Round Trip Time [RTT]

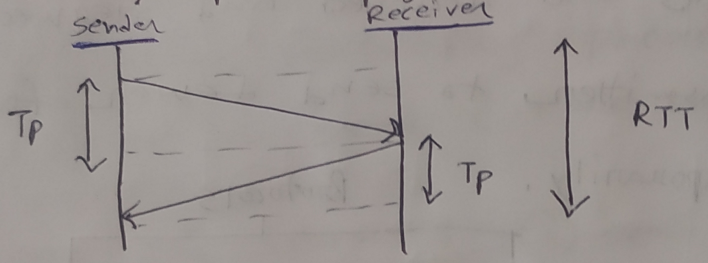
Also known as Round Trip Delay Time (RTD).

* It is the length of time it takes for a signal to be sent plus the length of time it takes for an acknowledgement of that signal to be received.

অর্থাৎ সিগন্যাল পাঠাতে যতটুকু সময় লাগে + এর প্রাপ্তিস্বীকার এর সময়।

This time consists of propagation time between two points

$RTT = 2T_p$, where, T_p = Propagation Time



Flow control

One of the service provided by data link layer is flow control.

☆ Speed Maching Mechanism. Receiver sender কে বলবে কতটুকু speed এ data পাঠালে সে রিসিভ করতে পারবে।

Defination -

* Flow control coordinates the amount of data that can be sent before receiving an acknowledgment.
* Flow control is a set of procedures that tells the sender how much data it can transmit before it must wait for an acknowledgement from the receiver.

Receiver কে সময় দিতে হবে -

Sender fast, receiver slow → Problem!

" slow, " fast → not a problem!

* Receiver has a limited speed at which it can process incoming data & a limited amount of memory in which to store incoming data.

* Receiver must inform the sender before the limits are reached and request that the transmitter to send fewer frames or stop temporarily.

Protocols

Noisy channels

- ☆ Stop and Wait ARQ
- ☆ Go Back N ARQ
- ☆ Selective Repeat ARQ

Noiseless Channels

- ☆ Simplest
- ☆ Stop and Wait

Noiseless – Stop & Wait Protocol

Noiseless channel এ data link layer protocol হিসেবে Stop & Wait protocol ব্যবহার হয়।

Undirectional data transmission (✓) Error control (✗)

Unidirectional → sending ও Receiving একসাথে সম্ভব না।

একটি ফ্রেম send করার পর acknowledgement পাবে তারপর অন্য ফ্রেমটি send করবে।

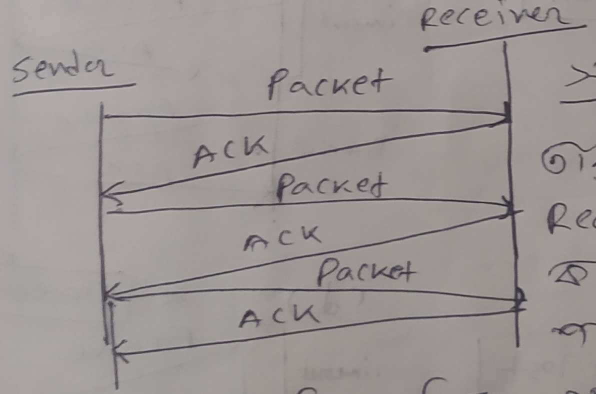
Rules →

Sender: Rule 1: send one data packet at a time.

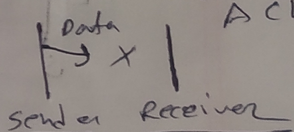
Rule 2: send the next packet only after Receiving ACK for the previous.

Receiver: Rule 1: Receive and consume data packet.

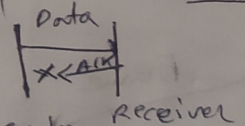
Rule 2: After consuming packet, ACK need to be send (Flow control).



