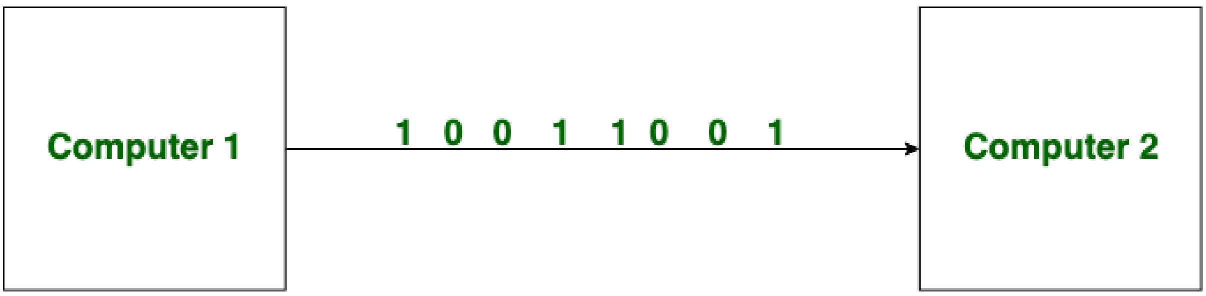
The Digital Data Communication Techniques: Asynchronous and Synchronous Transmission, Line Configurations, Interfacing. Data Link Control, Flow Control, Types of Errors, Error Detection, Error Control, High-Level Data Link Control (HDLC).
Learning Outcomes: At the end of this unit Students will be able to

1. Classify the state and types of digital transmissions.
2. Analyse the flow and error control methods.

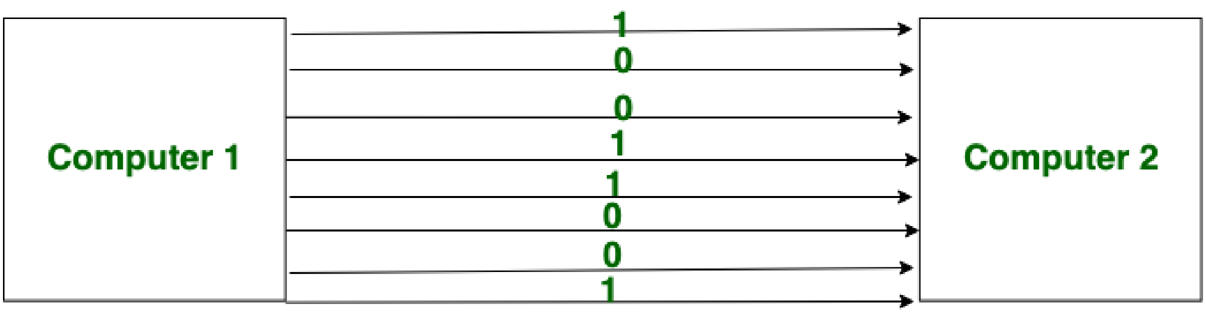
There are two methods used for transferring data between computers which are given below: Serial Transmission and Parallel Transmission.

- **Serial Transmission:**
  In Serial Transmission, data-bit flows from one computer to another computer in bi-direction.
- In this transmission, one bit flows at one clock pulse. In Serial Transmission, 8 bits are transferred at a time having a start and stop bit



Serial Transmission

- **Parallel Transmission:**
  In Parallel Transmission, many bits are flow together simultaneously from one computer to another computer.
- Parallel Transmission is faster than serial transmission to transmit the bits. Parallel transmission is used for short distance.



Parallel Transmission

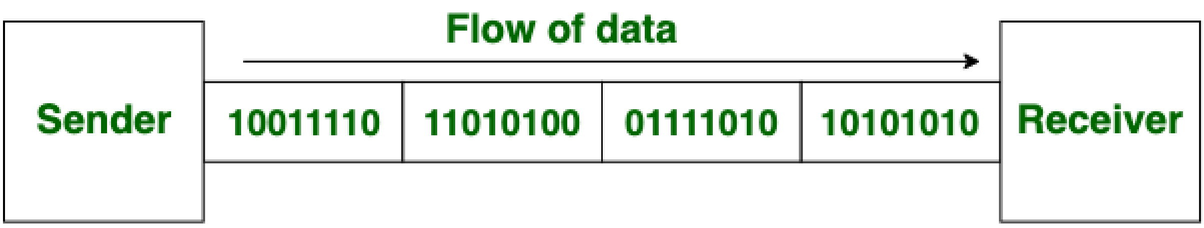
Difference between Serial and Parallel Transmission:

S.NO	Serial Transmission	Parallel Transmission

1.	In serial transmission, data(bit) flows in bi-direction.	In Parallel Transmission, data flows in multiple lines.
2.	Serial Transmission is cost-efficient.	Parallel Transmission is not cost-efficient.
3.	In serial transmission, one bit transferred at one clock pulse.	In Parallel Transmission, eight bits transferred at one clock pulse.
4.	Serial Transmission is slow in comparison of Parallel Transmission.	Parallel Transmission is fast in comparison of Serial Transmission.
5.	Generally, Serial Transmission is used for long-distance.	Generally, Parallel Transmission is used for short distance.
6.	The circuit used in Serial Transmission is simple.	The circuit used in Parallel Transmission is relatively complex.

