.

1.2.4. Layer 4: the transport layer

This layer is a *transport end-to-end control layer* (i.e. source-to-destination). A program on the source computer communicates with a similar program on the destination computer using the message headers and control messages, whereas all the lower layers are only concerned with communication between a computer and its immediate neighbours, not the ultimate source and destination computers.

The transport layer is often implemented as part of the operating system. The data link and physical layers are normally implemented in hardware.

1.2.5. Layer 5: the session layer

The session layer is the user's interface into the network. This layer supports the dialogue through session control, if services can be allocated. A connection between users is usually called a *session*. A session might be used to allow a user to log into a system or to transfer files between two computers. A session can only be established if the user provides the remote addresses to be connected. The difference between session addresses and transport addresses is that session addresses are intended for users and their programs, whereas transport addresses are intended for transport stations.

1.2.6. Layer 6: the presentation layer

This layer is concerned with transformation of transferred information. The controls include message compression, encryption, peripheral device coding and formatting.

1.2.7. Layer 7: the application layer

This layer is concerned with the application and system activities.The content of the application layer is up to the individual user.

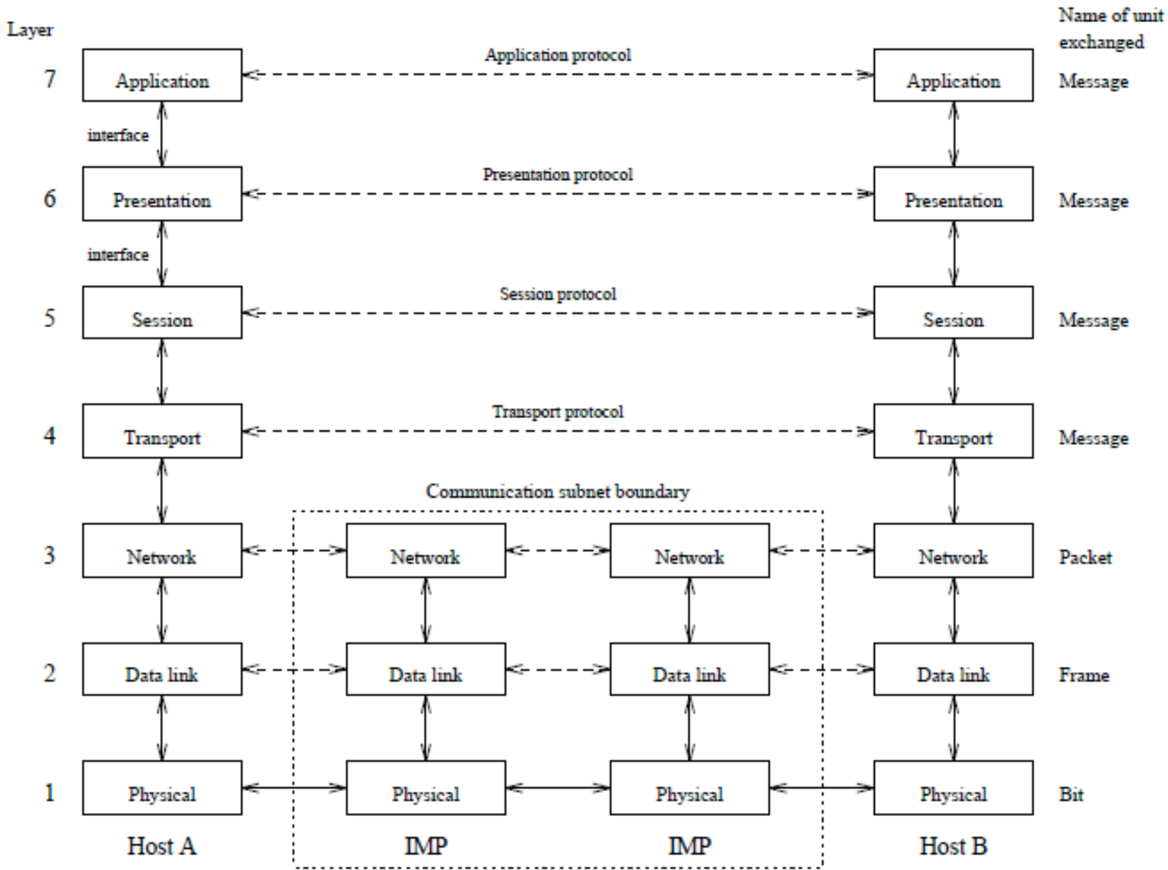

Figure 1.2. The OSI model

PHYSICAL LINKS:

In telecommunications a **link** is the *communications channel* that connects two or more communicating devices. This link may be an actual physical link or it may be a logical link that uses one or more actual physical links. When the link is a logical link the type of physical link should always be specified (e.g., data link,uplink,downlink,fiber optic link,pt to pt link etc. etc.) This term is widely used in computre networking to refer to the communications facilities that connect nodes of a network.

<u>Types of links</u>

- **Point-to-point**

A **point-to-point link** is a dedicated link that connects exactly two communication facilities (e.g., two nodes of a network, an intercom station at an entryway with a single internal intercom station, a radio path between two points, etc.).

- **Broadcast**

Broadcast links connect two or more nodes and support *broadcast transmission*, where one node can transmit so that all other nodes can receive the same transmission. Ethernet is an example.