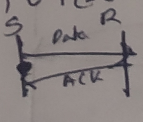
সমস্যাঃ (i) sender ডাটা পাঠালো তারপর মাঝপথে হারিয়ে গেলো, Receiver কে অনেক সময় অপেক্ষা করতে হবে। ACK পাবেনা।



(ii) ACK যদি হারিয়ে যায়, তখন sender কে অপেক্ষা করতে হবে,



(iii) ACK দেরিতে (timeout) পাঠালে sender ভাববে এটি অন্য কোনো data এর ack.



Noisy — Stop & Wait ARQ Protocol

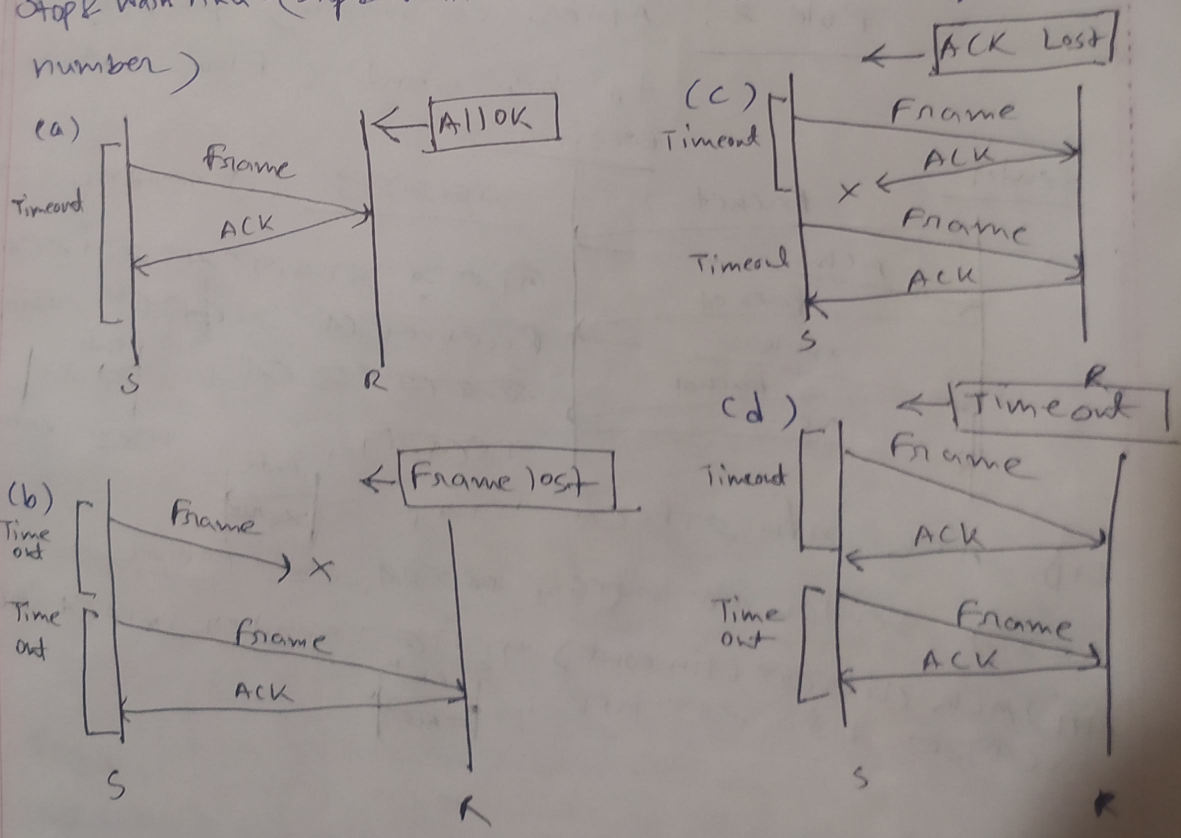
ARQ = Automatic Repeat Request

* After transmitting one frame, the sender waits for an acknowledgement before transmitting the next frame.

* If the ACK does not arrive after a certain period of time, the sender times out & retransmits the original frame.