Asynchronous and synchronous Transmission

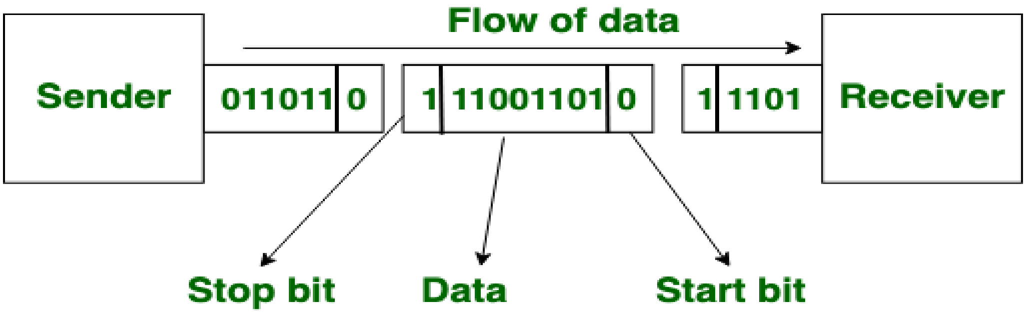
- In Synchronous Transmission, data is sent in form of blocks or frames.
- This transmission is the full duplex type.
- Between sender and receiver the synchronization is compulsory. In Synchronous transmission, There is no gap present between data.
- It is more efficient and more reliable than asynchronous transmission to transfer the large amount of data.



Synchronous Transmission

Asynchronous Transmission:

- In Asynchronous Transmission, data is sent in form of byte or character. This transmission is the half duplex type transmission.
- In this transmission start bits and stop bits are added with data. It does not require synchronization.



Asynchronous Transmission

S.NO	Synchronous Transmission	Asynchronous Transmission
1.	In Synchronous transmission, Data is sent in form of blocks or frames.	In asynchronous transmission, Data is sent in form of byte or character.
2.	Synchronous transmission is fast.	Asynchronous transmission is slow.
3.	Synchronous transmission is costly.	Asynchronous transmission is economical.
4.	In Synchronous transmission, time interval of transmission is constant.	In asynchronous transmission, time interval of transmission is not constant, it is random.
5.	In Synchronous transmission, there is no gap present between data.	In asynchronous transmission, there is present gap between data.
6.	Efficient use of transmission line is done in synchronous transmission.	While in asynchronous transmission, transmission line remains empty during gap in character transmission.
7.	Synchronous transmission needs precisely synchronized clocks for the information of new bytes.	Asynchronous transmission have no need of synchronized clocks as parity bit is used in this transmission for information of new

bytes.

Line Configuration in Computer Networks

- A network is two or more devices connected through a link. A link is a communication pathway that transfers data from one device to another.
- Devices can be a computer, printer, or any other device that is capable to send and receive data. For visualization purposes, imagine any link as a line drawn between two points.