- **Multipoint**

  Also known as a "multidrop" link, a **multipoint link** is a link that connects *two or more* nodes. Also known as **general topology** networks, these include ATM and Frame Relay links, as well as X.25 networks when used as links for a network layer protocol like Internet protocol.

Unlike broadcast links, there is no mechanism to efficiently send a single message to all other nodes without copying and retransmitting the message.

- **Point-to-multipoint**

A point to multipoint link is a specific type of *multipoint link* which consists of a central *connection endpoint* (CE) that is connected to multiple peripheral CEs. Any transmission of data that originates from the central CE is received by all of the peripheral CEs while any transmission of data that originates from any of the peripheral CEs is only received by the central CE.This term is also often used as a synonym for **multipoint**, as defined above.

Private and Public - Accessibility and Ownership:

Links are often referred to by terms which refer to the ownership and / or accessibility of the link.

- A **private link** is a link that is either owned by a specific entity or a link that is only accessible by a specific entity.
- A **public link** is a link that uses the Public switched telephone network or other public utility or entity to provide the link and which may also be accessible by anyone.

Channel access on links:

In telecommunications and computer networks, a **channel access method** or **multiple access method** allows several terminals connected to the same multi-point transmission medium to transmit over it and to share its capacity. Examples of shared physical media are wireless networks, bus networks, ring networks, hub networks and half-duplex point-to-point links.

A channel-access scheme is based on a mutiplexing method, that allows several data streams or signals to share the same communication channel or physical medium. Multiplexing is in this context provided by the physical layer.Note that multiplexing also may be used in full-duplex point-to-point communication between nodes in a switched network, which should not be considered as multiple access.

A channel-access scheme is also based on a multiple access protocol and control mechanism, also known as media access control (MAC). This protocol deals with issues such as addressing, assigning multiplex channels to different users, and avoiding collisions. The MAC-layer is a sub-layer in Layer 2 (Data Link Layer) of the OSI model and a component of the Link Layer of the TCP/IP model

Fundamental forms of channel access schemes

These are the fundamental forms of channel access schemes:

- The frequency division multiple access (FDMA) channel-access scheme is based on the frequency-division multiplex (FDM) scheme, which provides different frequency bands to different data-streams - in the FDMA case to different users or nodes. An example of FDMA systems were the first-generation (1G) cell-phone systems. A related technique is wave-length division multiple access (WDMA), based on wavelength division multiplex (WDM), where different users get different colors in fiber-optical communication.
- The time division multiple access (TDMA) channel access scheme is based on the time division multiplex (TDM) scheme, which provides different time-slots to different data-streams (in the TDMA case to different transmitters) in a cyclically repetitive frame structure. For example, user 1 may use time slot 1, user 2 time slot 2, etc. until the last user. Then it starts all over again.
- The code division multiple access (CDMA) scheme is based on spread spectrum. An example is the 3G cell phone system.
- Space division multiple access (SDMA).

- Packet mode multiple-access is typically also based on time-domain multiplexing, but not in a cyclically repetitive frame structure, and therefore it is not considered as TDM or TDMA. Due to its random character it can be categorised as statistical multiplexing methods, making it possible to provide dynamic bandwidth allocation.

List of channel access methods

Circuit mode and channelization methods

The following are common circuit mode and channelization channel access methods:

- ***Frequency division multiple access (FDMA)***, based on frequency-division multiplex (FDM)
    - Wavelength division multiple access (WDMA)
    - Orthogonal frequency division multiple access (OFDMA), based on Orthogonal frequency-division multiplexing (OFDM)
    - Single-carrier FDMA (SC-FDMA), a.k.a. linearly-precoded OFDMA (LP-OFDMA), based on single-carrier frequency-domain-equalization (SC-FDE).
- **Time-division multiple access *(TDMA)***, based on time-division multiplex (TDM)
    - Multi-Frequency Time Division Multiple Access (MF-TDMA)
- ***Code division multiple access (CDMA)***, a.k.a. Spread spectrum multiple access (SSMA)
    - Direct-sequence CDMA (DS-CDMA), based on Direct-sequence spread spectrum (DSSS)

- Frequency-hopping CDMA (FH-CDMA), based on Frequency-hopping spread spectrum (FHSS)
- Orthogonal frequency-hopping multiple access (OFHMA)
- Multi-carrier code division multiple access (MC-CDMA)

- ***Space division multiple access (SDMA)***

Packet mode methods

The following are examples of packet mode channel access methods:

- ***Contention based random multiple access methods***
  - Aloha
  - Slotted Aloha
  - Multiple Access with Collision Avoidance (MACA)
  - Multiple Access with Collision Avoidance for Wireless (MACAW)
  - Carrier sense multiple access (CSMA)
  - Carrier sense multiple access with collision detection (CSMA/CD) - suitable for wired networks
  - Carrier sense multiple access with collision avoidance (CSMA/CA) - suitable for wireless networks
    - Distributed Coordination Function (DCF)
    - Point Coordination Function (PCF)
  - Carrier sense multiple access with collision avoidance and Resolution using Priorities (CSMA/CARP)
  - Carrier Sense Multiple Access/Bitwise Arbitration (CSMA/BA) Based on constructive interference (CAN-bus)
- ***Token passing***:
  - Token ring

    - Token bus
- ***Polling***
- ***Resource reservation (scheduled) packet-mode protocols***
    - Dynamic Time Division Multiple Access (Dynamic TDMA)
    - Packet reservation multiple access (PRMA)
    - Reservation ALOHA (R-ALOHA)

Duplexing methods

Where these methods are used for dividing forward and reverse communication channels, they are known as duplexing methods, such as:

- Time division duplex (TDD)
- Frequency division duplex (FDD)

Hybrid channel access scheme application examples

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These are the four fundamental types of channel access schemes:

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Packet mode

Packet mode multiple-access is typically also based on time-domain multiplexing, but not in a cyclically repetitive frame structure, and therefore it is not considered as TDM or TDMA. Due to its random character it can be categorised as statistical multiplexing methods, making it possible to provide dynamic bandwidth allocation.

