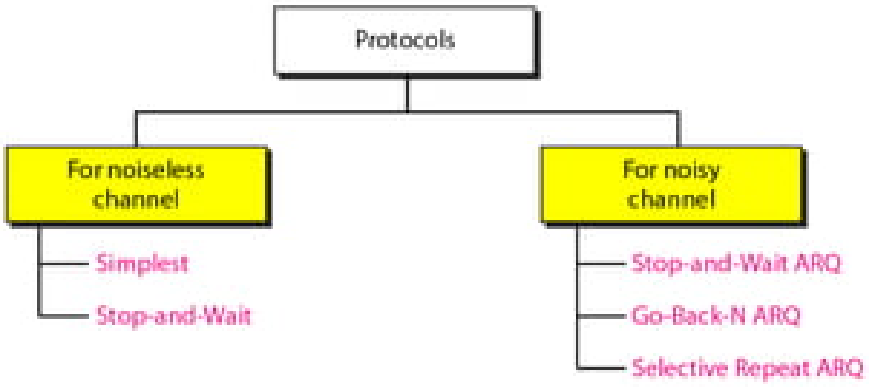
Flow Control

Flow control refers to a set of procedures used to restrict the amount of data that the sender can send before waiting for acknowledgment.

Error Control

Error control in the data link layer is based on automatic repeat request, which is the retransmission of data.



Noiseless Channels

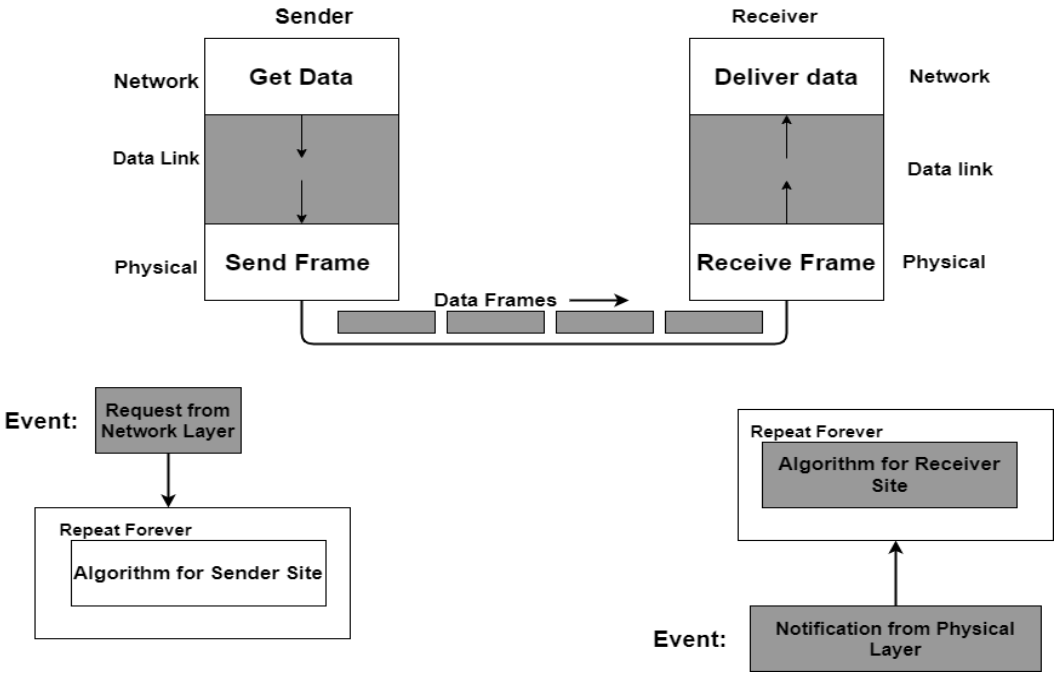
Noiseless Channel is an ideal channel in which no frames are lost, duplicated, or corrupted.There are two protocols for this type of channel:

1. Simplest Protocol
2. Stop and Wait Protocol

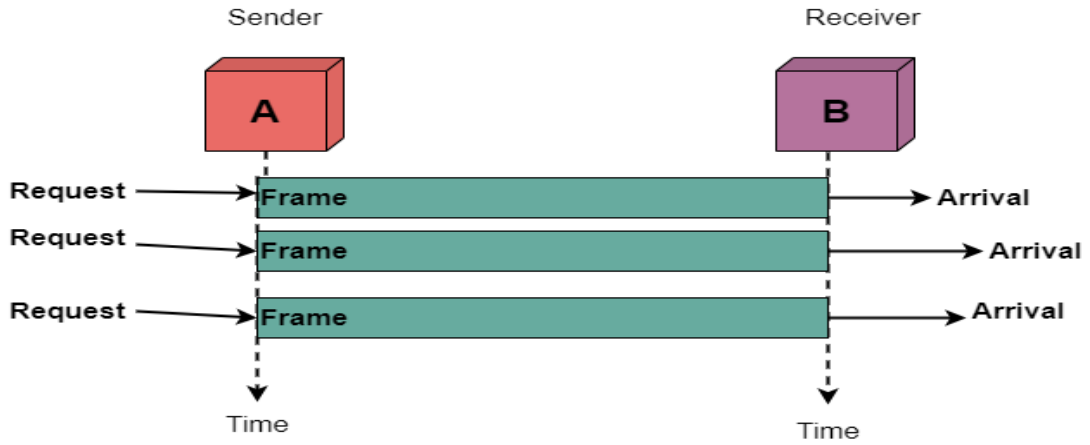
Note: In real world there are no Noiseless channels.

Simplex (Simplest) Protocol:

1. Simplest Protocol has no flow control and no error control mechanism.
2. It is a unidirectional protocol in which data frames are traveling in only one direction-from the sender to receiver.
3. The data link layer at the **Sender site** gets data from its network layer, makes a frame outof the data, and sends it.
4. The data link layer at the **Receiver site** receives a frame from its physical layer, extractsdata from the frame, and delivers the data to its network layer.
5. The data link layers of the sender and receiver provide transmission services for theirnetwork layers.



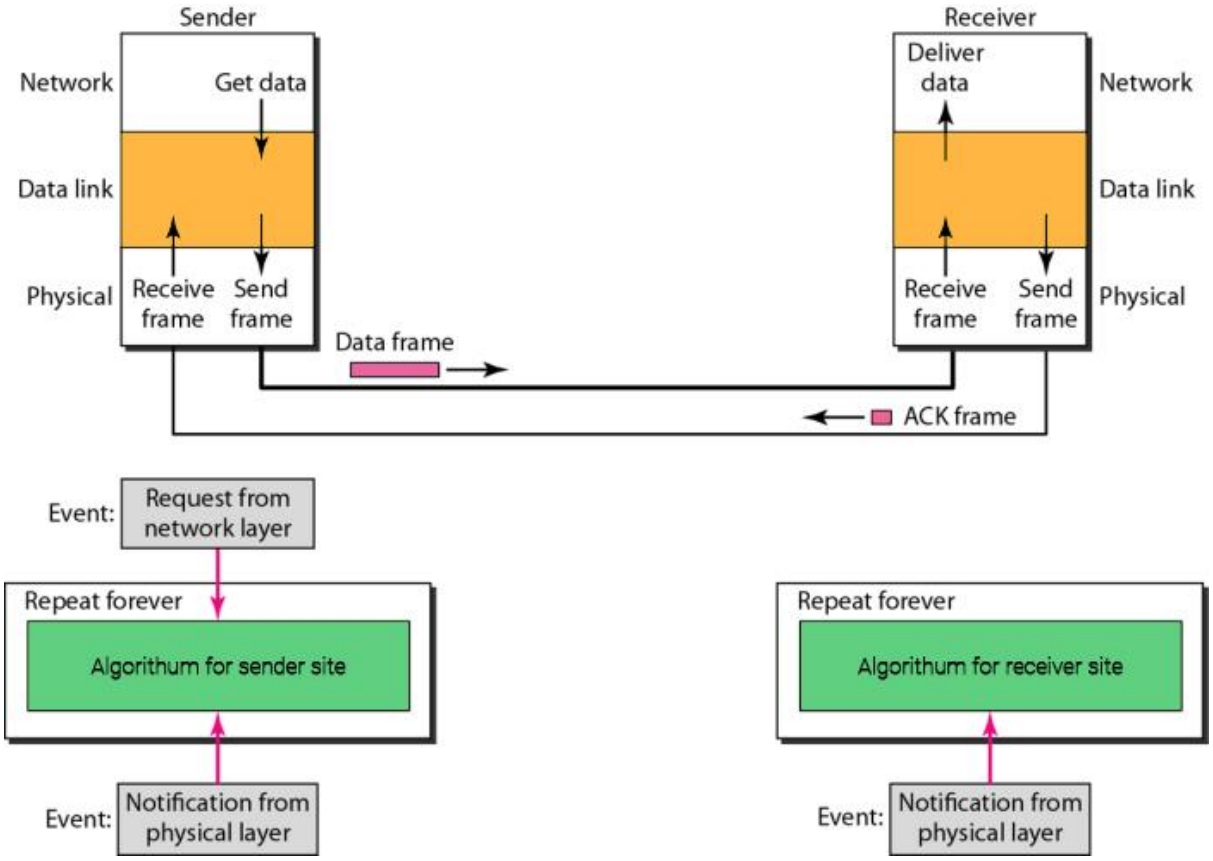
Using the simplest protocol the sender A sends a sequence of frames without even thinking about receiver .



2. Stop and Wait Protocol:

In Stop-and-Wait Protocol the sender sends one frame, stops until it receives confirmation (ACK's) from the receiver and then sends the next frame.

At any time, there is either one data frame on the forward channel or one ACK frame on thereverse channel. Therefore need a half-duplex link.



The sender sends one frame and waits for feedback from the receiver. When the ACK arrives,the sender sends the next frame.

The algorithm used at the sender site for the stop-and-wait protocol

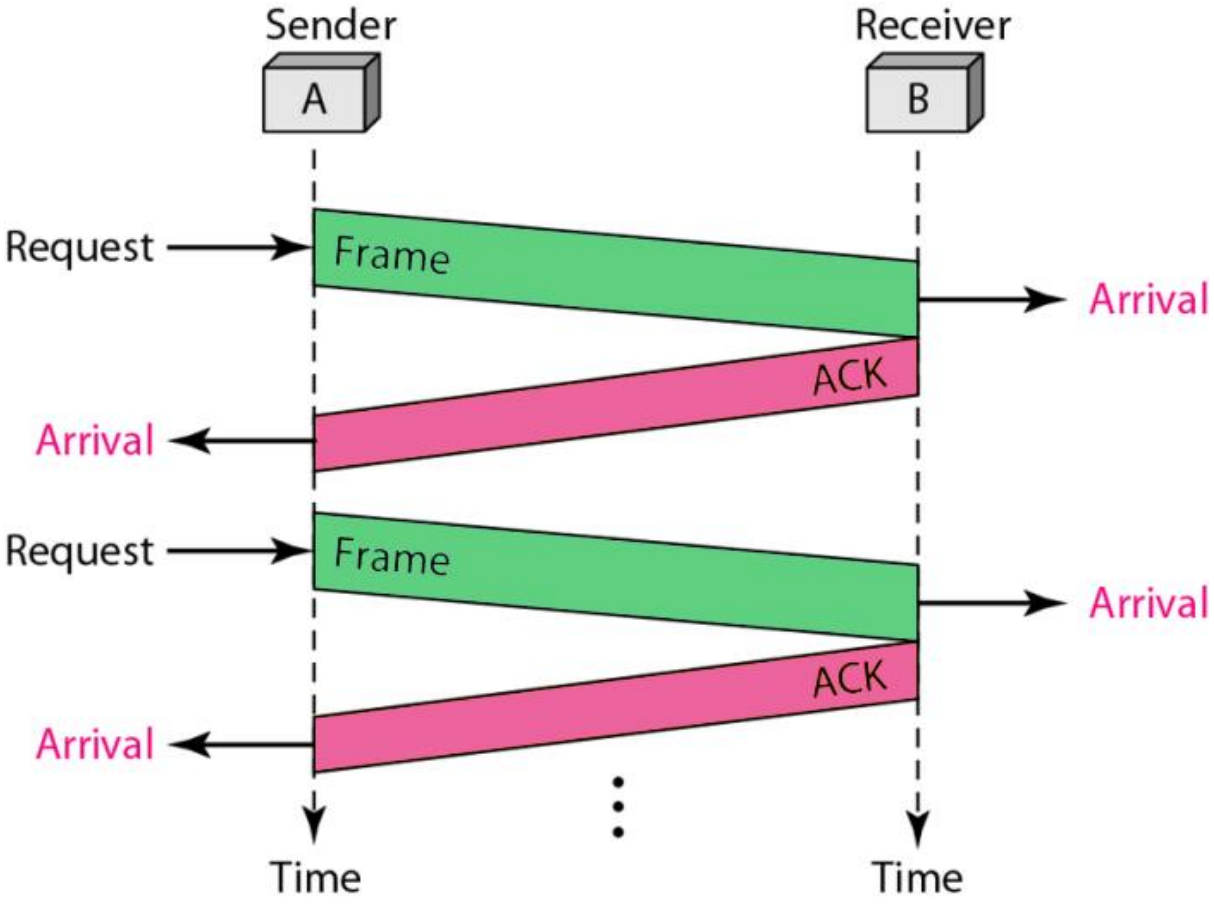
```
while(true)              //Repeat forever
canSend=true             //It will allow the first frame to go.
{
  WaitForEvent();        //sleep until the occurrence of an event
  if(Event(RequestToSend) AND canSend)
   {
     GetData();
     MakeFrame();
     SendFrame();   //Send the data frame
     canSend=false;   //cannot send until the acknowledgement arrives.
```

```
}
WaitForEvent();   //sleep until the occurrence of an event
if(Event(ArrivalNotification))  //indicates the arrival of the acknowledgement
  {
    ReceiveFrame();     //Means the ACK frame received
    canSend=true;
  }
     }
```

Algorithm At the Receiver Side

```
while(true)   //means Repeat forever
{
  WaitForEvent();  //sleep until the occurrence of an event
  if(Event(ArrivalNotification)) //indicates arrival of the data frame
  {
     ReceiveFrame();
     ExtractData();
     Deliver(data); //delivers the data to the network layer.
     SendFrame(); //Send the ACK frame
  }
     }
```

Flow diagram of the stop-and-wait protocol



Disadvantages of Stop and Wait Protocol

1. If the receiver does not respond when there is an error then sender doesn't know whichframe has to be resend.
2. In Stop and Wait protocol the sender does not send next frame until it receives ACK from receiver. If the ACK has lost then sender does not know when to send the frame.