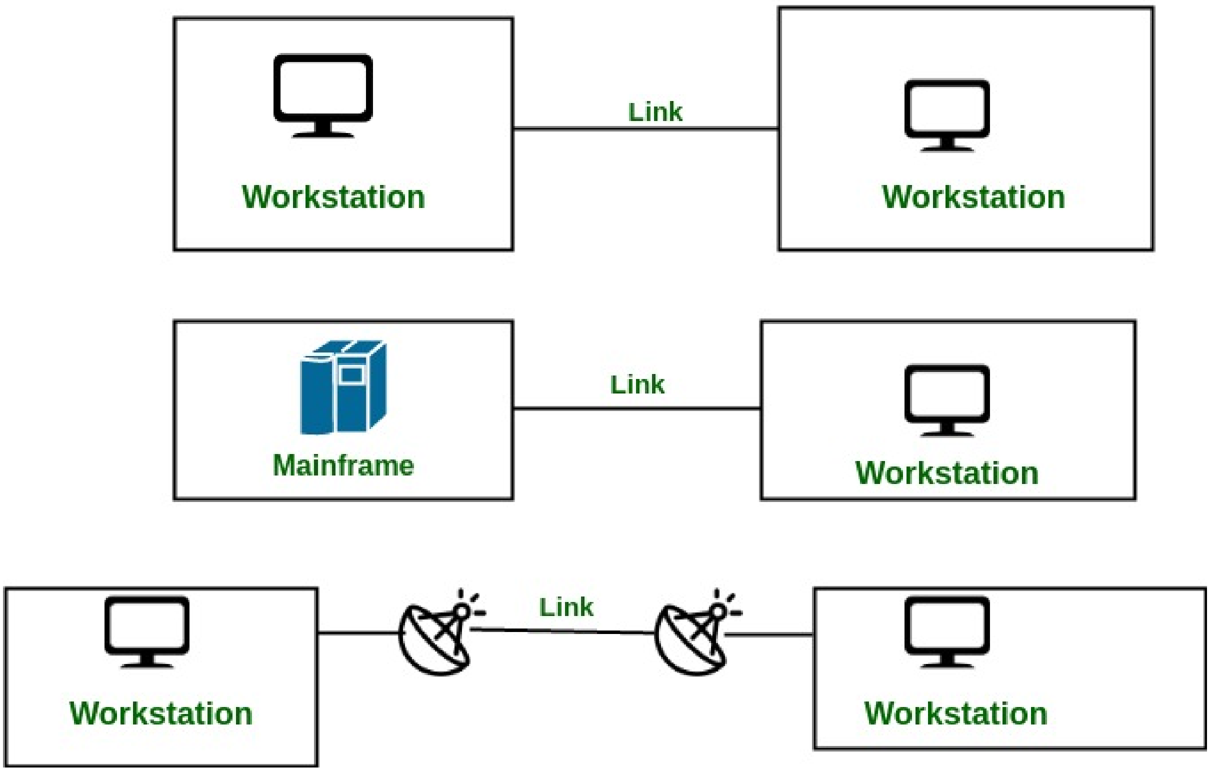
For communication to occur, two devices must be connected in some way to the same link at the same time. There are two possible types of connections:

1. **Point-to-Point Connection**
2. **Multipoint Connection**

Point-to-Point Connection :

1. A point-to-point connection provides a dedicated link between two devices.
2. The entire capacity of the link is reserved for transmission between those two devices.
3. Most point-to-point connections use an actual length of wire or cable to connect the two ends, but other options such as microwave or satellite links are also possible.
4. Point to point network topology is one of the easiest and most conventional networks
topologies.
5. It is also the simplest to establish and understand.

Example: Point-to-Point connection between the remote control and Television for changing the channels.

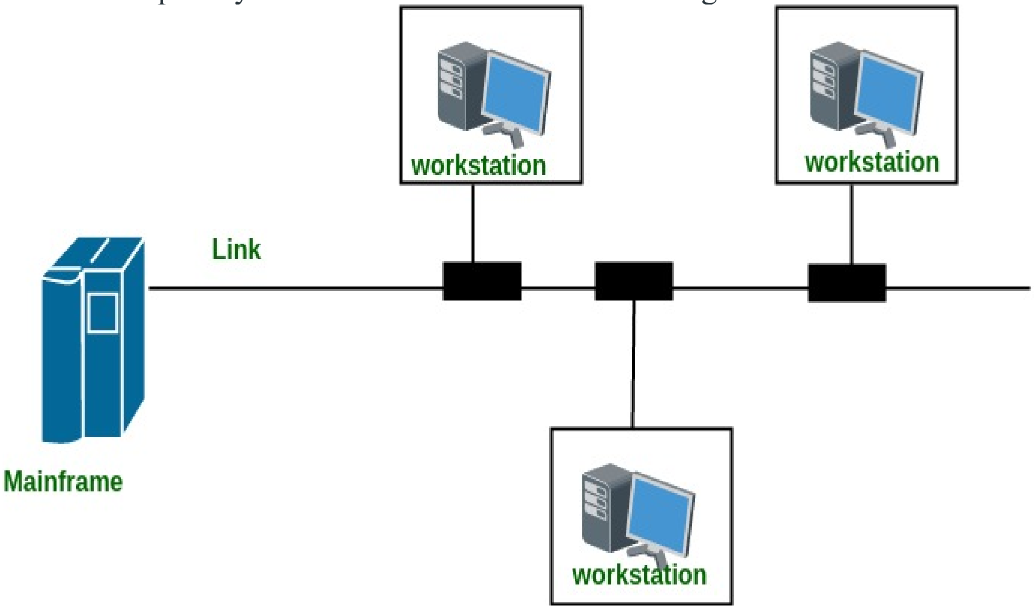


Multipoint Connection :