Code division multiple access (CDMA)

The code division multiple access (CDMA) scheme is based on spread spectrum. An example is the 3G cell phone system. **Code division multiple access** (**CDMA**) is a channel access method utilized by various radio communication technologies. It should not be confused with the mobile phone standards called cdmaOne and CDMA2000 (which are often referred to as simply *CDMA*), which use CDMA as an underlying channel access method. One of the basic concepts in data communication is the idea of allowing several transmitters to send information simultaneously over a single communication channel. This allows several users to share a bandwidth of different frequencies. This concept is called multiplexing. CDMA employs spread-spectrum technology and a special coding scheme (where each transmitter is assigned a code) to allow multiple users to be multiplexed over the same physical channel. By contrast, time division multiple access (*TDMA*) divides access by time, while frequency-division multiple access (*FDMA*) divides it by frequency. CDMA is a form of spread-spectrum signaling, since the modulated coded signal has a much higher data bandwidth than the data being communicated.

Space division multiple access (SDMA)

Space division multiple access (SDMA). Space-Division Multiple Access (SDMA) enables creating *parallel spatial pipes* next to *higher capacity pipes through spatial multiplexing and/or diversity,* by which it is able to offer superior performance in radio multiple access communication systems. In traditional mobile cellular network systems, the base station has no information on the position of the mobile units within the cell and radiates the signal in all directions within the cell in order to provide radio coverage. This results in wasting power on transmissions when there are no mobile units to reach, in addition to causing interference for adjacent cells using the same frequency, so called co-channel cells. Likewise, in reception, the antenna receives signals coming from all directions including noise and interference signals. By using smart antenna technology and by leveraging the spatial location of mobile units within the cell, space-division multiple access techniques offer attractive performance enhancements. The radiation pattern of the base station, both in transmission and reception, is adapted to each user to obtain highest gain in the direction of that user. This is often done using phased array techniques.

Hybrids of these techniques can be - and frequently are - used. Some examples:

- The GSM cellular system combines the use of frequency division duplex (FDD) to prevent interference between outward and return signals, with FDMA and TDMA to allow multiple handsets to work in a single cell.
- GSM with the GPRS packet switched service combines FDD and FDMA with slotted Aloha for reservation inquiries, and a Dynamic TDMA scheme for transferring the actual data.

- Bluetooth packet mode communication combines frequency hopping (for shared channel access among several private area networks in the same room) with CSMA/CA (for shared channel access inside a medium).
- IEEE 802.11b wireless local area networks (WLANs) are based on FDMA and DS-CDMA for avoiding interference among adjacent WLAN cells or access points. This is combined with CSMA/CA for multiple access within the cell.
- HIPERLAN/2 wireless networks combine FDMA with dynamic TDMA, meaning that resource reservation is achieved by packet scheduling.
- G.hn, an ITU-T standard for high-speed networking over home wiring (power lines, phone lines and coaxial cables) employs a combination of TDMA, Token passing and CSMA/CARP to allow multiple devices to share the medium.

Definition within certain application areas

Local and metropolitan area networks

In local area networks (LANs) and metropolitan area networks (MANs), multiple access methods enable bus networks, ring networks, hubbed networks, wireless networks and half duplex point-to-point communication, but are not required in full duplex point-to-point serial lines between network switches and routers, or in switched networks (logical star topology). The most common multiple access method is CSMA/CD, which is used in Ethernet. Although today's Ethernet installations typically are switched, CSMA/CD is utilized anyway to achieve compatibility with hubs.

Satellite communications

In satellite communications, multiple access is the capability of a communications satellite to function as a portion of a communications link between more than one pair of satellite terminals concurrently. Three types of multiple access presently used with communications satellites are code-division, frequency-division, and time-division multiple access.

Switching centers

In telecommunication switching centers, multiple access is the connection of a user to two or more switching centers by separate access lines using a single message routing indicator or telephone number.

Data Link Layer Issues

- Link Configuration Control
- Link Discipline Control
- Link Management - bringing link up and down
- Framing
- Flow Control
- Error Control

Link Configuration Control refers to the following:

- Link Topology
- Link Duplexity
- The topology of a communication link refers to the physical arrangement of the connection between the devices. In its fundamental form the topology of a data link between two devices could be:

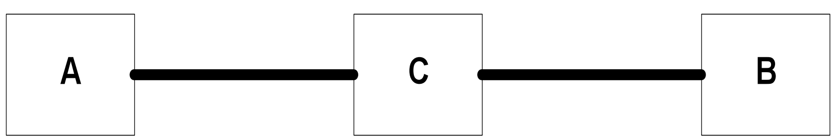
- Direct Link
- Indirect Link

DirectLink:

Two devices are connected by a direct link if there are no intermediate devices (except repeaters or amplifiers) in between them.