NOISY CHANNELS

In Noisy Channels we need to implement both Flow control and Error Control Mechanismsin the Protocols.

Stop-and-Wait Automatic Repeat Request (ARQ)

This Protocol uses Acknowledgements and Sequence Numbers to implement Flow and ErrorControl mechanisms. The corrupted and lost frames need to be resent in this protocol.

There are 2 Questions arises:

1. **If the receiver does not respond when there is an error, how the sender knows whichframe to resend?**

Solution: The sender keeps a copy of the sent frame. At the same time, it starts a timer.

If the timer expires and there is no ACK for the sent frame then **"3 actions"** to be performed

i. The frame is resent
ii. The copy is held
iii. The timer is restarted.

Note: Since the protocol uses the stop-and-wait mechanism, there is only one specific framethat needs an ACK even though several copies of the same frame can be in the network.

2. **What if an ACK frame is also lost?**

Solution:

Since an ACK frame can also be corrupted and lost, it needs a **Sequence Number** andRedundancy Bits.

The ACK frame for this protocol has a sequence number field.

In this protocol, the sender simply discards a corrupted ACK frame or ignores an out-of-orderone.

Sequence Numbers

- Sequence Number is the number that is given to the data frame.
- A field is added to the data frame to hold the sequence number of that frame.
- The sequence numbers are based on modulo-2 arithmetic.

Range: Consider the field is m bits long, the range of sequence numbers are from 0 to 2^m-1,and then the same number are repeated.

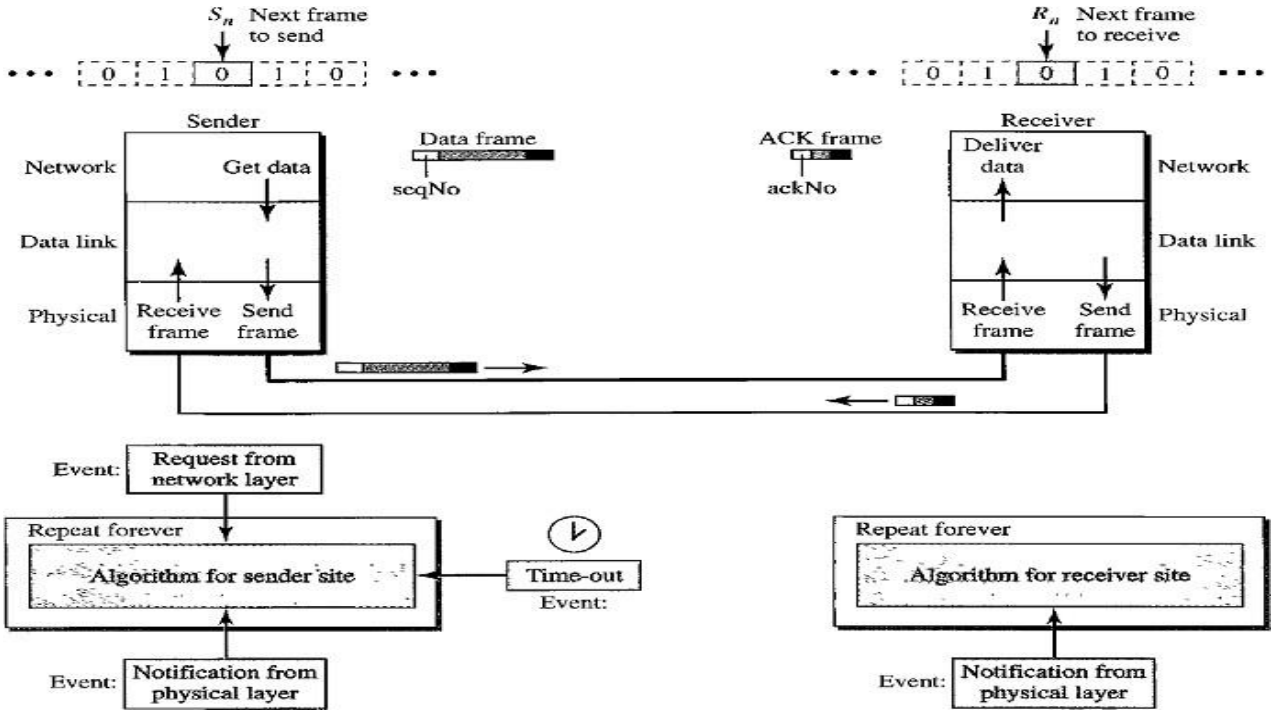
Acknowledgment Numbers

The acknowledgment numbers always announce the sequence number of the next frameexpected by the receiver.

Example:

1. If frame 0 has arrived safe and sound, the receiver sends an ACK frame withacknowledgment 1 (meaning frame 1 is expected next).
2. If frame 1 has arrived safe and sound, the receiver sends an ACK frame withacknowledgment 0 (meaning frame 0 is expected).

Design



Procedure:

- The sending device keeps a copy of the last frame transmitted until it receives anacknowledgment for that frame.
- The design contains:
  - **seqNo**: Sequecne Number
  - **ackNo**: Acknowledgement Number
  - **S_n**: Sender Control variable- that holds the sequence number for the next frame to besent (0 or 1).
  - **R_n**: Receiver Control Variable- that holds the number of the next frame expected.
- When a frame is sent, the value of **S_n** is incremented (modulo-2), which means if it is 0, itbecomes 1 and vice versa.
- When a frame is received, the value of **R_n** is incremented (modulo-2), which means if it is0, it becomes 1 and vice versa.
- **S_n** variable points to the slot that matches the sequence number of the frame that has beensent, but not acknowledged.
- Sequence numbers are modulo-2, the possible numbers are 0,1,0,1,0,1,……and so on.
- **R_n** points to the slot that matches the sequence number of the expected frame.
- Three events can happen at the sender site; one event can happen at the receiver site.

There are 3 Events can happen at Sender site.

1. RequestToSend (which comes from network layer to data link layer)
2. ArrivalNotification (which comes from physical layer to data link layer)
3. TimeOut

Event 1: Request to send

- Event RequestToSend is used to send the frame to receiver.
- Before the frame is sent, it is stored in the buffer. We need at least one buffer to hold thisframe until sender make sure that it is received safe and sound.
- The copy is used for resending a corrupt or lost frame.
- Sender has to prevent the network layer from making a request before the previous frameis received safe and sound.

Event 2: Arrival Notification

- If the frame is not corrupted then three actions will be done:
  1. The ackNo of the ACK frame matches the sequence number of the next frame to send.
  2. Timer is stopped
  3. Purge the copy of the data frame that was saved.
- If the frame is corrupted then it ignore arrival notification event and wait for the nextevent to happen.

Event 3: Time Out

- After each frame is sent, a timer is started.
- When the timer expires the frame is resent and the timer is restarted.

Receiver-site:

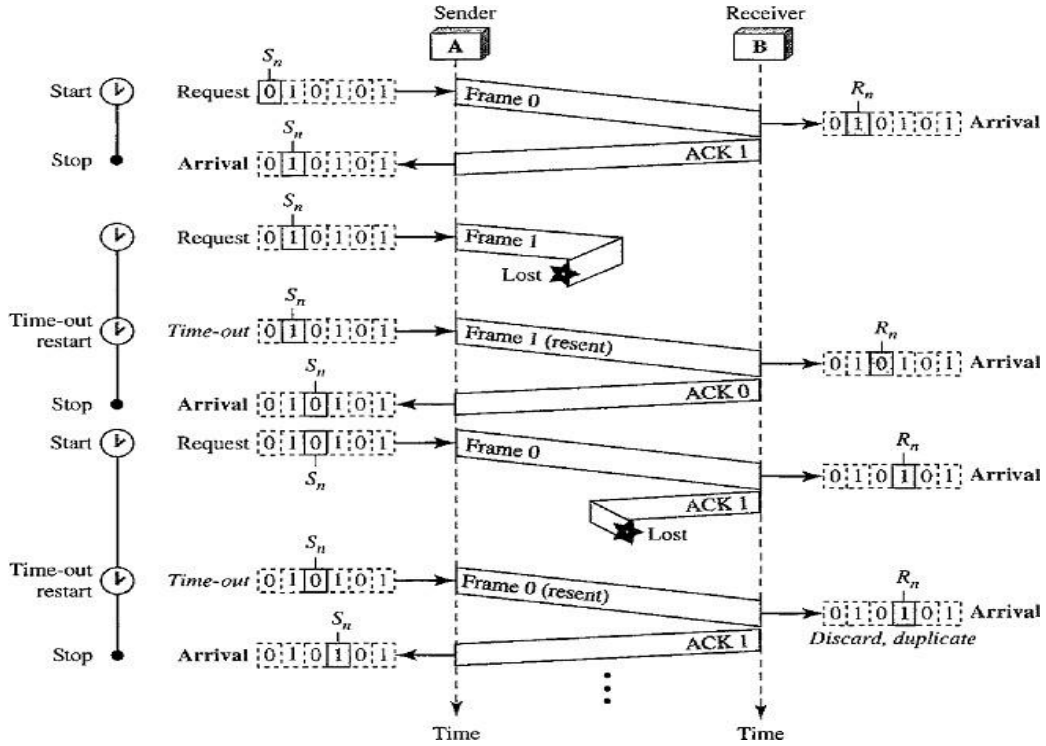
Only **One Event** happens at the receiver site.

- First, all arrived data frames that are corrupted are ignored.
- If the seqNo of the frame is the one that is expected ($\mathbf{R_n}$), the frame is accepted, the dataare delivered to the network layer, and the value of $\mathbf{R_n}$ is incremented.

Note:

- Even if the sequence number of the data frame does not match the next frame expected,an ACK is sent to the sender.
- This ACK reconfirms the previous ACK instead of confirming the frame received.
- This is done because the receiver assumes that the previous ACK might have been lost;the receiver is sending a duplicate frame.
- The resent ACK may solve the problem before the time-out does it.

Flow diagram



- Frame 0 is sent and acknowledged.
- Frame 1 is lost and resent after the time-out.
- The resent frame 1 is acknowledged and the timer stops.
- Frame 0 is sent and acknowledged, but the acknowledgment is lost.
- The sender has no idea if the frame or the acknowledgment is lost, so after the time-out, itresends frame 0, which is acknowledged.