1. It is also called Multidrop configuration. In this connection, two or more devices share a single link.
2. More than two devices share the link that is the capacity of the channel is shared now. With shared capacity, there can be two possibilities in a Multipoint Line configuration:

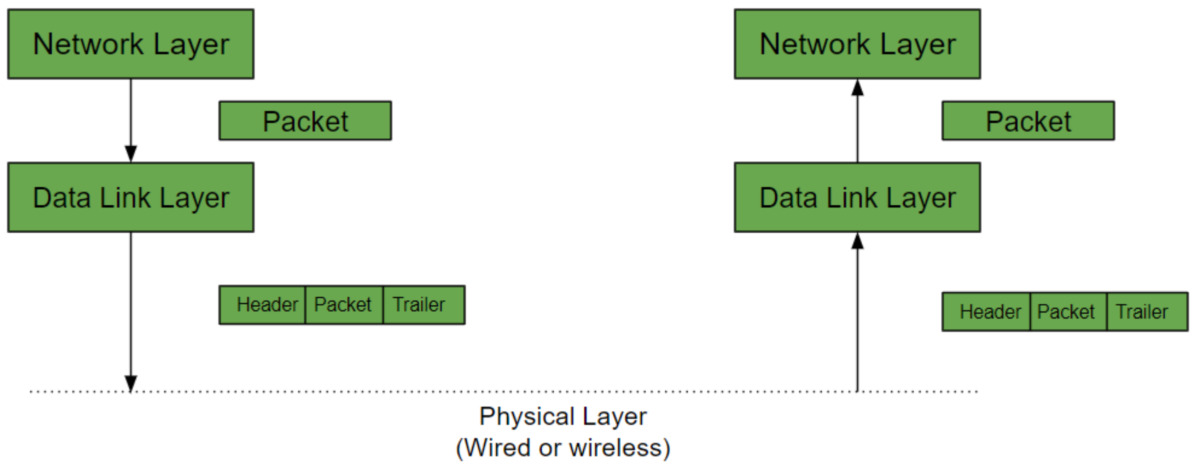
There are two kinds of Multipoint Connections :

- **Spatial Sharing:** If several devices can share the link simultaneously, it's called Spatially shared line configuration.
- **Temporal (Time) Sharing:** If users must take turns using the link, then it's called Temporally shared or Time-Shared Line configuration.



Data Link Layer

The data link layer is responsible for the node to node delivery of the message. The main function of this layer is to make sure data transfer is error-free from one node to another, over the physical layer. When a packet arrives in a network, it is the responsibility of DLL to transmit it to the Host using its MAC address. The working is as follows:



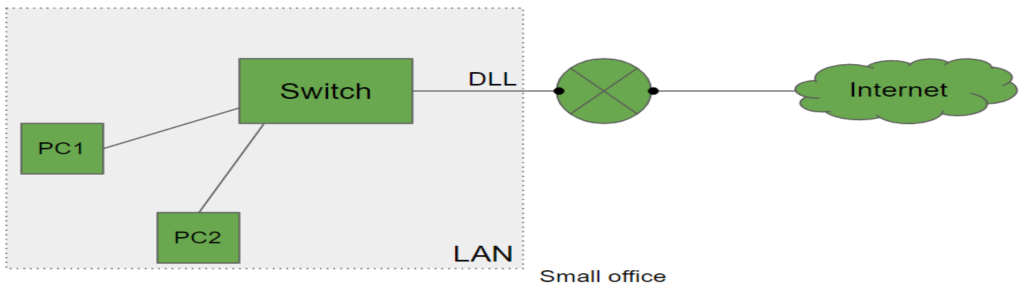
Data Link Layer is divided into two sub layers :

1. Logical Link Control (LLC)
2. Media Access Control (MAC)

The packet received from the Network layer is further divided into frames depending on the frame size of NIC(Network Interface Card). DLL also encapsulates Sender and Receiver's MAC address in the header.