Indirect Link

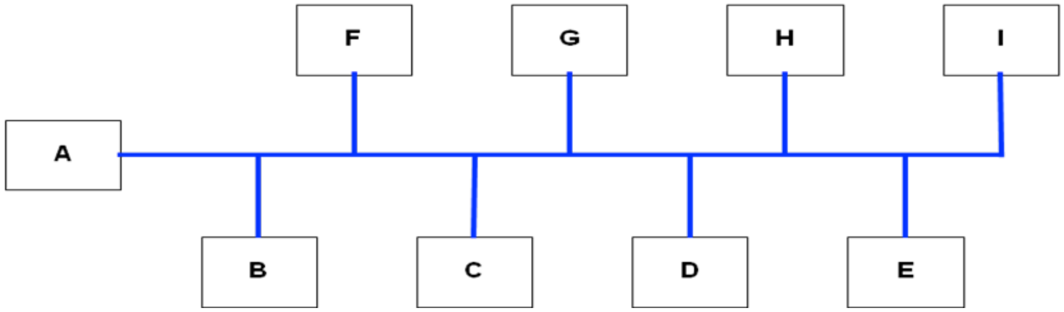
If there are one or more intermediate devices between two devices then the link between them is referred to as an indirect link.Devices A and C have a direct link between them whereas devices A and B have an indirect link between them



There are two possibilities with a direct link:

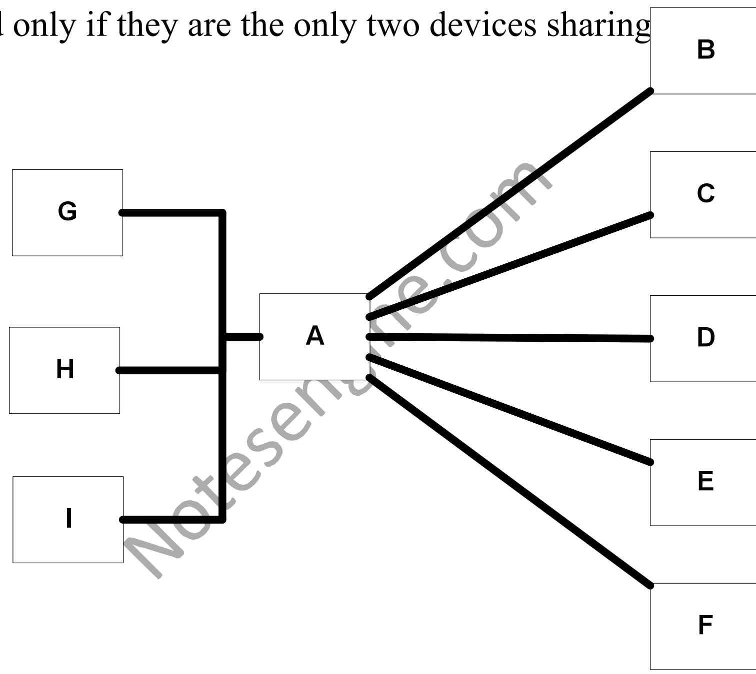
- Multipoint Link
- Point to Point Link

A direct link is called a multipoint link is there are more than two devices sharing the link.



Point to Point Link

- A direct link between two devices is called a point to point link if and only if they are the only two devices sharing k.



Link Duplexity:

Duplexity refers to the fact that either one station can transmit at a time (half duplex) or both can transmit simultaneously (full duplex)

Simple:

- Only one device can transmit to the other i.e. only transmit in one direction
- Not real communication, just one way communication, rarely used in data communications
- Examples: ordinary television, radio e.g., receiving signals from the radio station or CATV
- The sending station has only one transmitter the receiving station has only one receiver

Half Duplex:

- Both devices can transmit to each other but not simultaneously, data may travel in both directions, but only in one direction at a time
- Devices take turns to speak
- Usually implies single path for both transmission and reception
- Computers use control signals to negotiate when to send and when to receive
- The time it takes to switch between sending and receiving is called turnaround time

Full Duplex:

- Both devices can transmit simultaneously

- Usually implies separate transmit and receive paths
- Complete two-way simultaneous transmission
- Faster than half-duplex communication because no turnaround time is needed

Link Discipline Control

Link discipline is dependent on three things:

- The topology of the link
- Duplexity of the link
- Relationship of the devices on the link i.e. Peer to Peer or Primary - Secondary
    1. Primary - Secondary is the old terminal to host environment
    2. Peer - Peer is the modern computer network environment

Link Discipline with Point to Point Links

- Simple
- One device may send an ENQ message to see if the other is ready
- On receiving an ACK the DATA frame may be sent

Line Discipline with Multipoint Links

There are two possibilities:

- **Designated Primary Station**

This Primary-secondary relationship is the case for terminal host setup

- **No Designated Primary Station i.e. Peer - Peer**

Peer to Peer relationship holds in computer network.