Go-Back-N Automatic Repeat Request (ARQ)

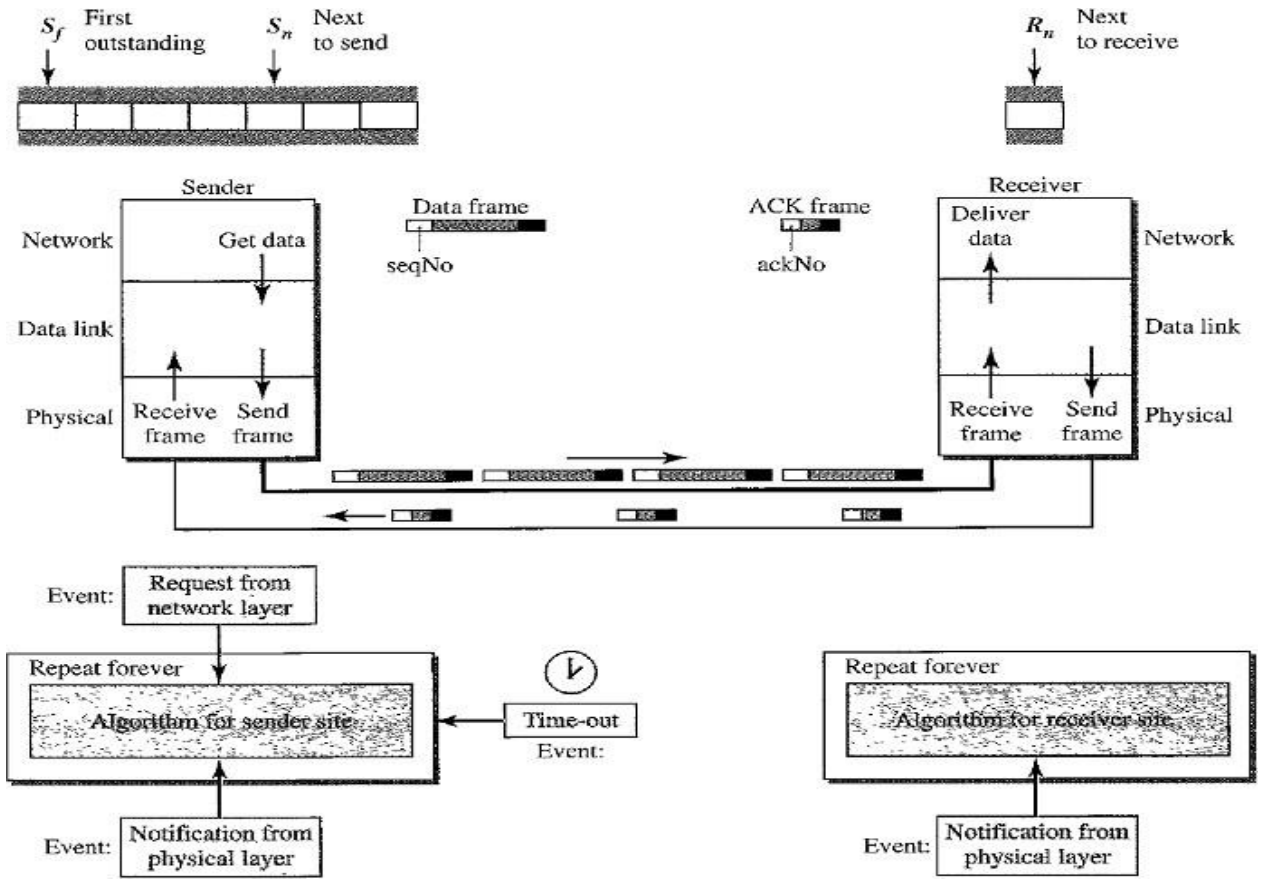
In this protocol

- Sender can send several frames before receiving acknowledgments.
- Sender keep a copy of these frames until the acknowledgments arrive.

Design of Go-Back-N ARQ

The idea is similar to Stop-and-Wait ARQ, multiple frames can be in transit in the forward direction, and multiple acknowledgments in the reverse direction.

The difference is that the send window allows us to have as many frames in transition as there are slots in the send window.



This protocol uses the following concepts:

1. Sequence Numbers
2. Sliding Window
3. Timers
4. Acknowledgement
5. Retransmission (Resending a Frame)

Sequence Numbers

- The header of the frame allows *m* bits for the sequence number, the sequence numbers range from 0 to 2^m-1.
- The sequence numbers are repeated after the number 2^m-1 (i.e) the sequence numbers are modulo-2^m

Example:
If m=4 , the sequence numbers are 0,1,2,3,4,5……14,15,0,1,2,3,4,5,6,……..

Sliding Window

Sliding Window is an abstract concept that defines the sender and receiver needs to deal with only part of the possible sequence numbers.

There are 2 types of windows are used:

i. Send Window
ii. Receive Window

The range that is the concern of sender is called the send sliding window or Send Window

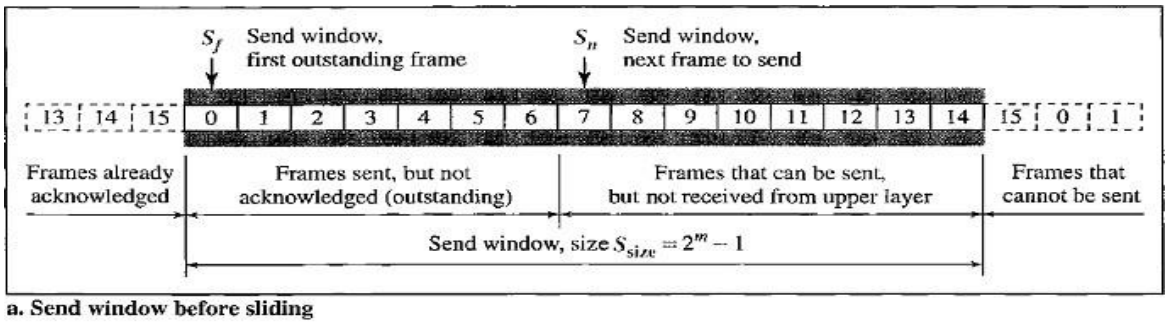
The range that is the concern of receiver is called receive sliding window or receive window.

Send Window

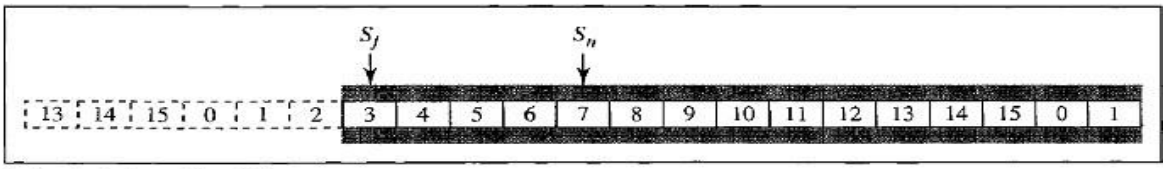
- The send window is an imaginary box covering the sequence numbers of the data frames which can be in transit.
- In each window position, some of these sequence numbers define the frames that have been sent; others define those that can be sent.
- The maximum size of the send window is **2^m –**

1.Example: Let us take m=4. Size of window=15.

Consider the below figure:



a. Send window before sliding



b. Send window after sliding

The window at any time divides the possible sequence numbers into four regions.

1. The first region (the left side of the window) defines the sequence numbers belonging to frames that are already acknowledged. The sender don‟t need to keep copies of the frames.
2. The second region defines the range of sequence numbers belonging to the frames that are sent and have an unknown status. The sender needs to wait to find out if these frames have

been received or were lost. These frames are called outstanding frames.

3. The third range defines the range of sequence numbers for frames that can be sent. The corresponding data packets have not yet been received from the network layer.
4. The fourth region defines sequence numbers that cannot be used until the window slides.

The window uses three variables define its size and location at any time.

i. S_f defines the sequence number of the first (oldest) outstanding frame.
ii. S_n holds the sequence number that will be assigned to the next frame to be sent.
iii. S_{size} defines the size of the window, which is fixed in our protocol.

The acknowledgments in this protocol are cumulative, meaning that more than one frame can be acknowledged by an ACK frame.

In the above figure frames 0, 1, and 2 are acknowledged, so the window has slid to the right three slots.

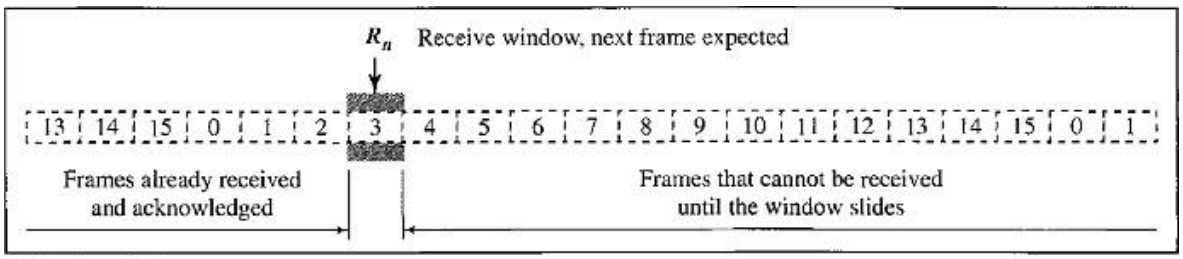
Receive Window

- The receive window makes sure that the correct data frames are received and that the correct acknowledgments are sent.
- The size of the receive window is always 1.
- The receiver is always looking for the arrival of a specific frame.
- Any frame arriving out of order is discarded and needs to be resent.

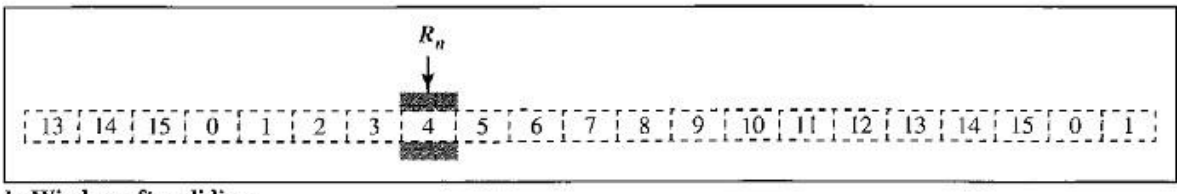
There is only one variable required, that is R_n

R_n: defines next frame expected, belongs to Receive Window.

- The sequence numbers to the left of the window belong to the frames already received and acknowledged.
- The sequence numbers to the right of this window define the frames that cannot be received.
- Any received frame with a sequence number in these two regions is discarded.
- Only a frame with a sequence number matching the value of R_n is accepted and acknowledged. (i.e. $S_n=R_n$)The receive window slides only one slot at a time, when the



a. Receive window



b. Window after sliding

correct frame is received thewindow slides.

Timers

The timer for the first outstanding frame always expires first.We send all outstanding frames when this timer expires.

Acknowledgment

- The receiver sends a positive acknowledgment if a frame has arrived safe and sound and in order.
- If a frame is damaged or frame is received out of order, the receiver is silent and will discard all subsequent frames until it receives the one it is expecting.
- The silence of the receiver causes the timer of the unacknowledged frame at the sender site to expire. This causes the sender to go back and resend all frames, beginning with the one with the expired timer.
- The receiver does not have to acknowledge each frame received. It can send one cumulative acknowledgment for several frames.

Retransmission (Resending a Frame)

When the timer expires, the sender resends all outstanding frames.

Example:

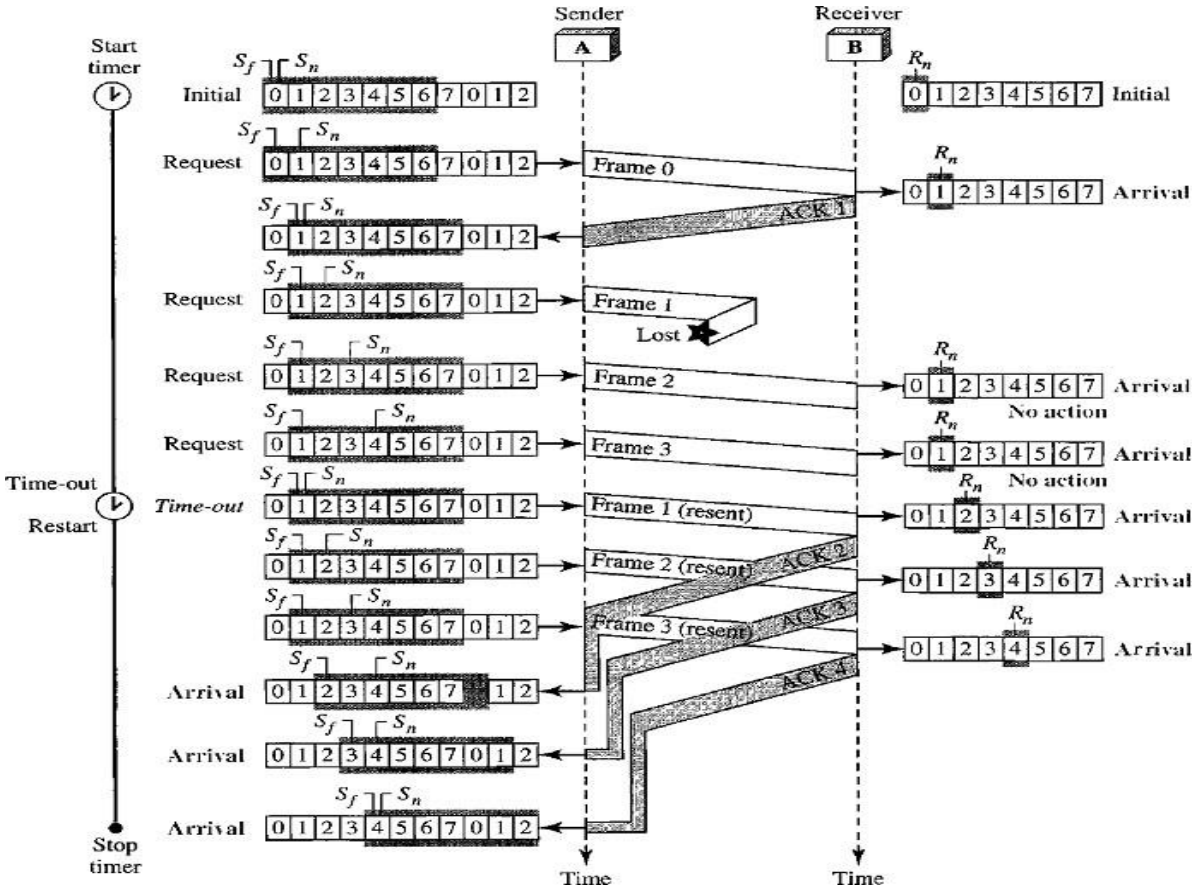
- Suppose the sender has already sent frame 6, but the timer for frame 3 expires.
- This means that frame 3 has not been acknowledged.
- The sender goes back and sends frames 3, 4,5, and 6 again.
- That is why the protocol is called ***Go-Back-N*** **ARQ**.

Flow Diagram

The below shows what happens when a frame is lost.

