1. Stop and Wait Protocols (Both SnW & SnW ARQ) with their Advantages and Disadvantages.

- Introduction:

The Stop-and-Wait Protocol is one of the Simplest data link layer protocol used for error control and flow control in computer networks. It is designed to ensure reliable communication between sender and receiver over a potentially unreliable channel. This protocol forms the foundation for more complex protocols like Sliding Window & ARQ-based mechanisms.

- Working of Stop and Wait protocol:

1. Initialization: The sender starts with a frame to send to the receiver.

2. Frame Transmission: The Sender sends a single data frame to the receiver.

3. Waiting for Acknowledgement: The sender halts all the operations and waits for a reply from receiver.

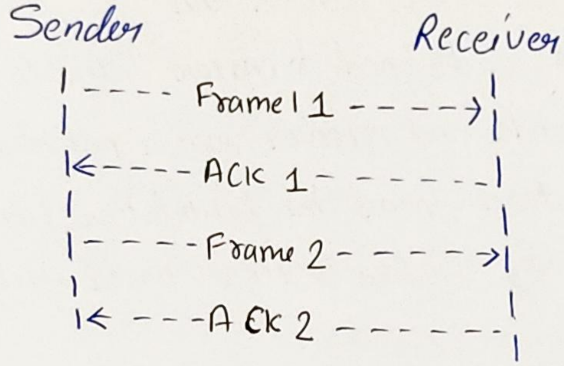
4. Acknowledgement handling:

- If the receiver receives the frame correctly, it send back an acknowledgement (ACK).

- If no acknowledgement is received (due to error, lost frame, or delay), the sender waits indefinitely unless timeout is used.

5. Next Frame Transmission: After receiving the ACK, the sender proceeds to send the next frame.

Diagram:



- Limitation of Basic Stop and Wait
  - The major issue with basic version is that it doesnot handle lost or ~~da~~ damaged frames. If frame or ACK is lost during transmission, the sender waits forever, causing the system to hang.
  - To overcome these challenges, the Stop and Wait ARQ (Automatic Repeat request) was developed.

- Stop and Wait ARQ (Automatic Repeat ~~repeat~~ request)

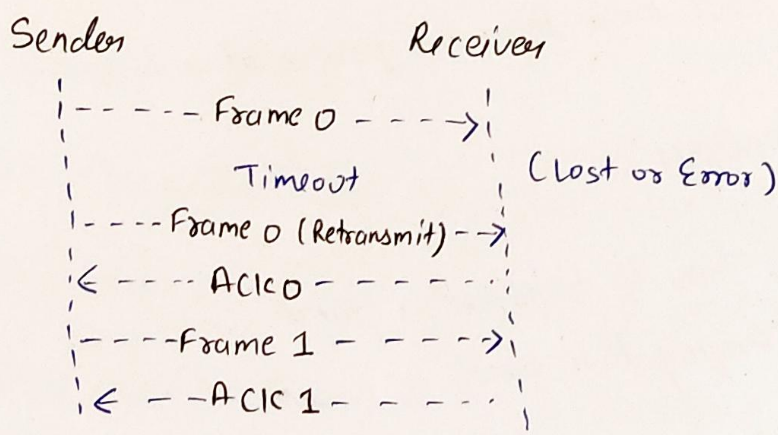
The Stop and Wait ARQ is a more reliable version of the basic Stop and Wait Protocol. It introduces three major improvements:

1. Sequence Numbers:
   - Each frame is assigned a unique sequence number, generally 0 or 1
   - This helps the receiver detect duplicates.

2. Timeout:
   - The sender sets a timer after sending a frame.
   - If the timer expires and no ACK is received, it automatically resends the same frame.
   - This ensures that lost frames or acknowledgement do not result in indefinite waiting.

3. Acknowledgement with feedback:
   - Acknowledgement is only sent if the frame is received correctly.
   - If the frame is damaged, the receiver discards it silently & sender resend it after timeout.

<u>Diagram:</u>



- Advantages of Stop and Wait ARQ:

1. Simple to implement - Ideal for small or embedded systems.
2. Provides reliable delivery over unreliable channels.
3. Good for low-speed links where delays are tolerable.
4. Detects and corrects losses & duplicate transmission.

- Disadvantages:

1. Insufficient for high-speed or long-delay networks:
   - Sender remain idle for long periods.
   - Leads to poor bandwidth utilization.
2. Throughput is very low:
   - Especially if the propagation delay is high compared to transmission time.
3. Limited window size of 1:
   - Cannot send more than one frame at a time.

- Efficiency Analysis:

Let:

T_trans = Time to transmit a frame

T_prop = Propagation time

Total time per frame = T_trans + 2* T_prop

Utilization (U) = T_trans / (T_trans + 2* T_prop)

As T_prop increases, U decreases.