অর্থাৎ ACK নির্দিষ্ট সময়ের মধ্যে না পেলে sender টি ফ্রেমটি পুনরায় পাঠাবে।

Stop & Wait ARQ = (Stop & Wait + Timeout Timer + Sequence number)



Sliding Window Protocol

Sliding Window Protocol →

(i) Go-Back-N-ARQ

(ii) Selective Repeat ARQ

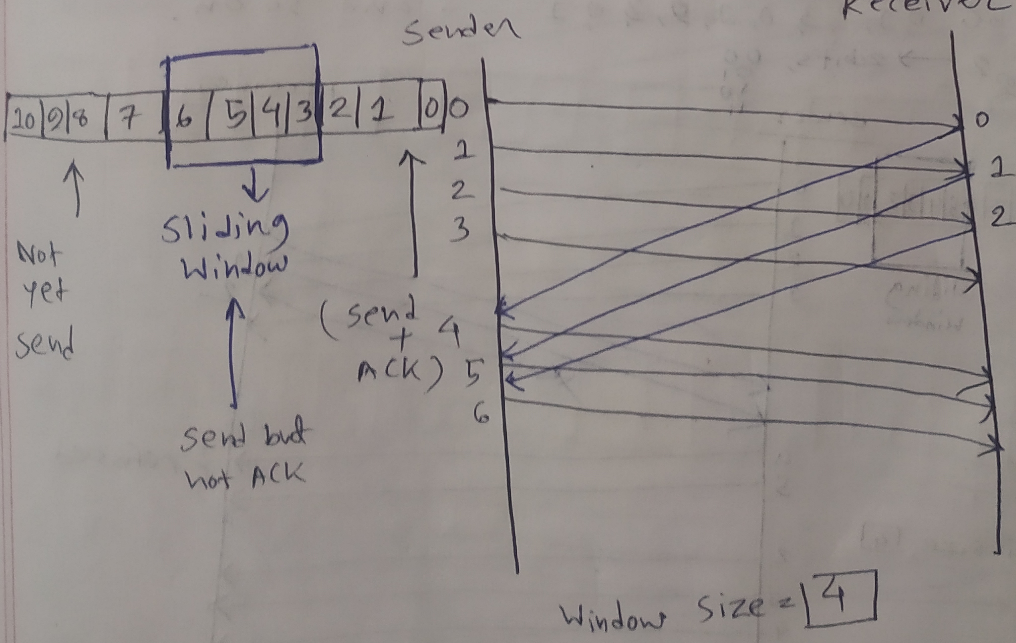
Stop-N-Wait ARQ Protocol drawbacks?

(i) sends one data packet at a time

(ii) Poor utilization of bandwidth, যার ফলে,

(iii) Poor Performance

Sliding window Protocol এ একসাথে multiple frame
পাঠানো যায়। Window size এর উপর based on.
প্রতিটা ফ্রেম নাম্বারিং করা থাকে sequence
Number দ্বারা।