- Frames 0, 1, 2, and 3 are sent.
- Frame 0 is acknowledged but **Frame 1** is lost.
- The receiver receives frames 2 and 3, but they are discarded because they are received out of order (frame 1 is expected).
- The sender receives no acknowledgment about frames 1, 2, or 3.
- Its timer finally expires. The sender sends all outstanding frames (1, 2, and 3) because it does not know whether the frame is lost or corrupted.
- Note that the resending of frames l, 2, and 3 is the response to one single event.
- When the sender is responding to this event, it cannot accept the triggering of other events.
- This means that when ACK 2 arrives, the sender is still busy with sending frame 3.
- The physical layer must wait until this event is completed and the data link layer goes back to its sleeping state.
- Vertical line in the figure is to indicate the delay.

Note that before the second timer expires, all outstanding frames have been sent and the timer is stopped.



Disadvantage with Go-Back-N ARQ

Go-Back-N ARQ protocol is very inefficient for a noisy link.

- *Go-Back-N* ARQ simplifies the process at the receiver site.
- The receiver keeps track of only one variable, and there is no need to buffer out-of-order frames and they are simply discarded.
- In a noisy link a frame has a higher probability of damage; so it leads to the resending of multiple frames.
- This resending uses more bandwidth and slows down the transmission. This is a major disadvantage.

Solution: When there is just one frame is damaged, then only the damaged frame is resent, instead of resending from **Nth** frame. This will be achieved by using **Selective Repeat ARQ** Protocol.

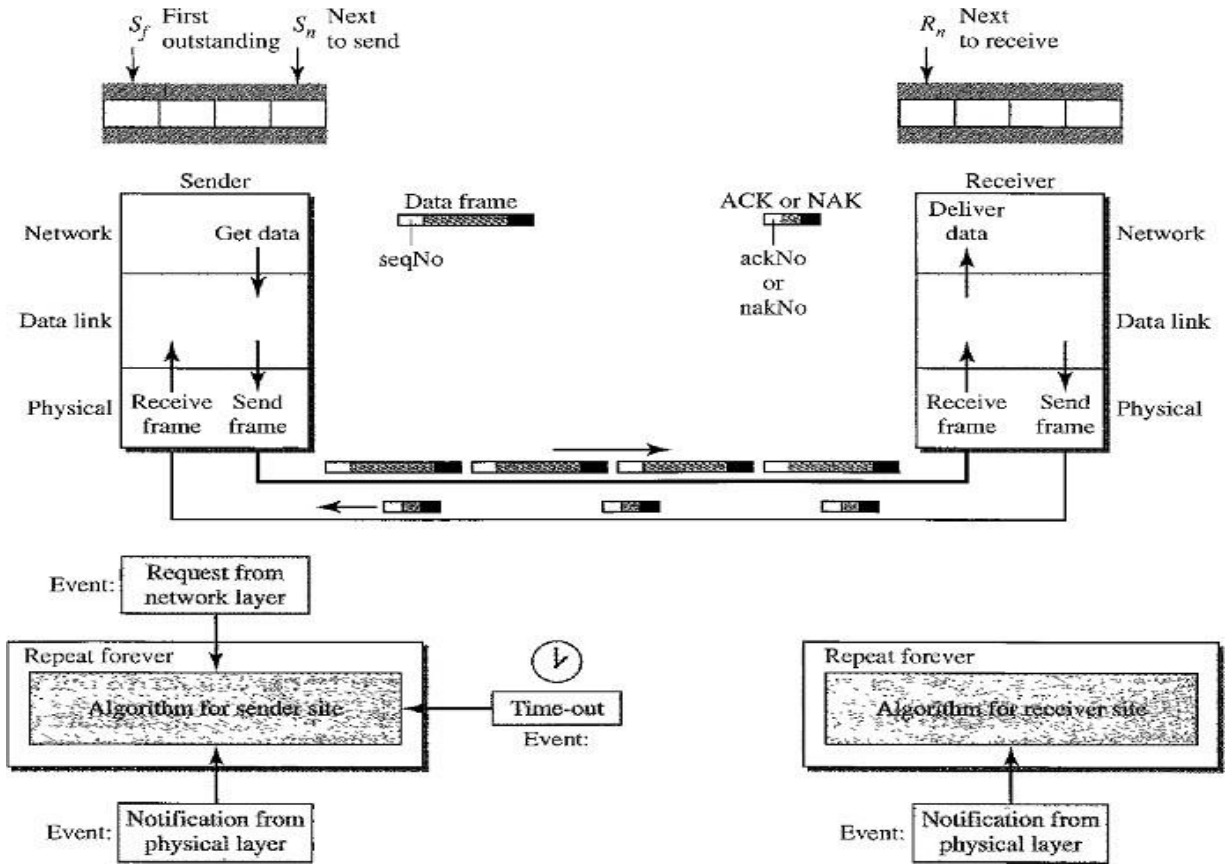
SELECTIVE REPEAT Automatic Repeat Request

It is more efficient for Noisy links but processing at the receiver is more complex.

Design

Window Sizes

Window size 2^{m-1} means the size of the sender and receiver window is at most one half of 2^m **(i.e** $2^m/2$).



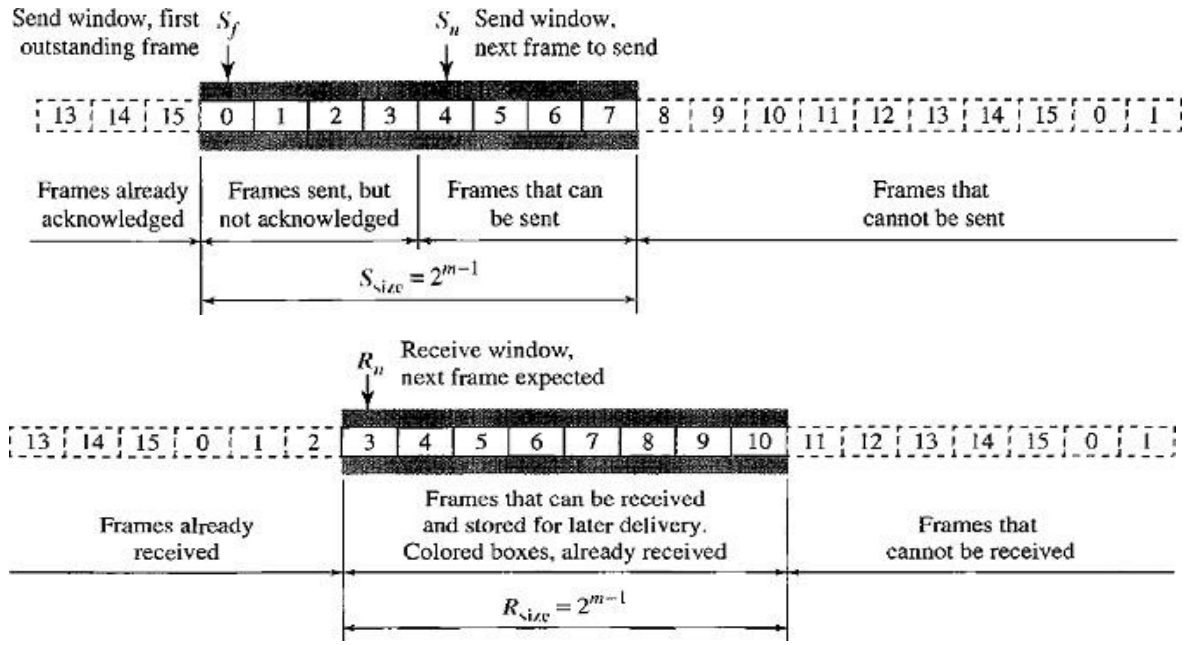
Windows

It uses two windows:

1. Send Window
2. Receive Window

The size of the send window and receive window is same as 2^{m-1}.

Example: If m = 4, the sequence numbers ranges from 0 to 15, but the size of the window is just 8.



- The Selective Repeat Protocol allows as many frames as the size of the receive window to arrive out of order and be kept until there is a set of in-order frames to be delivered to the network layer.
- Because the sizes of the send window and receive window are the same, all the frames in the send frame can arrive out of order and be stored until they can be delivered.
- We need to mention that the receiver never delivers packets out of order to the network layer.
- Those slots inside the receive window that are colored define frames that have arrived out of order and are waiting for their neighbors to arrive before delivery to the network layer.

Sender site:

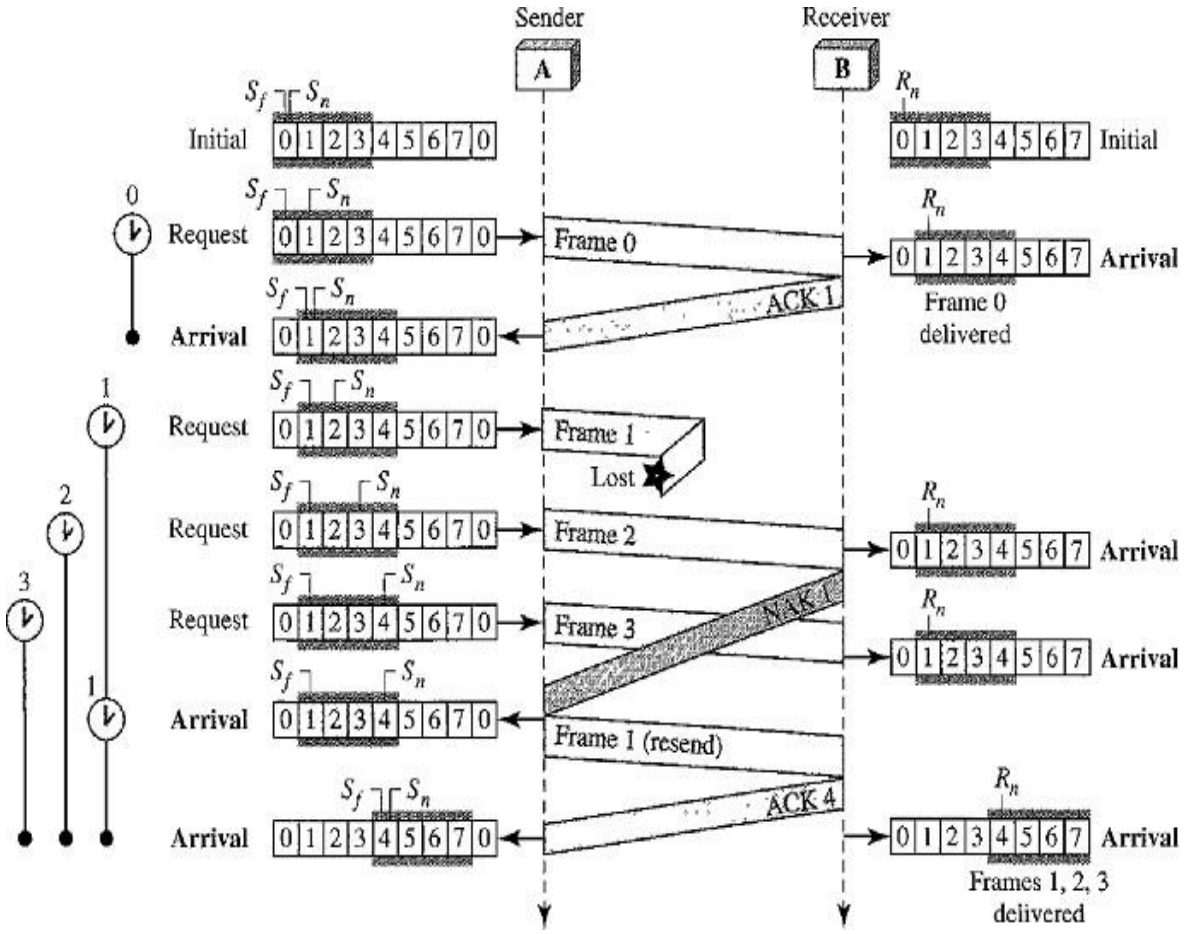
- For every request event a timer is started before sending any frame. The arrival event is more complicated. An ACK or a NAK frame may arrive at the sender site.
- If a valid NAK frame arrives, we just resend the corresponding frame.
- If a valid ACK arrives 3 actions will be done:
  1. Purge the buffers
  2. Stop the corresponding timer
  3. Move the left wall of the window.
- The time-out event is simpler, only the frame which times out is resent.

Receiver site:

- Receiver sends ACK and NAK frames to sender.
- If the Receiver receives a corrupted frame and a NAK has not yet been sent, Receiver sends a NAK to tell the sender that we have not received the frame we expected.
- If the frame is not corrupted and the sequence number is in the window, Receiver stores the frame and marks the slot.
- If contiguous frames, starting from R_n have been marked, Data link layer delivers their data to the network layer and slide the window.

Flow Diagram

By looking at the below flow diagram, we can observe below points:



Timers

- Each frame sent or resent needs a timer and the timers needs to be numbered such as 0,1,2,3..etc.
- The timer for frame 0 starts at the first request, but stops when the ACK for this frame arrives.
- The timer for frame 1 starts at the second request and restarts when a NAK arrives, and finally stops when the last ACK arrives.
- The other two timers start when the corresponding frames are sent and stop at the last arrival event.