2. Sliding Window Protocols (Go Back - N and selective Repeat) with proper diagram.

- To overcome the limitations of Stop and wait Protocols, Sliding window Protocols were introduced. These protocols allow multiple frames to be sent before waiting for acknowledgement, increasing the efficiency and throughput of the network.

A sliding window is a technique for flow control and error control, where sender maintains a window (a range of sequence numbers) that it can send without receiving an ACK for every frame individually.

There are 2 main types of sliding window protocols:

1. Go-Back-N (GBN)
2. Selective Repeat (SR)

Advantages:

1. Higher throughput than Stop and Wait.
2. Better channel utilization, especially on high-delay networks.
3. Allows multiple frames to be in transmit, maximizing network efficiency.
4. Efficient handling of lost or out-of-order frames.

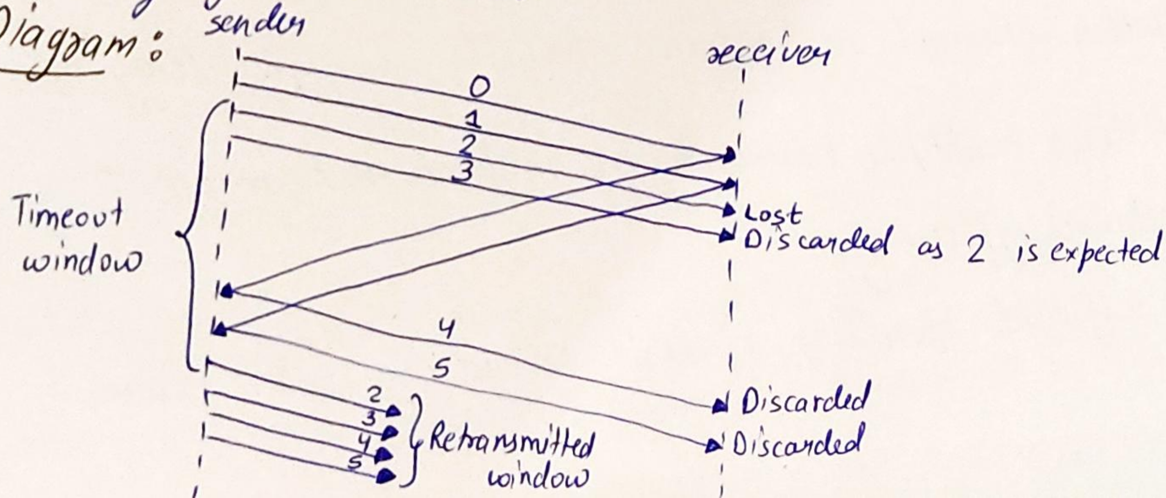
⇒ Go-Back-N (GBN) Protocol:

Go-Back-N is a sliding window protocol where the sender can send multiple frames (upto to N) before needing an ACK, but the receiver only accept frames in order.

How its worked:

1. Sender's Window:
   - Maintains a window of size N.
   - Can send all frames within the window without waiting.
2. Receiver's Side:
   - Always expects the next frame in order.
   - If frame i is lost, all frames after i are rejected even if correct
3. Acknowledgement:
   - Receiver sends cumulative ACKs.
   - ACK for frame i means all frames upto i are received.
4. Error Handling:
   If a frame is lost or corrupted, the sender resends all frames starting from the error.

<u>Diagram</u>:



Advantages of Go-Back-N :

1. More efficient than Stop and Wait - allows multiple frame in flight.
2. Simpler receive logic - it only accept frames in order.
3. Cummulative ACKs - reduces the number of ACK packets needed.

Disadvantages of Go-Back-N:

1. Waste bandwidth if a single frame is lost - all subsequent frames retransmitted.
2. Receiver discards correct frames that arrive out of order.
3. Higher retransmission cost, espicially in poor network conditions.

=> Selective Repeat Protocol (SR)

Selective Repeat improves on Go-Back-N by allowing the receiver to accept out-of-order frames & only request retransmission of specific lost or damaged frames.

How it Works:

1. Sender Window:- Maintain a sliding window of size N
   - Sends multiple frames, just like GBN.
2. Receiver Side:- Maintain a window of the same size.
   - Accepts any frames within the window.
   - Stores the frame in a buffer & waits for missing one.
3. Acknowledgement :- Each frame is acknowledgement individially.
   - If frame 2 is lost, only frame 2 is resent - not frame 4, 5, etc.