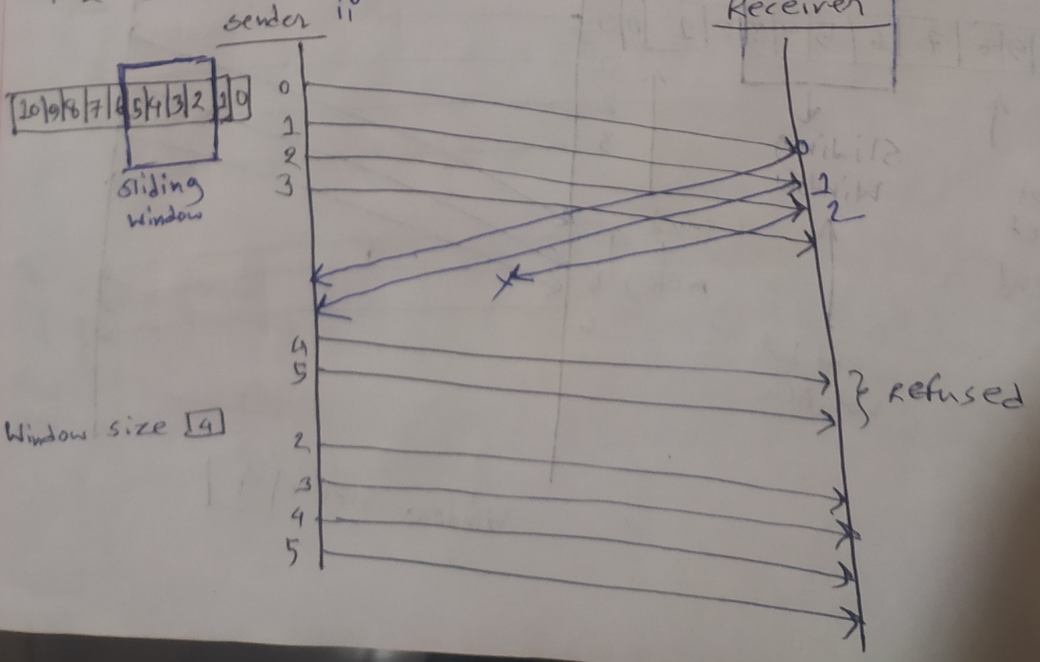
Noisy – Go – Back – N – ARQ

N = sender window size

* Uses the concepts of protocol pipelining. eg → sender can send multiple frames before receiving the acknowledgement for the first frame.
* Finite numbers of frames are numbered in sequential manner.
* sending frame limit depends on N.
* ACK is not received within an agreed time period ? all frames will be retransmitted.

If sending window is 4 (2^2), the sequence numbers will be 0, 1, 2, 3, 0, 1, 2, 3, 0, 1 - - - and so on.

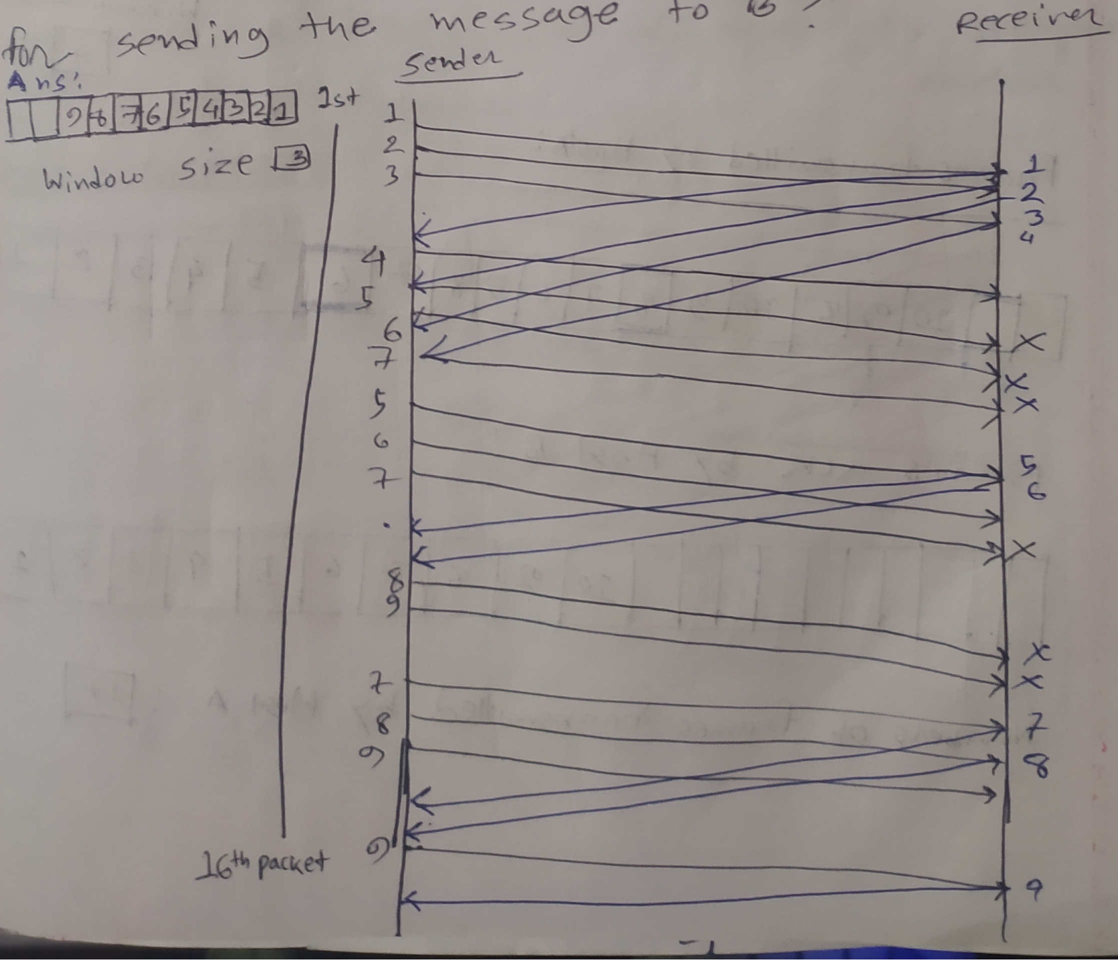
$4 = 2^2 = \rightarrow$ 2 bits, 00 01 10 11