Receiver Site

- At the receiver site we need to distinguish between the acceptance of a frame and its delivery to the network layer.
- At the second arrival, frame 2 arrives and is stored and marked (colored slot), but it cannot be delivered because frame 1 is missing.
- At the next arrival, frame 3 arrives and is marked and stored, but still none of the frames can be delivered.
- Only at the last arrival, when finally a copy of frame 1 arrives and frames 1, 2, and 3 be delivered to the network layer.
- There are two conditions for the delivery of frames to the network layer:
  i. a set of consecutive frames must have arrived.
  ii. the set starts from the beginning of the window.
- After the first arrival, there was only one frame and it started from the beginning of the window.
- After the last arrival, there are three frames and the first one starts from the beginning of the window.

Importance of NAK's

- Here a NAK is sent after the second arrival, but not after the third.
- The reason is that the protocol does not want to crowd the network with unnecessary NAKs and unnecessary resent frames.
- The second NAK would still be NAK1 to inform the sender to resend frame 1 again; this has already been done.
- The first NAK sent is remembered and is not sent again until the frame slides.
- A NAK is sent once for each window position and defines the first slot in the window.

Importance of ACK's

- There are only two ACKs are sent here. The first one acknowledges only the first frame The second one acknowledges three frames.
- In Selective Repeat, ACKs are sent when data are delivered to the network layer.
- If the data belonging to *n* frames are delivered in one shot, only one ACK is sent for all of them.
- In the above figure frame 1,2,3, are sent to Network layer and then ACK4 is sent, to represent that Frame1, Frame2, Frame3 are delivered.

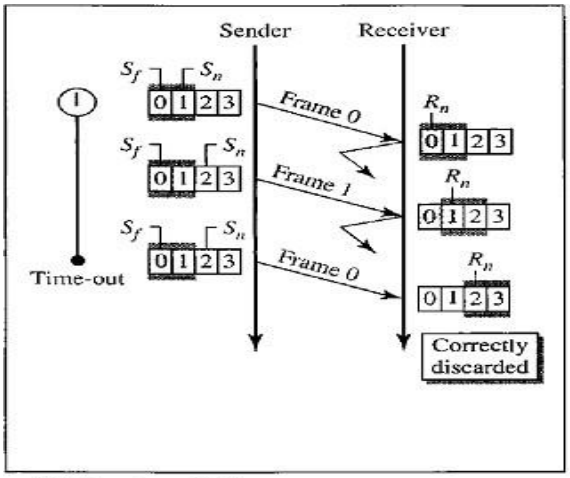
There is a question arises that :

Why the size of the sender and receiver windows is 2^{m-1}?

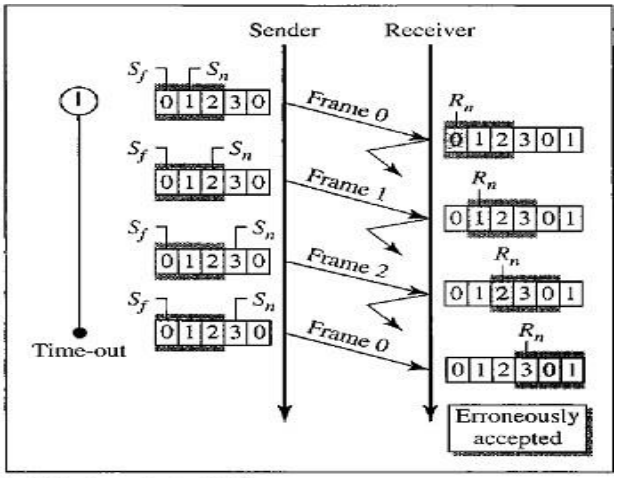
Sol: For an example, take m = 2, which means the size of the window is **$2^m/2$**, or 2.Now we compare window size=2 and window size =3.

Window size=2

- If the size of the window is 2 and all acknowledgments are lost, the timer for frame 0expires and frame 0 is resent.
- The window of the receiver is now expecting frame 2, not frame 0, so this duplicate frameis correctly discarded.



a. Window size = 2^{m-1}



b. Window size > 2^{m-1}

Window Size=3

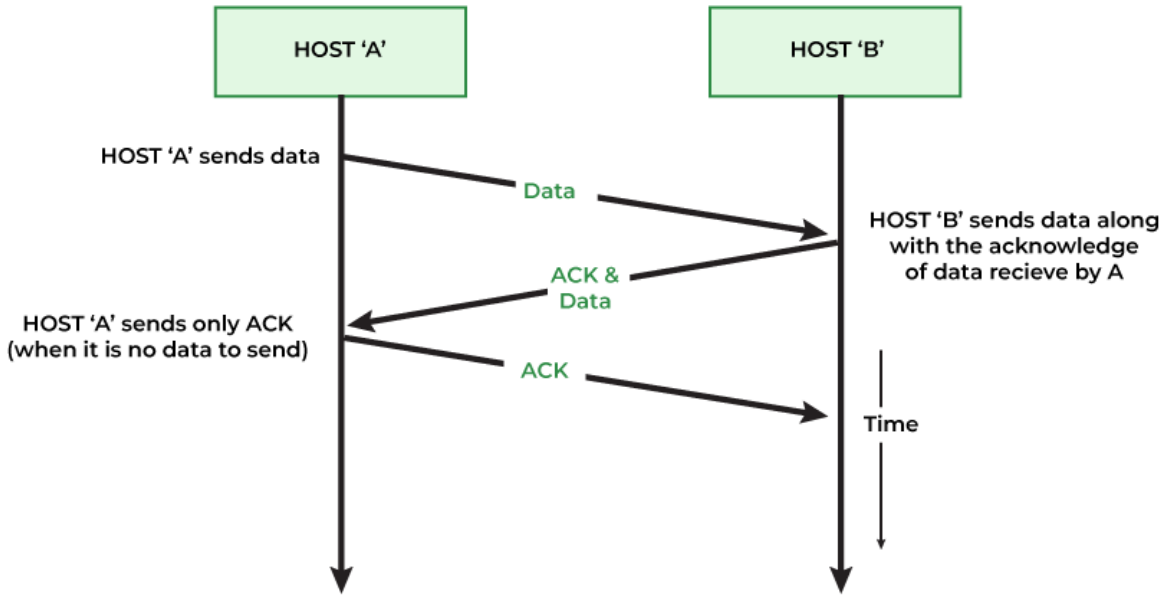
- When the size of the window is 3 and all acknowledgments are lost, the sender sends aduplicate of frame 0.
- However, this time, the window of the receiver expects to receive frame 0 (0 is part of thewindow), so it accepts frame 0, not as a duplicate, but as the first frame in the next cycle.
- This is clearly an error.

Piggybacking:

Piggybacking is the technique of delaying outgoing acknowledgment and attaching it to the next data packet.

When a data frame arrives, the receiver waits and does not send the control frame (acknowledgment) back immediately. The receiver waits until its network layer moves to the next data packet. Acknowledgment is associated with this outgoing data frame. Thus the acknowledgment travels along with the next data frame. This technique in which the outgoing acknowledgment is delayed temporarily is called Piggybacking.

Working of Piggybacking

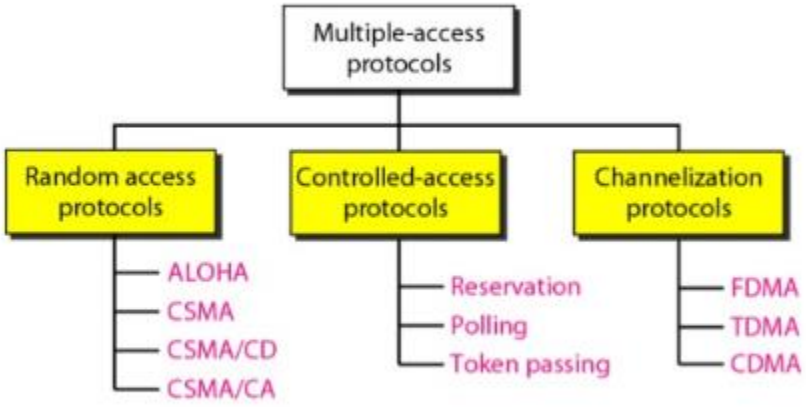


The Data Link Layer can be divided into 2 sublayers:

1. Data Link Control
2. Multiple Access Resolution

- The Multiple access resolution layers is responsible for resolving access to the shared media.

These protocols are categorized as below:



Random Access Protocols

Random Access method is also called Contention method.

- There is no scheduled time for a station to transmit. Transmission is random among the stations. That is why these methods are called **Random Access methods**.
- There are no rules to specify which station should send next. Stations compete with one another to access the medium. That is why these methods are also called **Contention Methods**.

If more than one station tries to send, there is an **Access Conflict-Collision** and the frames will be either destroyed or modified during the collision.

In order to avoid these collisions 4 protocols are implemented, they are:

- ALOHA
- CSMA
- CSMA/CD
- CSMA/CA

ALOHA

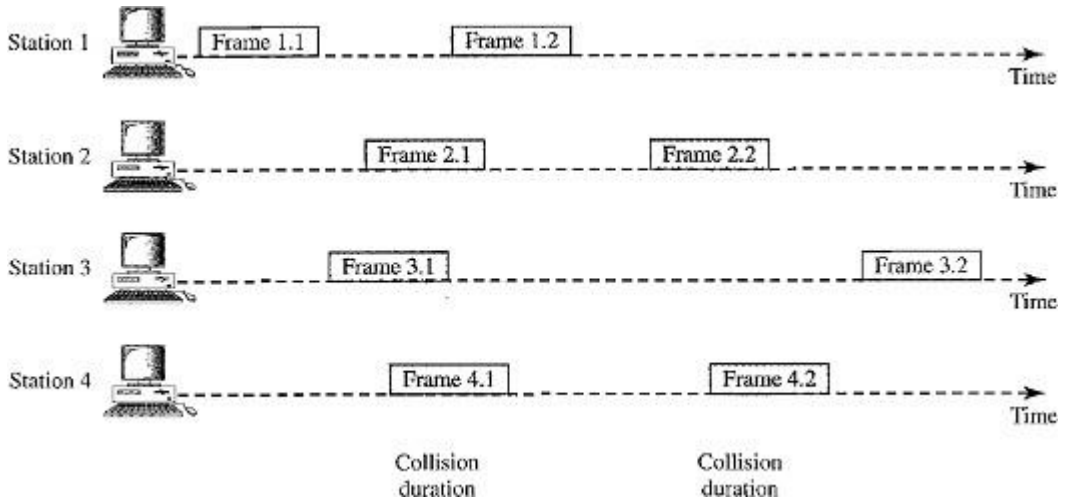
ALOHA was developed at the University of Hawaii in early **1970**. It was designed for a Wireless radio LAN, but it can be used on any shared medium. Due to shared medium there are potential collisions in this arrangement.

There are two types of methods in ALOHA 1. Pure ALOHA 2. Slotted ALOHA

Pure ALOHA

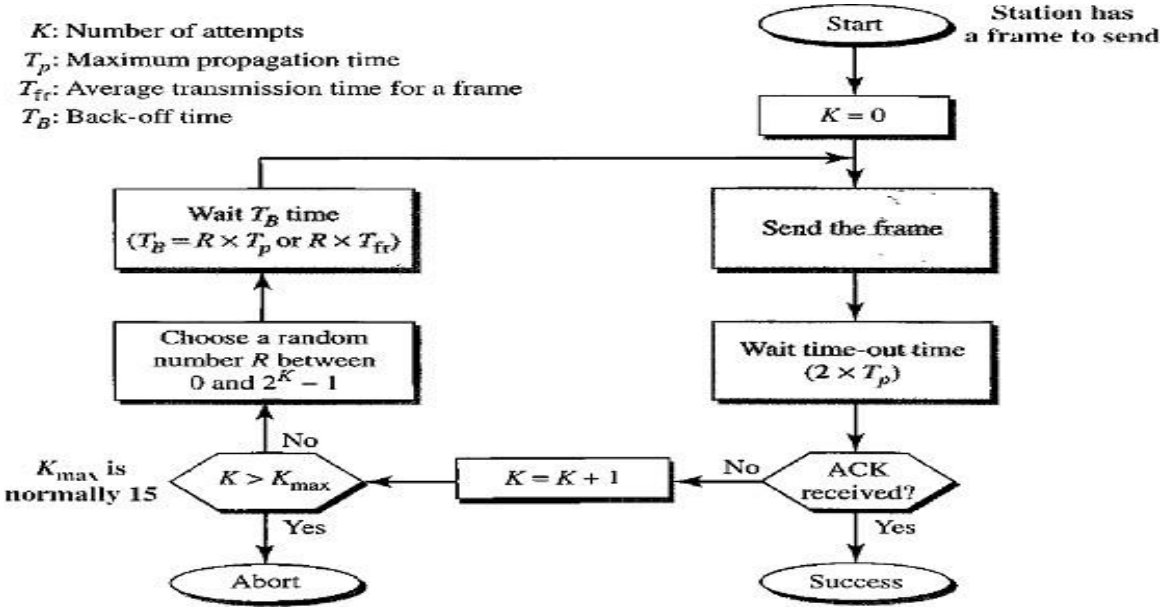
The original ALOHA or Pure ALOHA is a simple protocol.

The idea is that each station sends a frame whenever it has a frame to send, there is only one channel to share, and there is the possibility of collision between frames from different stations.