Designated Primary Station

- The Primary station controls the link
- Primary either polls the secondaries or selects one of them to transmit

No Designated Primary Station

- Various Medium Access Control (MAC) schemes are in use in Local Area Networks
- Examples CSMA/CD, Token Ring
- These are distributed link discipline control schemes

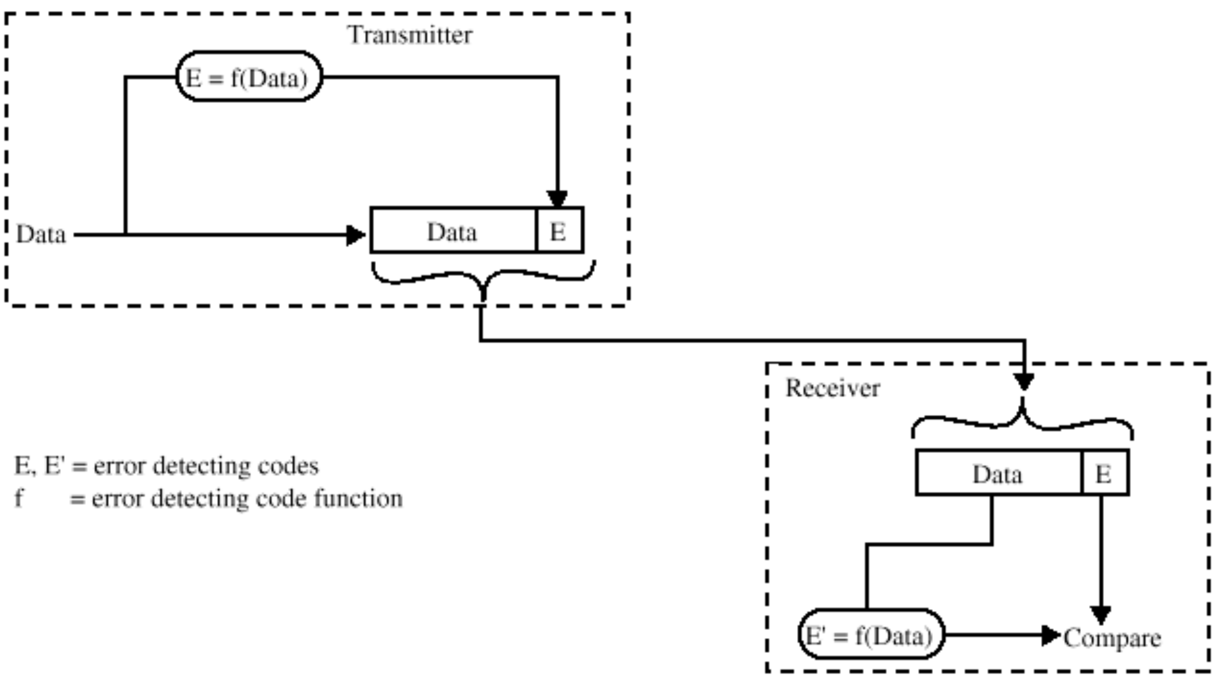
Framing:

- Framing refers to the fact that the beginning and the end of data are marked so to be recognized and help in synchronization.
- A frame is a quantum of data usually at layer two of the OSI reference model.
- The size of a frame is measured in bits. The size of a frame could range from a few bits (5 to 8) to few hundred or even thousand bits.

Error correction and Detection:

- All transmission media have potential for introduction of errors

- Error Control refers to the facts that errors must be:
    - Detected reliably
- Something should be done to retransmit the frame that has been received in error
- Error detection refers to the techniques used to send extra information that can help in indicating to the receiver if the data might have been changed during the course of travelling through the medium.
- Parity error detection and CRC error detection are two techniques that will be discussed for error detection.



- Value of parity bit is such that character has even (even parity) or odd (odd parity) number of ones
- Even number of bit errors goes undetected

- Two types of parity:
    - Simple Parity
    - LRC/VRC

Data							Parity
1	0	0	1	1	1	0	0
0	0	1	1	1	0	0	1
1	1	1	0	1	1	1	0

Simple parity

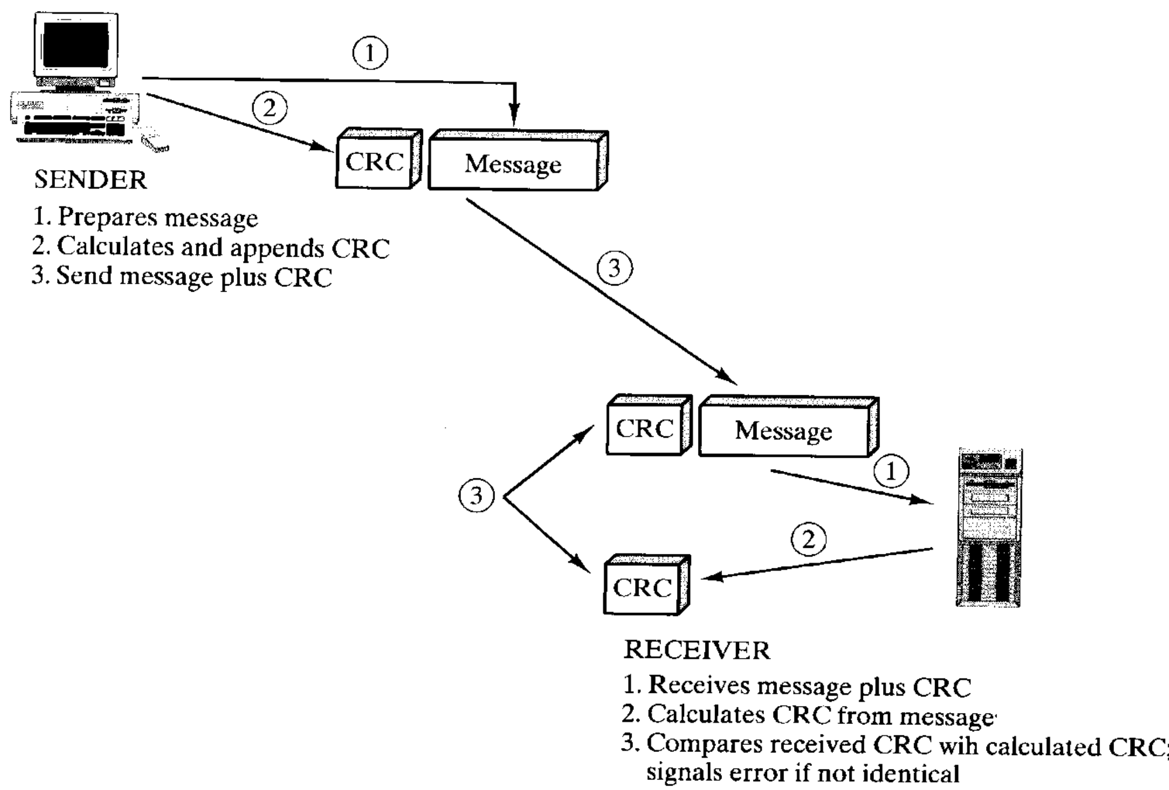
Data							VRC	
1	0	0	1	1	1	0	0	
0	0	1	1	1	0	0	1	
1	1	1	0	1	1	1	0	
1	1	1	0	1	1	1	0	
0	0	1	1	1	0	0	1	
0	0	1	0	1	0	1	1	
0	0	1	1	1	0	0	1	
1	0	0	0	1	1	1	0	LRC