Example 1 (GATE CS 2006):

Station A needs to send a message consisting of 9 packets to station B using a sliding window (window size 3) and go-back-n error control strategy. All packets are ready and immediately available for transmission. If every 5th packet that A transmits gets lost (but no ACKs from B ever get lost), then what is the number of packets that A will transmit for sending the message to B?

Ans:



Example-2: (Shortcut)

Host A wants to send 10 frames to Host B. The host agreed to go with Go-Back-4. How many number of frames are transmitted by Host A if every 6th frame that is transmitted by Host A is either corrupted or lost?

Ans:

sender window

10	9	8	7	6	5	4	3	2	1

Window size $\boxed{4}$

Frames transmitted by Host A:

		10	9	8	10	9	8	7	6	9	8	7	6	5	4	3	2	1

Frames ack by Host B:

									10	9	8	7	6	5	4	3	2	1

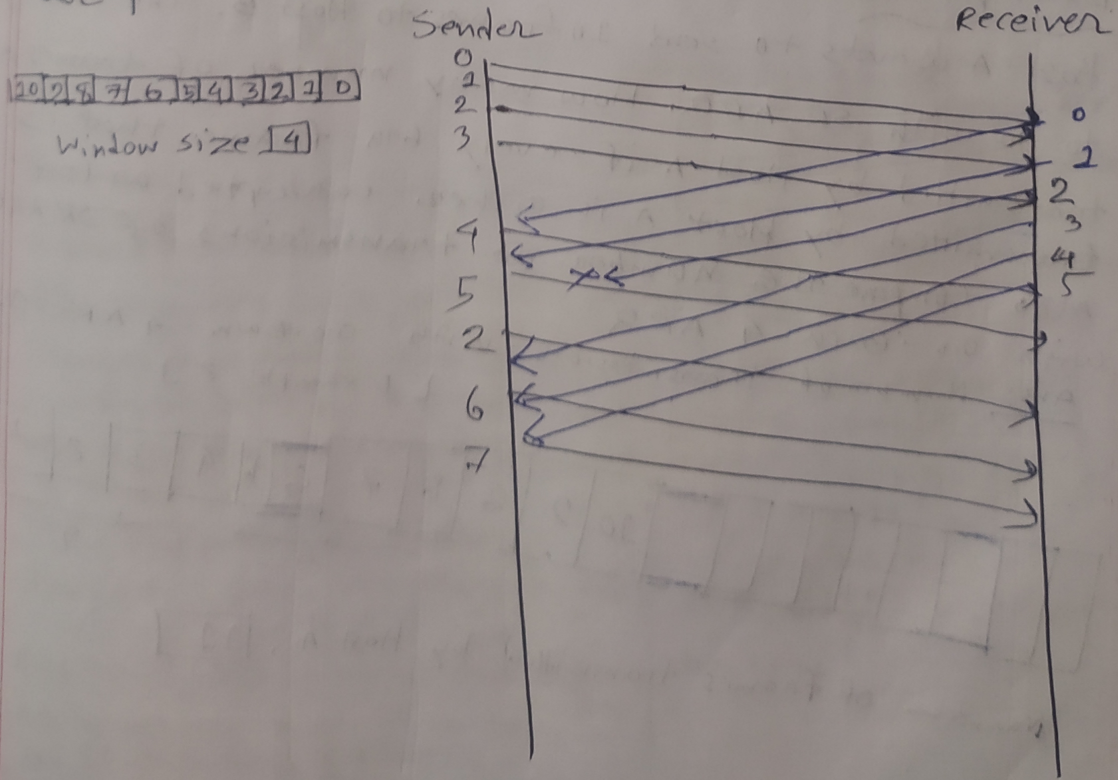
Numbers of frames transmitted by Host A : $\boxed{17}$