- In the above figure, there are four stations each sending two frames and shares the same channel. Some of these frames collide because multiple frames are in contention for the shared channel.
- By observing the above figure only 2 frames frame 1.1 and frame 3.2 can be delivered at receiver, and the remaining frames collide with each other and they are lost or discarded at the receiver side.
- The pure ALOHA protocol relies on Acknowledgments (ACK) from the receiver. When a station sends a frame, it expects the receiver to send an acknowledgment.
- If the acknowledgment does not arrive after a time-out period, the station assumes that the frame (or the acknowledgment) has been destroyed and resends the frame.
- A collision involves two or more stations. If all these stations try to resend their frames after the time-out, the frames will collide again.
- Pure ALOHA dictates that when the time-out period passes, each station waits a random amount of time before resending its frame. The randomness will help avoid more collisions; this time is called the Back-Off Time $\mathbf{T_B}$.
- Pure ALOHA has a second method to prevent congesting the channel with retransmitted frames. After a maximum number of retransmission attempts $\mathbf{K_{max}}$ a station must give up and try later.

The procedure for pure ALOHA is given in the figure:



- The time-out period is equal to the maximum possible round-trip propagation delay,which is twice the amount of time required to send a frame between the two most widely separated stations (2 x T_p).
- The back-off time T_B is a random value that normally depends on K (the number of attempted unsuccessful transmissions).
- For each retransmission, a multiplier in the range 0 to $2^K - 1$ is randomly chosen and multiplied by T_p (maximum propagation time) or T_{fr} (Frame transmission time or the average time required to send out a frame) to find T_B.
- Note that in this procedure, the range of the random numbers increases after each collision. The value of K_{max} is usually chosen as **15**.

Vulnerable time

Vulnerable time is the length of time, in which there is a possibility of collision.

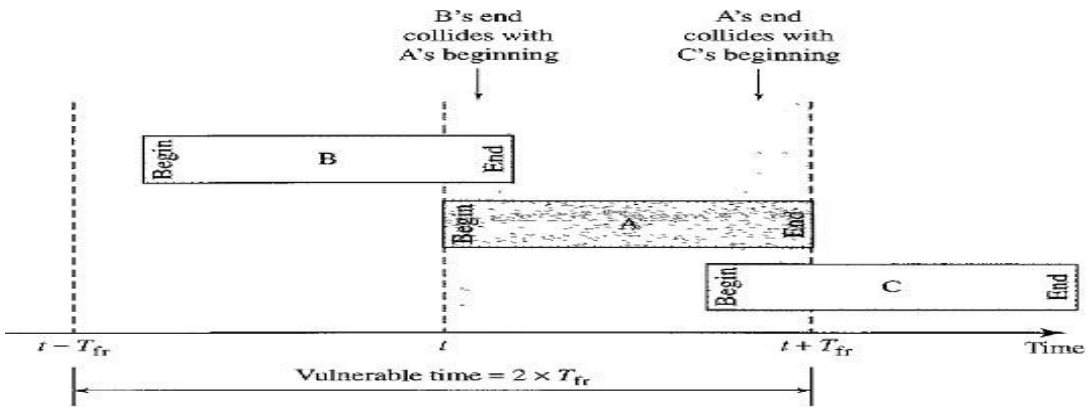
Let us assume that the stations send fixed-length frames with each frame taking T_{fr}**'s** to send.

Station A sends a frame at time **t.**

Now station B has already sent a frame between **t** - T_{fr} and **t**.

This leads to a collision between the frames from station A and station B.

The end of B's frame collides with the beginning of A's frame.



Suppose that station C sends a frame between **t** and **t + T_{fr}** .

Here, there is a collision between frames from station A and station C. The beginning of C's frame collides with the end of A's frame.

The vulnerable time, during which a collision may occur in pure ALOHA, is 2 times the frame transmission time.

Pure ALOHA vulnerable time = **2 x T_{fr}**

Throughput

- The throughput for pure ALOHA is **$S = G \times e^{-2G}$**.
- The maximum throughput **S_{max}** = 0.184 when G = (½).
- (i.e.) one frame is generated during two frame transmission times, then 18.4 percent of these frames reach their destination successfully.

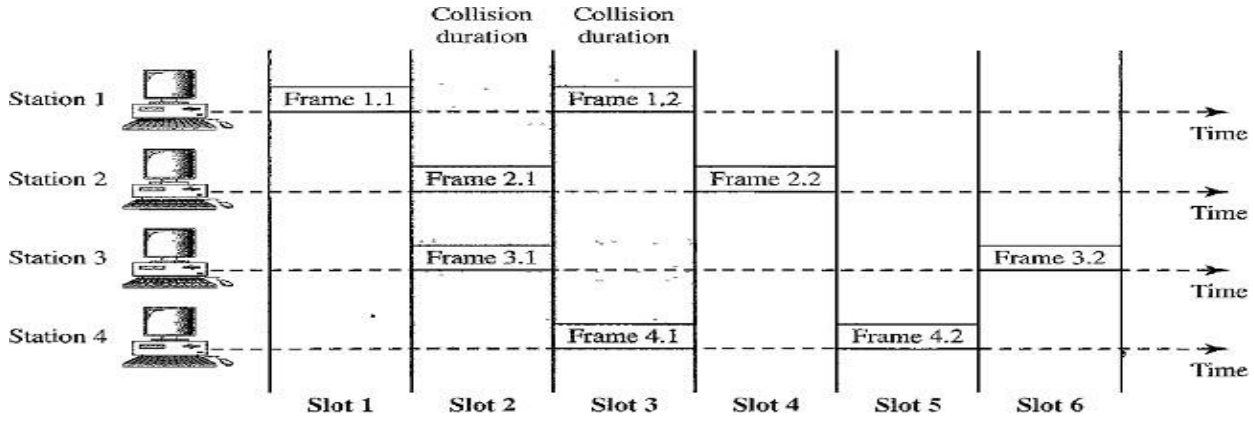
Slotted ALOHA

Pure ALOHA has a vulnerable time of **2 x T_{fr}** . This is so because there is no rule that defines when the station can send.

- A station may send soon after another station has started or soon before another station has finished.
- Slotted ALOHA was invented to improve the efficiency of pure ALOHA.
- In slotted ALOHA we divide the time into slots of **T_{fr}**"s and force the station to send only at the beginning of the time slot.
- A station is allowed to send only at the beginning of the synchronized time slot, if a station misses this moment, it must wait until the beginning of the next time slot.
- This means that the station which started at the beginning of this slot has already finished sending its frame.
- There is still the possibility of collision if two stations try to send at the beginning of the same time slot.

i.e. the vulnerable time for slotted ALOHA is one-half that of pure ALOHA.

Slotted ALOHA vulnerable time = **T_{fr}.**



Below figure shows an example of frame collisions in slotted ALOHA.

Throughput

- The throughput for slotted ALOHA is $S =: G \times e^{-G}$.
- The maximum throughput $S_{max} == 0.368$ when G =1.
- If a frame is generated during one frame transmission time, then 36.8 percent of these frames reach their destination successfully.

Example:

Consider a system generating 20 bit frames and connected through a shared 20kbps channel. Find throughput in percent if slotted ALOHA is used and frame rate is 1000 fps.

Frame size = L = 20 bits
Rate = R = 20kbps
Transmission time,T = L/R = $1 * 10^{-3}$ s
Throughput, S = G e^{-G}, where G= Number of frames per T
So, G = $1000 * 10^{-3} = 1$
Therefore, S = e^{-1} = 0.368 = 36.8%

CSMA (Carrier Sense Multiple Access)

It is a **carrier sense multiple access** based on media access protocol to sense the traffic on a channel (idle or busy) before transmitting the data. It means that if the channel is idle, the station can send data to the channel. Otherwise, it must wait until the channel becomes idle. Hence, it reduces the chances of a collision on a transmission medium.

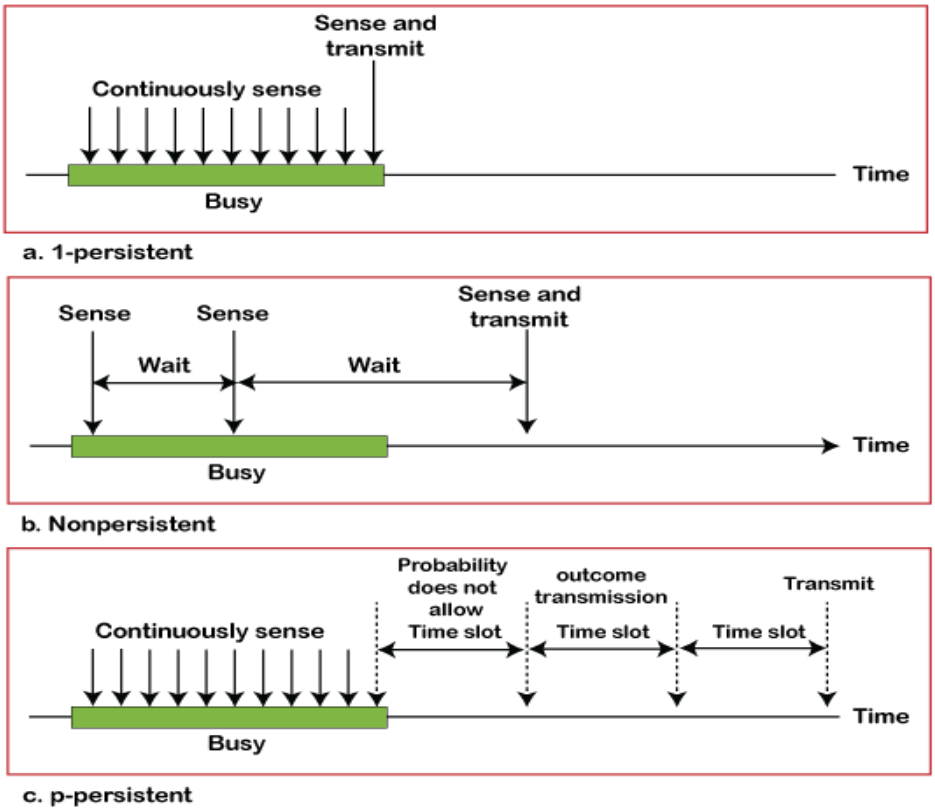
CSMA Access Modes

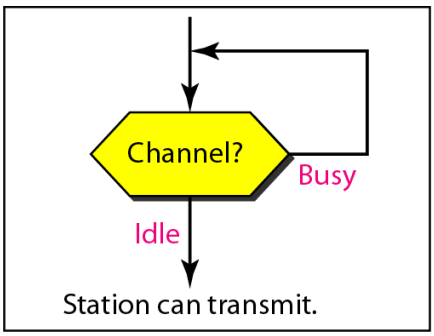
1-Persistent: In the 1-Persistent mode of CSMA that defines each node, first sense the shared channel and if the channel is idle, it immediately sends the data. Else it must wait and keep track of the status of the channel to be idle and broadcast the frame unconditionally as soon as the channel is idle.

Non-Persistent: It is the access mode of CSMA that defines before transmitting the data, each node must sense the channel, and if the channel is inactive, it immediately sends the data. Otherwise, the station must wait for a random time (not continuously), and when the channel is found to be idle, it transmits the frames.

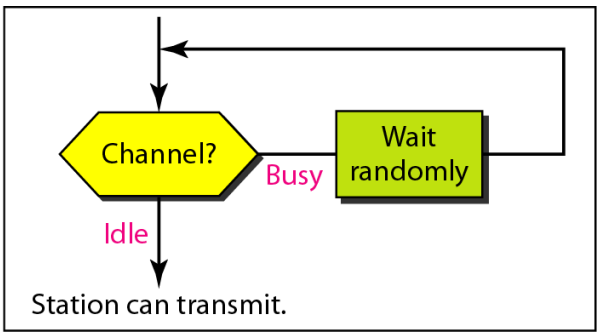
P-Persistent: It is the combination of 1-Persistent and Non-persistent modes. The P-Persistent mode defines that each node senses the channel, and if the channel is inactive, it sends a frame with a **P** probability. If the data is not transmitted, it waits for a (**q = 1-p probability**) random time and resumes the frame with the next time slot.

O- Persistent: It is an O-persistent method that defines the superiority of the station before the transmission of the frame on the shared channel. If it is found that the channel is inactive, each station waits for its turn to retransmit the data.