LRC/VRC

Cyclic redundancy check:

- For a Message block of *k* bits (called M) transmitter generates *n* bit sequence (Called Frame Check Sequence or F)
- Transmit $k+n$ bits which is exactly divisible by some number called P which is $n+1$ bits long
- Receive divides frame by that number
    - If no remainder, assume no error

FIGURE 5.14 Error Detection Using CRC.



1. Given

$$\begin{aligned} \text{Message } M &= 1010001101 \text{ (10 bits)} \\ \text{Pattern } P &= 110101 \text{ (6 bits)} \\ \text{FCS } R &= \text{to be calculated (5 bits)} \end{aligned}$$

2. The message is multiplied by 2^5, yielding 101000110100000.
3. This product is divided by P:

```
                  1101010110<-Q
P->110101 | 101000110100000<-2^nM
            110101
            ------
             111011
             110101
             ------
              111010
              110101
              ------
               111110
               110101
               ------
                101100
                110101
                ------
                 110010
                 110101
                 ------
                   1110<-R
```

4. The remainder (R = 01110) is added to $2^n M$ to give T = 101000110101110, which is transmitted.
5. If there are no errors, the receiver receives T intact. The received frame is divided by P:

```
             1101010110
      110101|101000110101110
             110101
              111011
              110101
               111010
               110101
                111110
                110101
                 101111
                 110101
                  110101
                  110101
                      00
```

Since there is no remainder, it is assumed that there have been no errors. ■

Forward Error Correction

- Forward Error Correction (FEC) can also be used.
- In FEC Error Correcting Codes (ECC) are used instead of just Error Detecting Codes (EDC) as in ARQ.
- However, since ECC imply a sizeable overhead they are rarely used in data communication. It is more efficient to just retransmit the frame in error. This is so because errors occur once in a thousand or more frames whereas the overhead of ECC would be occurring with every single frame that is transmitted.
- A situation where FEC might make sense would be where a satellite is transmitting to multiple earth stations and an error occurs for only one of the stations. In that case it would be burdensome for all the other stations that the frame is

retransmitted. It would be more desirable that the station receiving the frame in error could correct the error for itself

Automatic Repeat Request

Three type of ARQ are in common use:

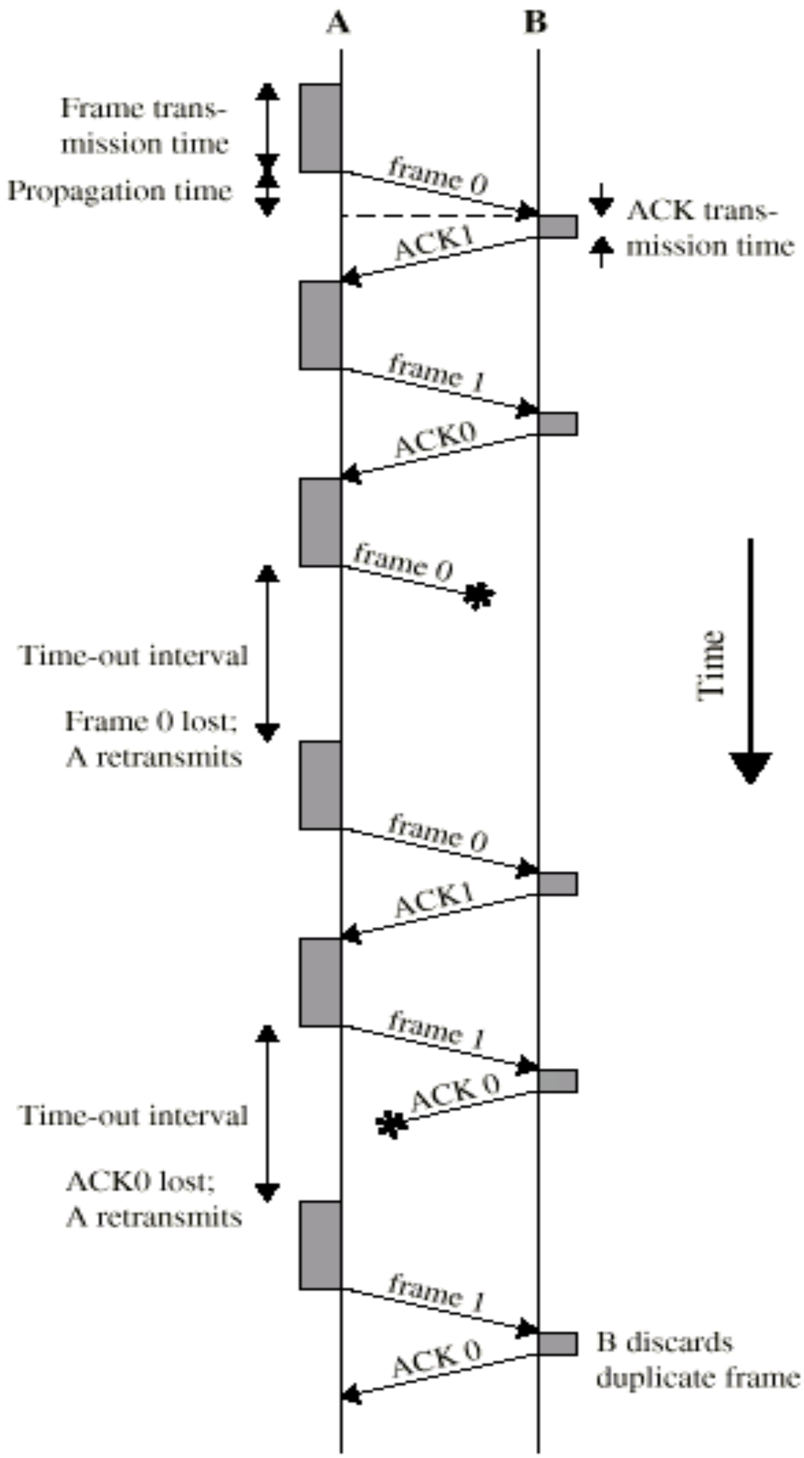
- Stop and wait
- Go back N
- Selective reject (selective retransmission)

Stop and Wait Error Control is in-efficient for the same reasons that Stop and Wait Flow Control was. Therefore Sliding Window Error Control is used. In this context it is called continuous ARQ. There are two variants:

- Go Back N ARQ
- Selective Reject ARQ

Stop and wait ARQ

- Source transmits single frame
- Wait for ACK
- If received frame damaged, discard it
    - Transmitter has timeout
    - If no ACK within timeout, retransmit
- If ACK damaged, transmitter will not recognize it
- Transmitter will retransmit
- Receive gets two copies of frame
- Use ACK0 and ACK1


A
B
Frame trans-
mission time
Propagation time
frame 0
ACK trans-
mission time
ACK1
frame 1
ACK0
frame 0
Time-out interval
Frame 0 lost;
A retransmits
Time
frame 0
ACK1
frame 1
ACK 0
Time-out interval
ACK0 lost;
A retransmits
frame 1
ACK 0
B discards
duplicate frame