Noisy - Selective Repeat ARQ

* In selective Repeat ARQ, only the erroneous or lost frames are retransmitted, while correct frames are received and buffered.

* The receiver while keeping track of sequence numbers buffers the frames in memory and sends NACK (negative ACK) for only frame which is missing or damaged.

* The sender will send/retransmit packet for which NACK is received
অর্থাৎ শুধু নষ্ট হওয়া ফ্রেমগুলো selectively retransimitted হবে।



Example-1: (Shortcut)

In SR Protocol, suppose frames through 0 to 4 have been transmitted, Now imagine that 0 times out, 5 (a new frame) is transmitted, 1 times out, 2 times out and 6 (another new frame) is transmitted. At this point, what will be the outstanding packets in the senders window?

Ans:

6	2	1	5	0	4	3

sender's window

$\underbrace{2 \quad 1 \quad 0}_{\text{times out}}$

Example-2:

Host A wants to send 10 frames to Host B. The hosts agreed to go with SR ARQ. How many number of frames are transmitted by Host A if every 6th frame that is transmitted by Host A is either corrupted or lost? Also compare the number of transmissions of SR ARQ with Go-Back-4 ARQ.

Ans: Number of transmission with Go-Back-4 ARQ = 17
[Example 2]

									10	9	6	8	7	6	5	4	3	2	1

$\underbrace{\quad}_{4}$ $\underbrace{\quad}_{4}$

Number of frames transmitted by Host A : $\boxed{11}$

Sliding Window Protocol

Practice

Example-1: (Gate CS 2006)

Station A uses 32 byte packets to transmit message to station B using a sliding window protocol, The round trip delay between A and B is 80 miliseconds and the bottleneck bandwidth on the path between A and B is 128 Kbps. What is the optimal window size that A should use?

Ans: Delay = 80 miliseconds

Bandwidth = 128 Kbps

Packet size = 32 bytes

Bandwidth-delay product = (Bandwidth × Delay)

$= 128 \text{ Kbps} \times 80 \text{ milliseconds}$

$= \underbrace{(128 \times 1024)}_{bps} \times (\underbrace{80 \times 10^{-3}}_{\rightarrow second})$ bits

$= \dfrac{128 \times 1024 \times 80 \times 10^{-3}}{8 \times 32 \rightarrow byte}$ bytes

$= 40$ = Optimal window size **Ans.**

Example-2: The distance between two stations M and N is L kilometres. All frames are K bits long. The propagation time per kilometer is t seconds. Let R bits/second be the channel capacity. Assuming the processing delay is negligible, the minimum number of bits for the sequence number field (is) in a frame for maximum utilization, when the sliding window protocol is used, is:

Ans: Propagation delay = Lt sec

Round trip time = 2 × propagation delay $= 2Lt$

Bits transmitted in round trip = $2LtR$ bits

All frames are k bit long, so

No. of frames = $\left(\frac{2LtR}{k}\right)$

Let the bits in the sequence numbers be b.

$2^b = \left(\frac{2LtR}{K}\right)$, take log on both,

$b = \log_2\left(\frac{2LtR}{K}\right)$

Ethernet

* One of the most widely used wired LAN technologies.
* Operates in the data link layer & the physical layer.
* Family of networking technologies that are defined in the IEEE 802.2 & 802.3 standards.
* Supported data bandwidth → 10, 100, 1000, 10,000, 40,000 & 1,00,000 Mbps (100 Gbps)

Ethernet Standards

* Define Layer 2 protocols & Layer 1 technologies.
* Two separate sublayers of the data link layer to operate - logical link control (LLC) & the MAC sublayers.