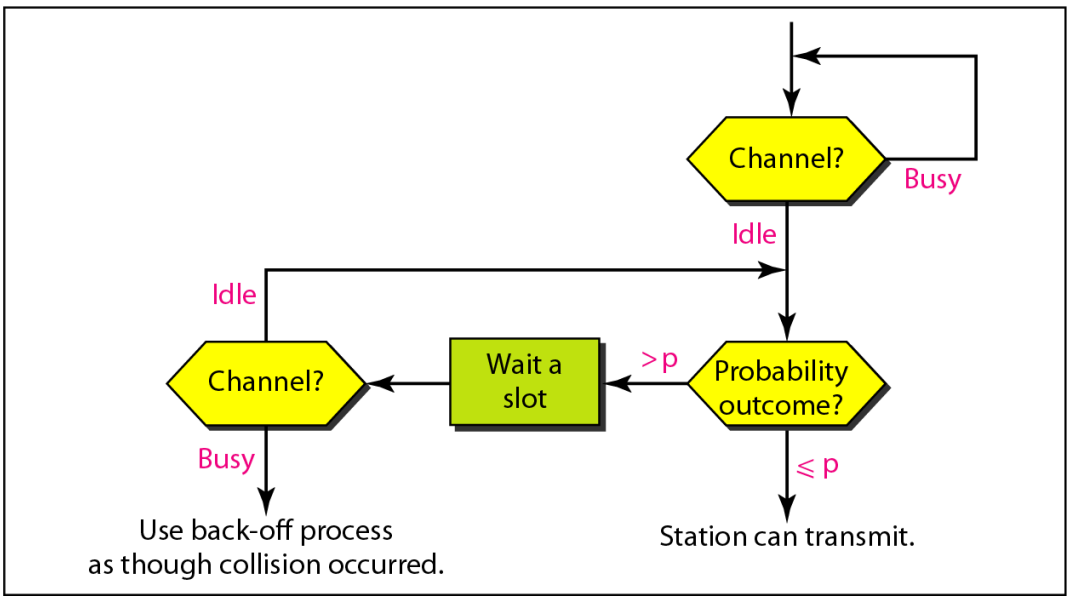




a. 1-persistent



b. Nonpersistent



c. p-persistent

CSMA/ CD

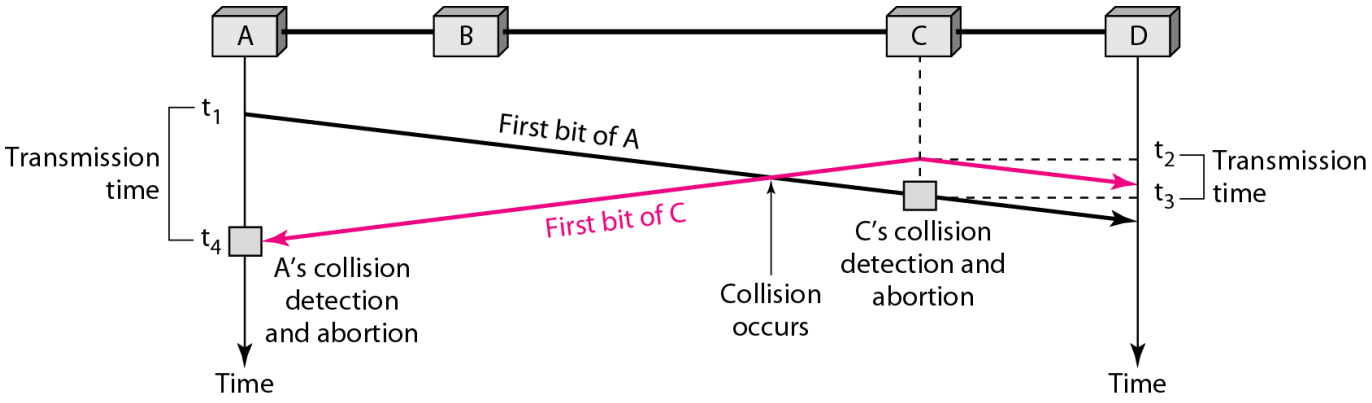
It is a **carrier sense multiple access/ collision detection** network protocol to transmit data frames. The CSMA/CD protocol works with a medium access control layer. Therefore, it first senses the shared channel before broadcasting the frames, and if the channel is idle, it transmits a frame to check whether the transmission was successful. If the frame is successfully received, the station sends another frame. If any collision is detected in the CSMA/CD, the station sends a jam/ stop signal to the shared channel to terminate data transmission. After that, it waits for a random time before sending a frame to a channel.

Carrier Sense Multiple Access with Collision Detection (CSMA/CD)

CSMA method does not specify the procedure following a collision but CSMA/CD augments the algorithm to handle the collision.

In this method, a station monitors the medium after it sends a frame to see if the transmission was successful.

- If it is successful the station is finished.
- If it not successful and there is a collision, the frame is sent again.



- At time **t 1**, station A has executed its persistence procedure and starts sending the bits of its frame.
- At time **t2**, station C has not yet sensed the first bit sent by A.
- Station C executes its persistence procedure and starts sending the bits in its frame, which propagate both to the left and to the right.
- The collision occurs sometime after time **t2** Station C detects a collision at time **t3** when it receives the first bit of A's frame. Station C immediately aborts transmission.
- Station A detects collision at time **t4** when it receives the first bit of C's frame; it also immediately aborts transmission.
- A transmits for the duration **t4 – t1**; C transmits for the duration **t3 - t2**
- At time **t4,** the transmission of A‟s frame is aborted; at time t3, the transmission of C's frame is aborted. Both are incomplete.
- This is so because the station, once the entire frame is sent, does not keep a copy of the frame and does not monitor the line for collision detection.

Minimum Frame Size (2Tp)

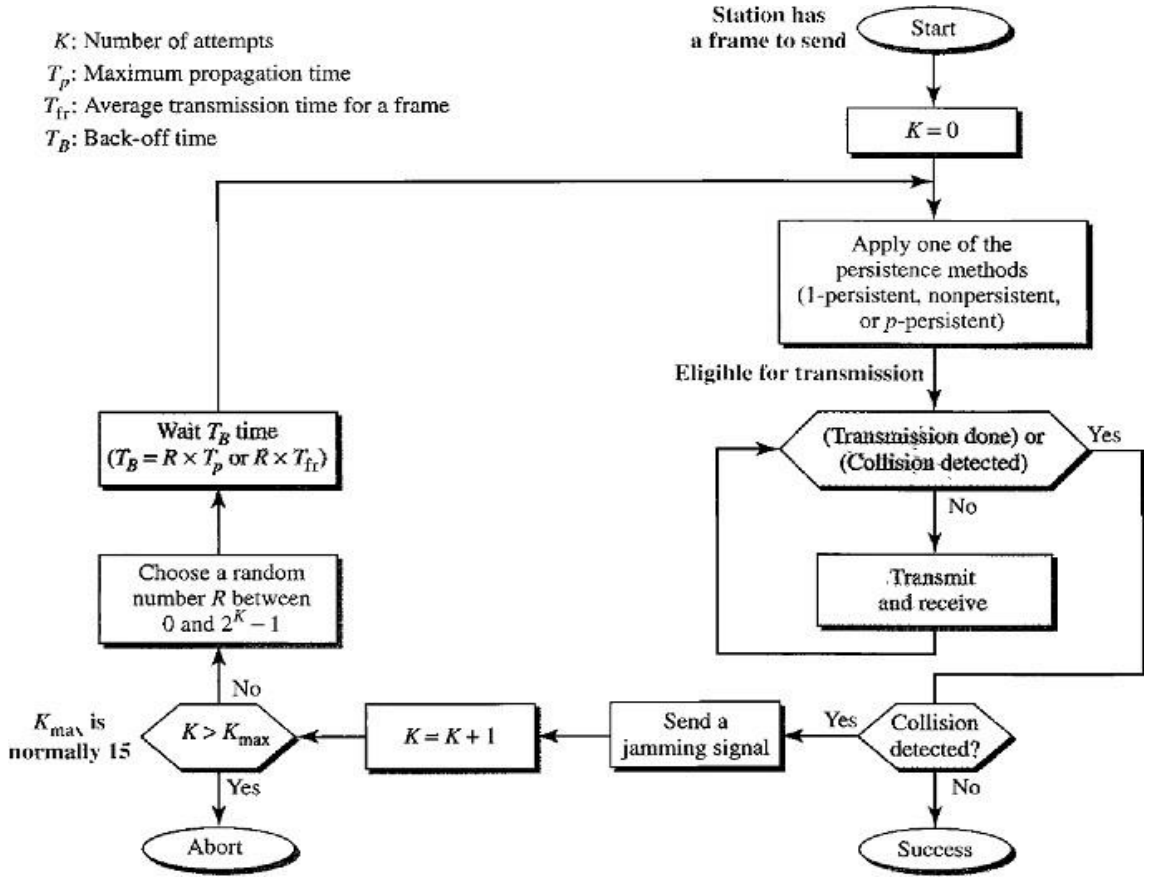
If the two stations involved in a collision are the maximum distance apart, the signal from the first station takes Tp time to reach the second station and the effect of the collision takes another Tp time to reach the first station.

Therefore, the frame transmission time $\mathbf{T_{fr}}$ must be at least two times the maximum propagation time Tp. So the first station must still be transmitting after 2Tp .

Procedure

- We need to sense the channel before we start sending the frame by using one of the persistence processes.
- In ALOHA, we first transmit the entire frame and then wait for an acknowledgment. In *CSMA/CD*, transmission and collision detection is a continuous process.
- We do not send the entire frame and then look for a collision. The station transmits and receives continuously and simultaneously using two different ports.
- We use a loop to show that transmission is a continuous process.
- We constantly monitor in order to detect one of two conditions:
  either transmission is finished or a collision is detected. Either event stops transmission.
- When we come out of the loop, if a collision has not been detected, it means that transmission is complete; the entire frame is transmitted. Otherwise, a collision has occurred.

- Here we send a short jamming signal that enforces the collision in case other stations have not yet sensed the collision.



CSMA/ CA

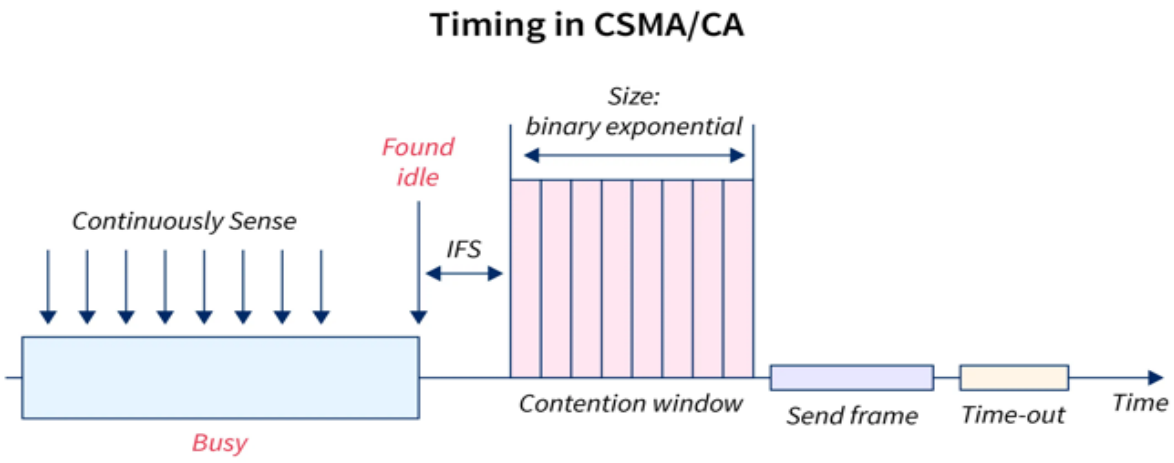
It is a **carrier sense multiple access/collision avoidance** network protocol for carrier transmission of data frames. It is a protocol that works with a medium access control layer. When a data frame is sent to a channel, it receives an acknowledgment to check whether the channel is clear. If the station receives only a single (own) acknowledgments, that means the data frame has been successfully transmitted to the receiver. But if it gets two signals (its own and one more in which the collision of frames), a collision of the frame occurs in the shared channel. Detects the collision of the frame when a sender receives an acknowledgment signal.

Following are the methods used in the CSMA/ CA to avoid the collision:

Interframe space: In this method, the station waits for the channel to become idle, and if it gets the channel is idle, it does not immediately send the data. Instead of this, it waits for some time, and this time period is called the **Interframe** space or IFS. However, the IFS time is often used to define the priority of the station.

Contention window: In the Contention window, the total time is divided into different slots. When the station/ sender is ready to transmit the data frame, it chooses a random slot number of slots as **wait time**. If the channel is still busy, it does not restart the entire process, except that it restarts the timer only to send data packets when the channel is inactive.

Acknowledgment: In the acknowledgment method, the sender station sends the data frame to the shared channel if the acknowledgment is not received ahead of time.



WIRED LANS: ETHERNET (802.3)

Local Area Network (LAN) is a computer network that is designed for limited geographic area such as building or campus. LAN is a shared resource.

LAN technologies: Ethernet, Token Ring, Token Bus, FDD, ATM LAN.

IEEE STANDARDS for LAN

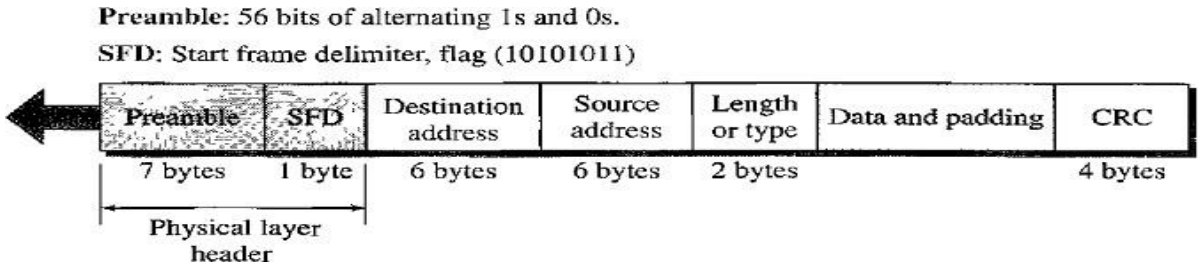
The IEEE has subdivided the data link layer into two sublayers:

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

Note: A frame defined in HDLC is divided into a PDU at the LLC sub layer and a frame at the MAC sub-layer

Frame Format

The Ethernet frame contains **seven** fields: Preamble, SFD, DA, SA, Length or Type of protocol data unit (PDU), Upper-layer data, and CRC.



Preamble

- The first field of the 802.3 frame contains 7 bytes (56 bits) of alternating 0"s and 1"s that alerts the receiving system to the coming frame and enables it to synchronize its input timing.
- The pattern provides only an alert and a timing pulse.
- The 56-bit pattern allows the stations to miss some bits at the beginning of the frame.