→ Advantages:

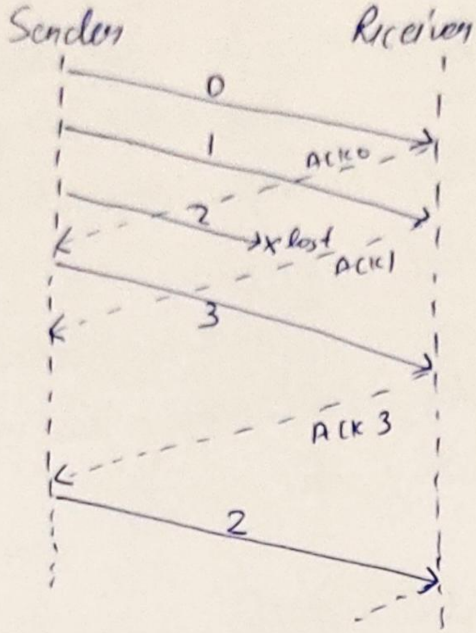
1. Highly efficient - retransmits only whats needed.
2. Maximize bandwidth usage in highly-delay, high error network
3. No need to resend already-received frames.

⇒ Go-Back-N (...

Disadvantages:

1. More Complex Implementation - both sender & receiver need buffers & tracking mechanisms.
2. Individuals ACKs can result in more control messages.
3. Receiver must reorder out-of-order frames, increasing memory usage.

Diagram:



→ Go-Back-N V/S Selective Repeat (Comparison Table)

Feature	Go-Back-N	Selective Repeat
ACK Type	Cumulative	Individual
Frame Handling	Discard out-of-out order frames	Accept out-of-order frames
Retransmission	From error onwards	Only the specific lost frame
Complexity	Simpler	More Complex
Efficiency	Lower	Higher
Buffer at Receiver	Not required	Required

3. Multiple Access Protocols (Pure Aloha & Slotted Aloha) with their differences and implementation.

· In communication networks, when multiple devices share the same channel, there is a high possibility of data collection if two or more devices transmit at the same time. To handle this, Multiple Access Protocol are used. These protocols manage how different devices can access and use the shared medium efficiently and reduce the chance of collisions.

Two multiple Access Protocols are:

1) Pure Aloha

2) Slotted Aloha

Pure ALOHA Protocol -

- How its work :

• Stations transmit data anytime they want, without checking if the channel is free.

• After sending, the stations waits for an Acknowledgement.

• If no ACK is received within a time frame, the station assumes a collision occured and retransmits the data after a random backoff time.

Key Concepts:

1. No synchronisation - transmission can happen any time
2. Vulnerable time = 2 × Transmission Time - chances of collision are hig
3. Collisions are detected directly by lack of ACK.

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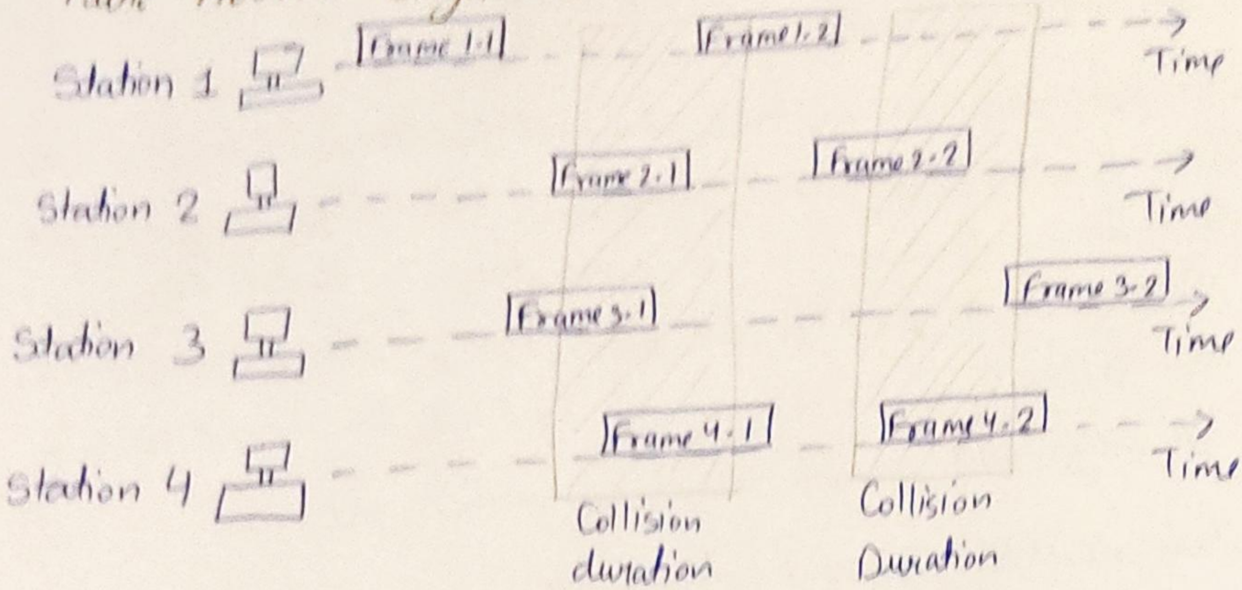
① Pure ALOHA Diagram:



⇒ Advantages of Pure ALOHA

1. Simple and easy to implement - no complex coordination needed.
2. Decentralized - every device can transmit freely.
3. Suitable for low-traffic network like satellite communication.