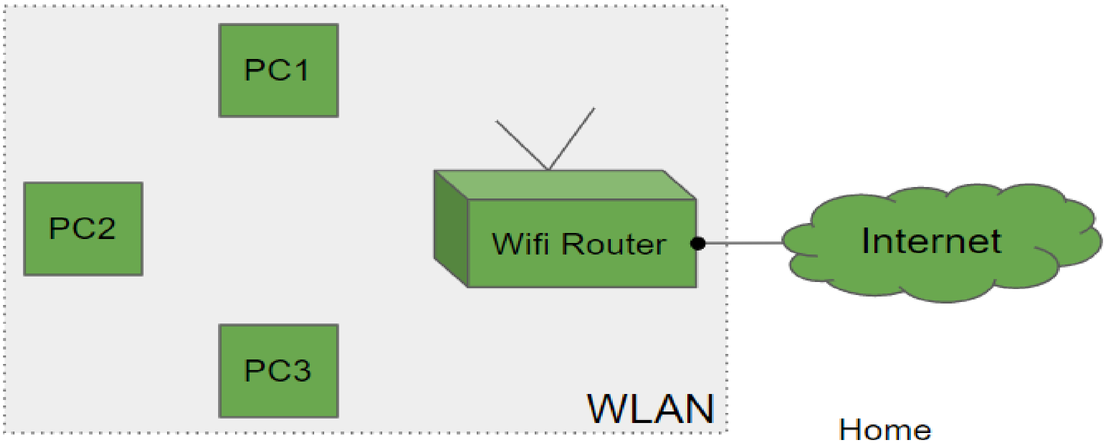
The Receiver's MAC address is obtained by placing an ARP(Address Resolution Protocol) request onto the wire asking "Who has that IP address?" and the destination host will reply with its MAC address.

Now let's see how the DLL works in a small office:



The switch is used to connect multiple computers or laptops which in turn is connected to a router. This is then connected to the internet. All the 1-to-1 connection is done using DLL. The setup is called LAN as they are all connected in Local Area Network.

Now let's see how the DLL works in a small office:



Here the router is used to convey the connection in wireless form. This is then connected to the internet. All the 1-to-1 connection is again done using DLL. The setup is called WLAN as they are all connected in Wireless Local Area Network. This network might have a collision.

The functions of the Data Link layer are :

- Framing: Framing is a function of the data link layer. It provides a way for a sender to transmit a set of bits that are meaningful to the receiver. This can be accomplished by attaching special bit patterns to the beginning and end of the frame.
- Physical addressing: After creating frames, Data link layer adds physical addresses (MAC address) of sender and/or receiver in the header of each frame.
- Error Detection: Data link layer provides the mechanism of error control in which it detects and retransmits damaged or lost frames.
- Error and Flow Control: The data rate must be constant on both sides else the data may get corrupted thus, flow control coordinates that amount of data that can be sent before receiving acknowledgement.
- Access control: When a single communication channel is shared by multiple devices, MAC sub-layer of data link layer helps to determine which device has control over the channel at a given time.

Stop and Wait Protocol

Characteristics

- Used in Connection-oriented communication.
- It offers error and flow control
- It is used in Data Link and Transport Layers
- Stop and Wait ARQ mainly implements Sliding Window Protocol concept with Window Size 1

Useful Terms:

- **Propagation Delay:** Amount of time taken by a packet to make a physical journey from one router to another router.

Propagation Delay = (Distance between routers) / (Velocity of propagation)

- RoundTripTime (**RTT**) = 2* Propagation Delay
- TimeOut (**TO**) = 2* RTT
- Time To Live (**TTL**) = 2* TimeOut. (Maximum TTL is 180 seconds)

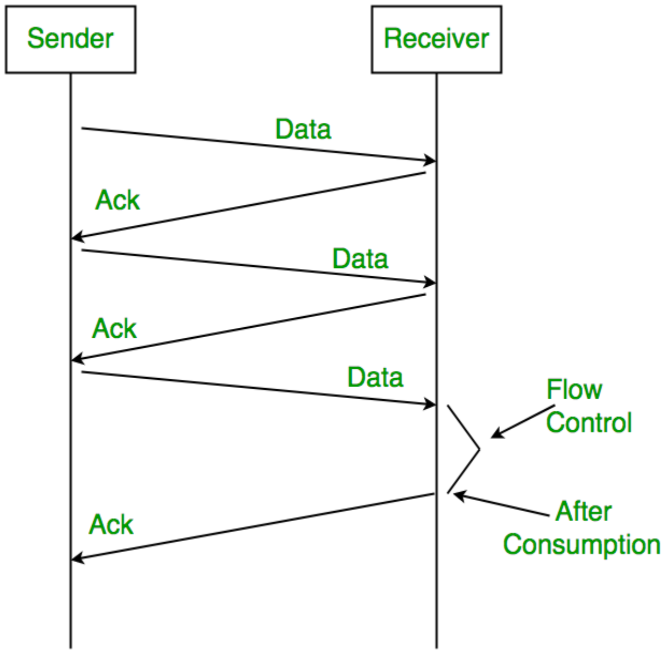
Simple Stop and Wait

Sender:

Rule 1) Send one data packet at a time.
Rule 2) Send next packet only after receiving acknowledgement for previous.