Note: The preamble is actually added at the physical layer and is not (formally) part of the frame.

Start Frame Delimiter (SFD)

- The second field (l byte: 10101011) signals the beginning of the frame.
- The SFD warns the stations that "This is the last chance for synchronization".
- The last 2 bits is 11 and alerts the receiver that the next field is the destination address.

Destination address (DA)

- The DA field is 6 bytes and contains the physical address of the destination station (i.e.) stations to receive the packet.

Source address (SA)

- The SA field is also 6 bytes and contains the physical address of the sender of the packet.

Length or Type

- This field is defined as a type field or length field. Both uses are common today.
- The original Ethernet used this field as the **Type field** to define the upper-layer protocol using the MAC frame.
- The IEEE standard used it as the length field to define the number of bytes in the data field.

Data

- This field carries data encapsulated from the upper-layer protocols.
- It is a minimum of 46 bytes and a maximum of 1500 bytes.

CRC

- The last field contains Error Detection information. The Length of this field is 4 byte (32-bit) hence a CRC-32 is used.

Addressing

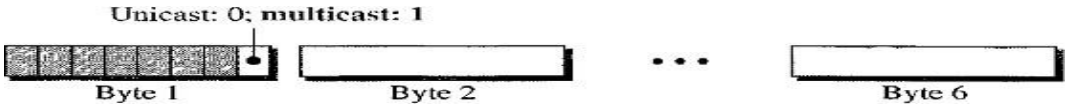
- Each station on an Ethernet network (such as a PC, workstation, or printer) has its own network interface card(NIC).
- The NIC fits inside the station and provides the station with a 6-byte physicaladdress.
- The Ethernet address is 6 bytes (48 bits), normally written in hexadecimal notation, with a colon between thebytes.

Example: **06 : 01 : 02 : 01 : 2C : 4B**

There are 3 types addressing:

1. UnicastAddressing
2. MulticastAddressing
3. BroadcastAddressing

- A source address is always a unicast address-the frame comes from only onestation.
- The destination address can be unicast, multicast, orbroadcast.
- If the least significant bit of the first byte in a destination address is 0, the addressis **Unicast Address,** otherwise (i.e. 1) it is **Multicast**.



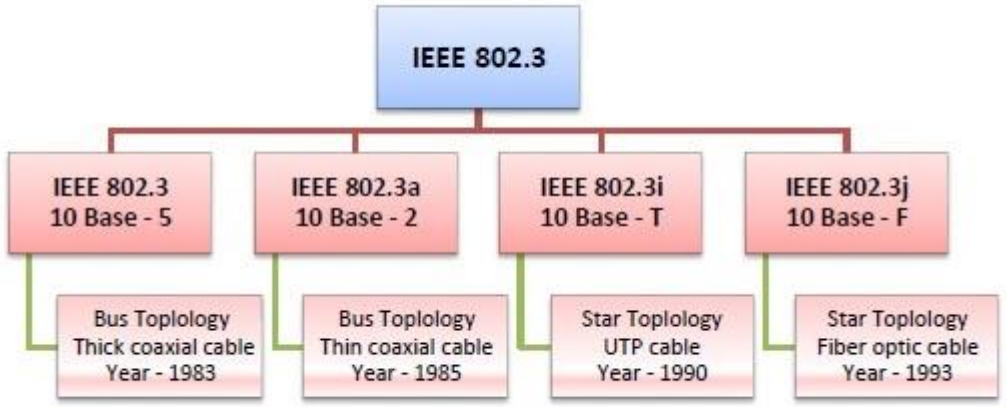
Unicast Destination Address defines only one recipient; the relationship between the sender and the receiver is one-to-one.

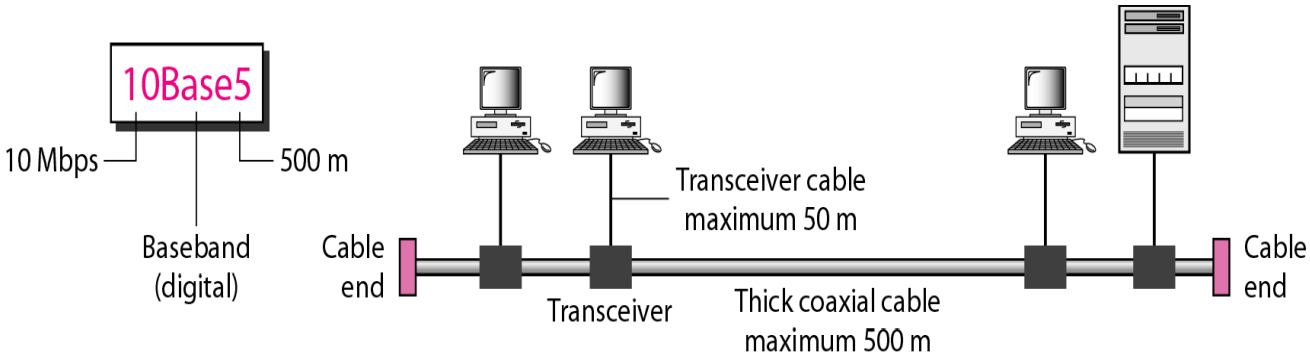
Multicast Destination Address defines a group of addresses; the relationship between the sender and the receivers is one-to-many.

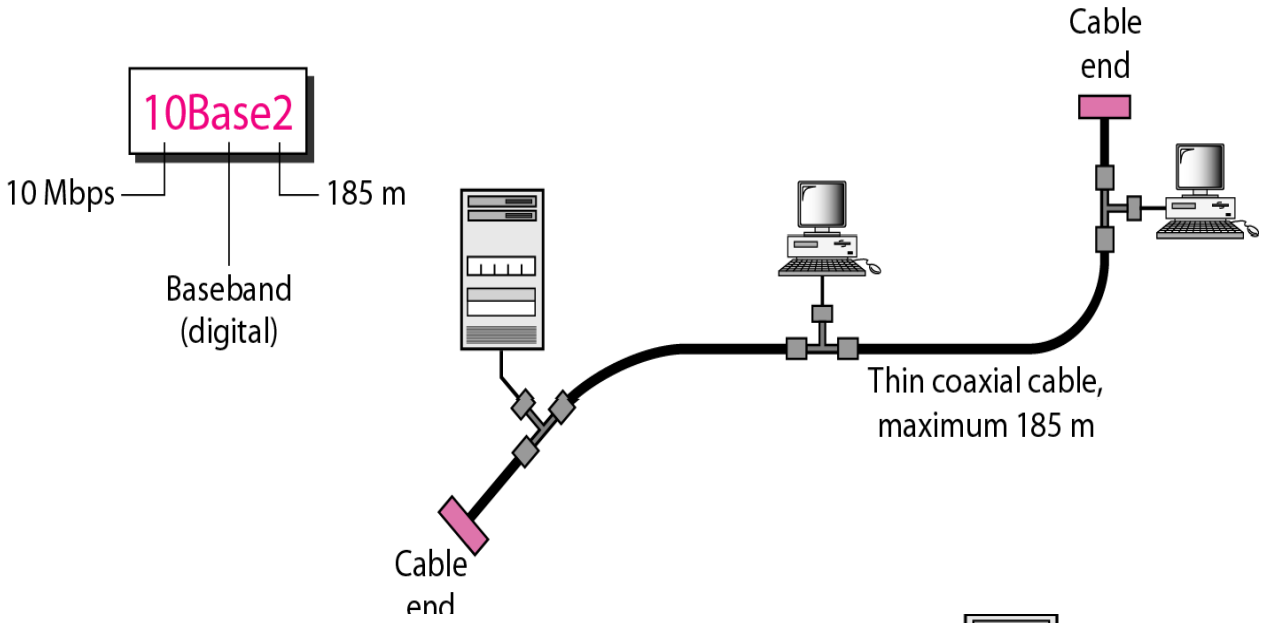
Broadcast Address is a special case of the multicast address; the recipients are all the stations on the LAN. A broadcast destination address is 48-1‟s (all 1‟s in theaddress).

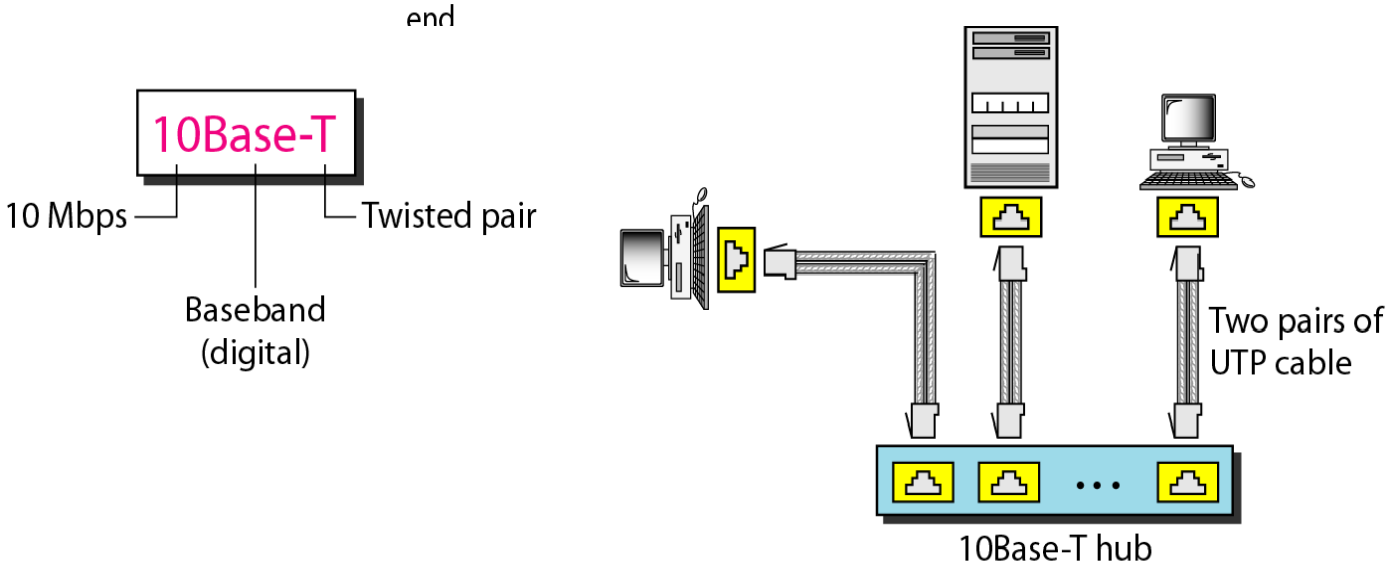
Slot time = round-trip time + time required to send the jam sequence

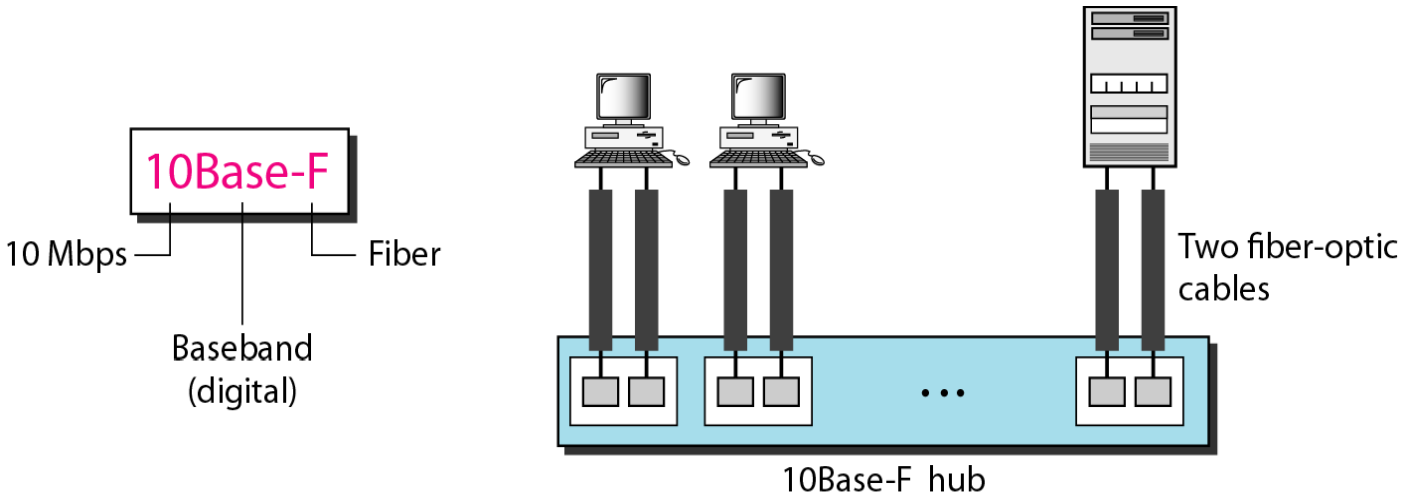
Categories of Standard Ethernet






10Base2
10 Mbps
185 m
Baseband
(digital)
Cable
end
Thin coaxial cable,
maximum 185 m
Cable
end


10Base-T
10 Mbps
Twisted pair
Baseband
(digital)
Two pairs of
UTP cable
10Base-T hub


10Base-F
10 Mbps
Fiber
Baseband
(digital)
Two fiber-optic
cables
10Base-F hub