⇒ Disadvantages of Pure ALOHA

1. High collision rate, especially in high-traffic networks.
2. Very low efficiency - maximum throughput is only 18.4%
3. Poor use of channel capacity.

=> Slotted ALOHA Protocol:

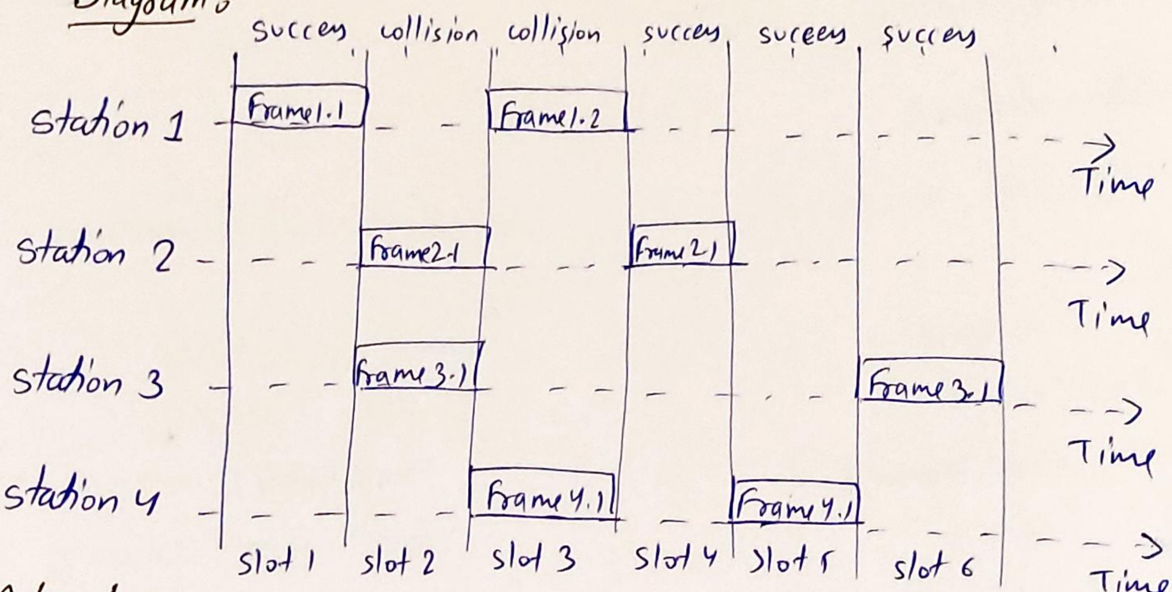
How it Works:-

- Time is divided into equal slots, and each station can only send at the start of a slot.
- This reduces the chance of collision because devices are synchronized to time slots.
- Like Pure ALOHA, stations wait for ACKs and retransmit on failure after a random delay.

→ Key concepts

- Synchronization is required among devices.
- Vulnerable Time = 1 × Transmission Time (half of Pure ALOHA)
- Higher channel utilisation that Pure ALOHA.

Diagram:



→ Advantages:

1. Improve efficiency over Pure ALOHA.
2. Lower collision probability due to time slot restriction.
3. Better suited for medium-load networks.

→ Disadvantages:

1. Require Time Synchronization, which add complexity.
2. Still has collisions, just less frequent that Pure ALOHA.
3. Maximum efficiency is only 36.8% - still not ideal for modern high-speed networks.

→ Comparison Table: Pure ALOHA vs Slotted ALOHA

Feature	Pure ALOHA	Slotted ALOHA
Time Synchronization	Not required	required
Transmission Time	Any time	Only at beginning of slot
Vulnerable time	2× Transmission time	1× Transmission Time
Efficiency	~18.4%	~36.8%
Collision Rate	High	Lower than Pure ALOHA
Implementation complexity	Simple	Moderate

⇒ Implementation:

Pure ALOHA pseudocode:

```
loop:
    if data to send:
      send (data)
    wait (ACK_Timeout)
    if no ACK:
       wait (random_backoff)
    go to loop
```

Slotted ALOHA Pseudocode

```
loop:
    wait_for_slot()
    if data to send:
      send (data)
      wait (ACK_TIMEOUT)
    if no ACK:
       wait (random_backoff)
      go to loop.
```