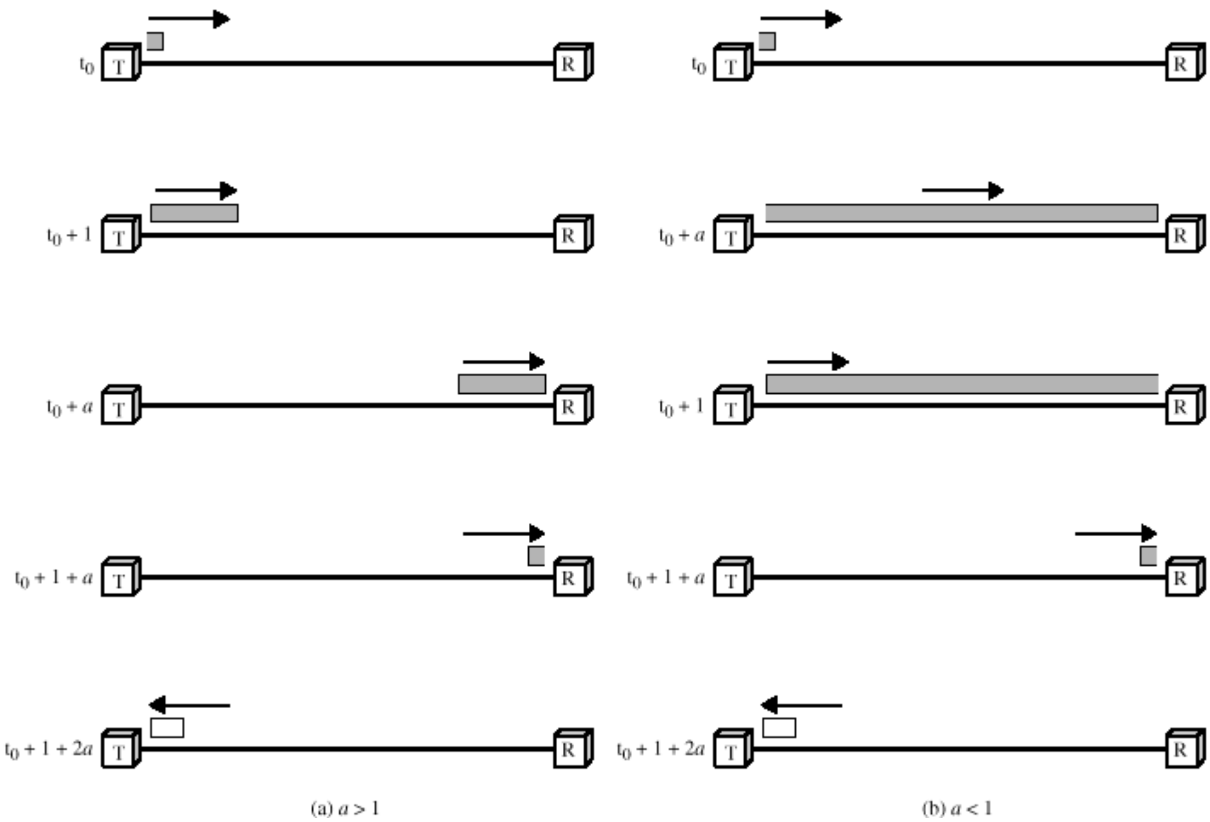
Flow Control

- Flow Control refers to mechanisms that make sure that the sending station cannot overwhelm the receiving station with data.
- Preventing buffer overflow
- Transmission time
- Time taken to emit all bits into medium
- Propagation time
- Time for a bit to traverse the link

Stop and Wait Flow Control.

- Stop and Wait Flow Control works like this:
- The simplest form of flow control is Stop and Wait Flow Control.
- Stop and Wait Flow Control works like this:
- The sending station sends a frame of data and then waits for an acknowledgement from the other station before sending further data
- The other party can stop the flow of data by simply withholding an acknowledgement
- Source may not send new frame until receiver acknowledges the frame already sent
- Very inefficient, especially when a single message is broken into separate frames
- Stop and Wait Flow control works great if data are sent as a few large frames.

- However large frames are undesirable for the following reasons:
- Large frame means one station occupies the link for a longer time (undesirable on a multipoint link)
- There is more chance of error in a large frame resulting in more lost data and more retransmission



Utilization = U = frame time / total time

$\boldsymbol{U = 1/1+2a}$

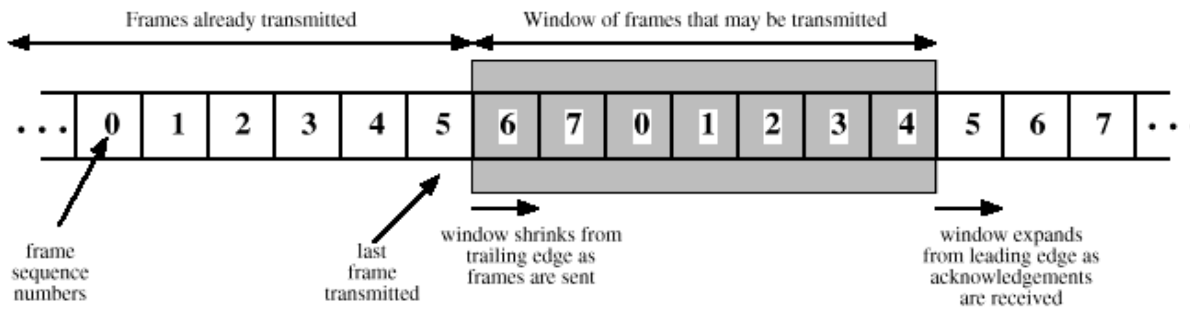
a = Propagation Time / Transmission Time

a = Medium length in bits / Frame length in bits

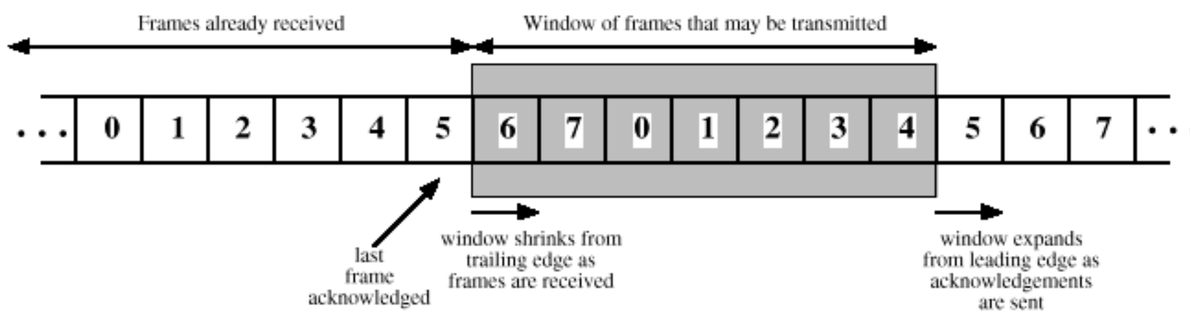
Sliding window Flow control

- Allows multiple frames to be in transit

- Receiver sends acknowledgement with sequence number of anticipated frame
- Sender maintains list of sequence numbers it can send, receiver maintains list of sequence numbers it can receive
- ACK (acknowledgement) supplemented with RNR (receiver not ready)



(a) Transmitter's Perspective



(b) Receiver's Perspective