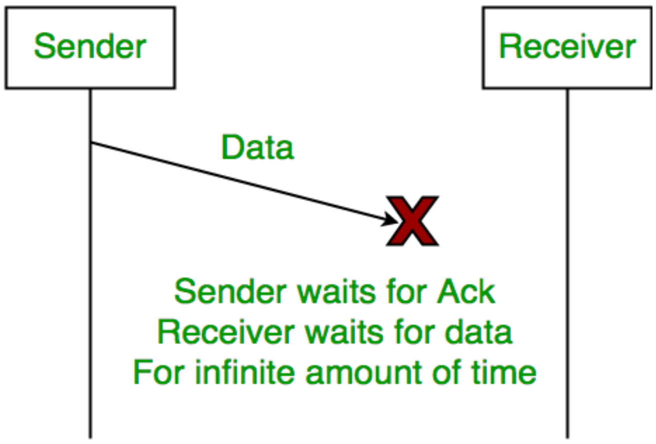
Receiver:

Rule 1) Send acknowledgement after receiving and consuming of the data packet.
Rule 2) After consuming packet acknowledgement need to be sent (Flow Control)

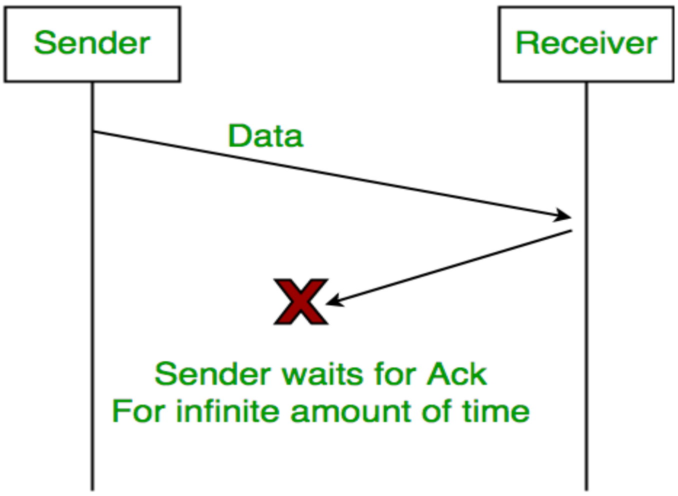


Problems :

1. Lost Data



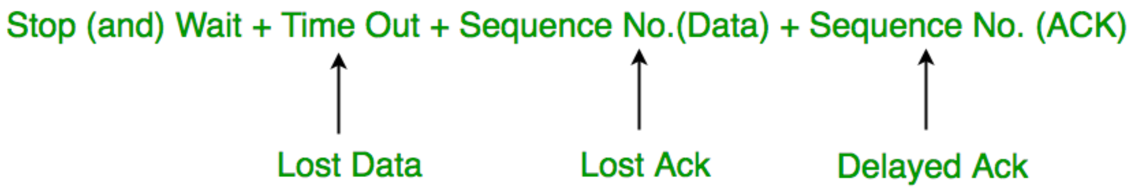
2. Lost Acknowledgement:

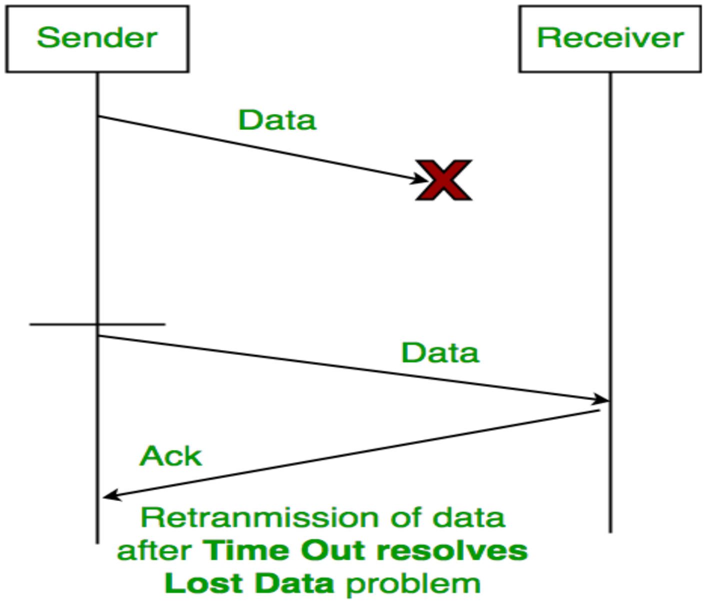


3. Delayed Acknowledgement/Data: After timeout on sender side, a long delayed acknowledgement might be wrongly considered as acknowledgement of some other recent packet.

Stop and Wait ARQ (Automatic Repeat Request)

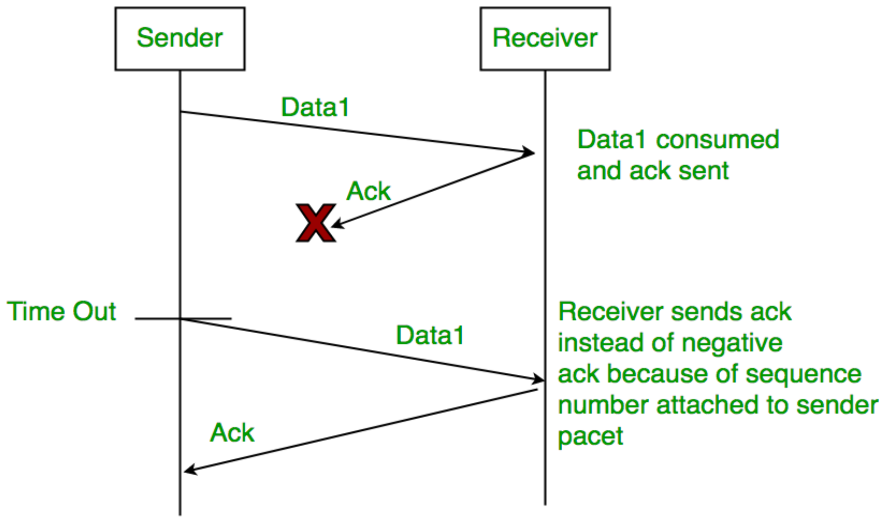
Above 3 problems are resolved by Stop and Wait ARQ (Automatic Repeat Request) that does both error control and flow control.





1. Time Out:

2. Sequence Number (Data)

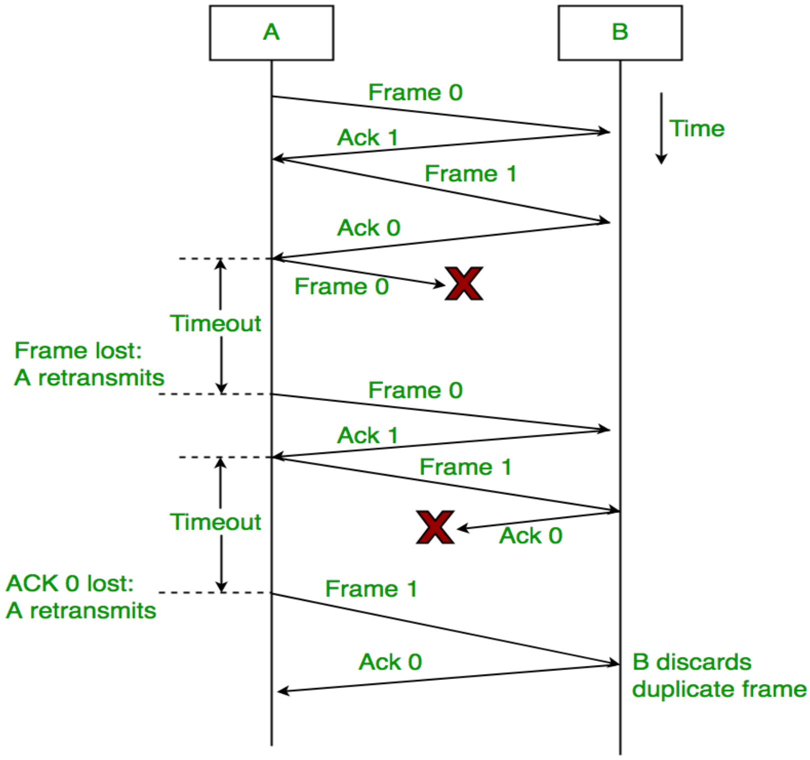


3. Delayed Acknowledgement: This is resolved by introducing sequence number for acknowledgement also.

Working of Stop and Wait ARQ:

1) Sender A sends a data frame or packet with sequence number 0.

2) Receiver B, after receiving data frame, sends an acknowledgement with sequence number 1 (the sequence number of next expected data frame or packet) There is only a one-bit sequence number that implies that both sender and receiver have a buffer for one frame or packet only.



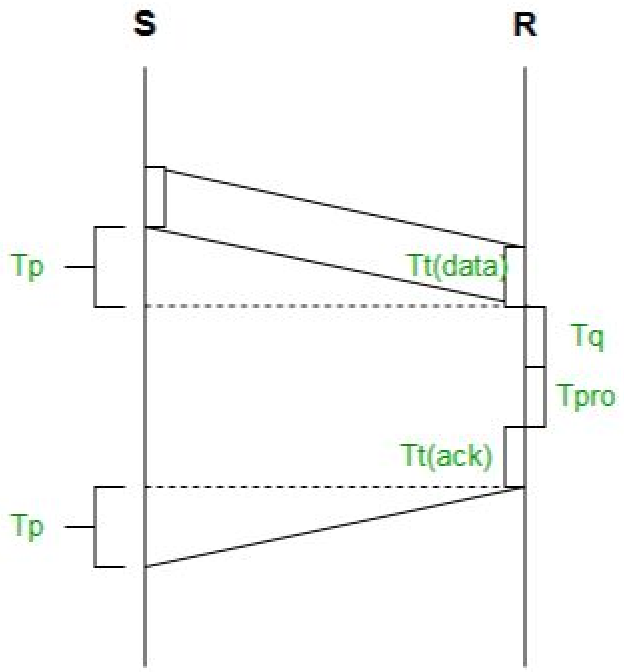
Characteristics of Stop and Wait ARQ:

- It uses the link between sender and receiver as half-duplex link
- Throughput = 1 Data packet/frame per RTT
- If Bandwidth*Delay product is very high, then stop and wait protocol is not so useful. The sender has to keep waiting for acknowledgements before sending the processed next packet.
- It is an example for "**Closed Loop OR connection-oriented** " protocols
- It is a special category of SWP where its window size is 1
- Irrespective of number of packets sender is having stop and wait for protocol requires only 2 sequence numbers 0 and 1

The Stop and Wait ARQ solves main three problems but may cause big performance issues as sender always waits for acknowledgement even if it has next packet ready to send. Consider a situation where you have a high bandwidth connection and propagation delay is also high (you are connected to some server in some other country through a high-speed connection). To solve this problem, we can send more than one packet at a time with a larger sequence number.

So Stop and Wait ARQ may work fine where propagation delay is very less, for example, LAN connections, but performs badly for distant connections like satellite connection.

Efficiency: Stop and Wait is a flow control protocol. In which the sender sends one packet and waits for the receiver to acknowledge and then it will send the next packet. In case if the acknowledgement is not received, the sender will retransmit the packet. This is the simplest one and easy to implement. but the main disadvantage is the efficiency is very low.



Total time taken to send one packet,

```
= Tt(data) + Tp(data) + Tq + Tpro + Tt(ack) + Tp(ack)



Since,

Tp(ack) = Tp(data)
```

```
And,

Tt(ack) << Tt(data).


So we can neglect Tt(ack)

Tq = 0 and Tpro = 0
```

```
Hence,

Total time = Tt(data) + 2 * Tp
```

Where,

```
Tt(data) : Transmission delay for Data packet

Tp(data) : propagation delay for Data packet

Tq: Queuing delay

Tpro: Processing delay

Tt(ack): Transmission delay for acknowledgment

Tp(ack) : Propagation delay for acknowledgment
```

We know that the **Efficiency (η)**,

```
= Useful time / Total cycle time.

= Tt / (Tt + 2*Tp)

= 1 / (1+2*(Tp/Tt))
```

```
= 1 / (1+2*a)



where,
```

```
a = Tp / Tt
```

Throughput: Number of bits send per second, which is also known as Effective Bandwidth or Bandwidth utilization.

```
Throughput,

= L/(Tt + 2*Tp)

= ((L/BW)*BW)/(Tt + 2*Tp)

= Tt/(Tt + 2*Tp) * BW

= 1/(1 + 2a) * BW



Hence, Throughput

= η * BW
```

```
where,

BW : BandWidth

L : Size of Data packet
```

Factors affecting Efficiency:

```
n = 1/(1 + 2*(Tp/Tt)

= 1/(1 + 2*(d/v)*(BW/L))
```

```
where,

d = distance between source and receiver
```

```
v = velocity
```

Let's see an example.

Example: Given,

```
Tt = 1ms

Tp = 2ms

Bandwidth = 6 Mbps



Efficiency(η)

= 1/(1 + a)

= 1/(1 + (2/1))

= 1/3

= 33.33 %



Throughput
```

```
= η * BW

= (1/3) * 6

= 2 Mbps
```

Note: As we can observe from the above given formula of Efficiency that:

1. On increasing the distance between source and receiver the Efficiency will decrease. Hence, Stop and Wait is only suitable for small area network like LAN. It is not suitable for MAN or WAN, as the efficiency will be very low.
2. If we increase the size of the Data packet, the efficiency is going to increase. Hence, it is suitable not for small packets. Big data packets can be send by Stop and Wait efficiently.