Ethernet Evolution

Standard	Fast	Gigabit	Ten-gigabit
10Mbps	100Mbps	1Gbps	10Gbps

Frame Format:

Preamble	SFD	Destination MAC Address	Source MAC Address	Length/Type	Data & Padding	CRC
7 bytes	1 byte	6 bytes	6 bytes	2 bytes		4 bytes

Physical layer header

Preamble: 56 bits of alternating 1s and 0s
SFD: Start Frame Delimiter, flag (10101011)

Min. & Max. length & Ethernet frame legacy:

Destination Address	Source Address	Length PDU	Data & Padding	CRC
6 bytes	6 bytes	2 bytes		4 bytes

Min. Payload = 46 bytes
Max. Payload = 1500 bytes

Minimum frame length: 512 bits = 64 bytes (46+6+6+2+4) bytes
Maximum frame length: 12,144 bits = 1518 bytes (1500+6+6+2+4) bytes

Ethernet Address:

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

6 bytes = 12 hex digits
$\rightarrow$ (6×8) = 48 bits

The least significant bit of the first byte defines the type of address.

If the bit (LSB) 0 → unicast, otherwise → multicast

All bits 1 → broadcast

Solved Questions

Q1: What is the hexa equivalent of the following ethernet address?

Ans: $\underbrace{01011010}_{BA}$ $\underbrace{00010001}_{11}$ $\underbrace{01010101}_{55}$ $\underbrace{00011000}_{18}$ $\underbrace{10101010}_{AA}$ $\underbrace{00001111}_{0F}$

Q2: Find the type of the following destination address.

(A) 4A:30:10:21:10:1A

(B) 47:20:1B:2E:08:EE

(C) FF:FF:FF:FF:FF:FF

Ans: (A) 4A = 01001010 → Unicast

(B) 47 = 01000111 → Multicast

(C) Broadcast (all F)

Q3: Show how the address is sent out on line.

47:20:1B:2E:08:EE

Ans: The address is sent left-to-right

For each byte it is sent right-to-left

←

1110 0010	0000 0100	1101 1000	0111 0100	0001 0000	0111 0111
7 4	0 2	B 1	E 2	8 0	E E

in reverse byte order, [7 = 0111 = 1110 like this]

Q4: The address has been shown as the source address in an ethernet fram has been discarded by the receiver. Why?

Ans: 43 = 01000011 → multicast

A multicast address can be a destination address but not a source address, so receiver knows there is an error.

Q5: An ethernet MAC sublayer receives 42 bytes of data from the upper layer. How many bytes of padding must be added to the data?

Ans: 46 bytes is minimum. so add 4 bytes of data to make the minimum data size of 46 bytes.

Q6: An Ethernet MAC sublayer receives 1510 bytes of data from the upper layer. Can the data be encapsulated in one frame? If not, how many frames need to be sent? What is the size of the data in each frame?

Ans: No. Maximum load is 1500 bytes.
So it needs to be spilled into two frames.

1st frame: 1500 bytes.

2nd frame: 46 bytes (with padding, not 10 bytes because of the minimum requirement)

Q7: What is the ratio of useful data to the entire packet for the smallest Ethernet frame? What is the ratio for the largest frame?

Ans: Smallest frame: frame/data = $\cancel{64}^{46} / \cancel{46}^{64}$ bytes $\times 100\%$ = 71.875 %

Largest frame: frame/data = $\cancel{1518}^{1500} / \cancel{1500}^{1518}$ bytes $\times 100\%$ = 98.814 %

Q8: The data rate of 10base5 is 10Mbps. How long does it take to create the smallest frame - Show calculation.

Ans: Transmission delay = $\frac{\text{Message size}}{\text{Bandwidth}}$

$= \frac{512 \text{ bits}}{10 \text{Mbps}} = \frac{512 \text{ bits}}{(10 \times 10^6) \text{bps}} \Rightarrow 0.0000512 \text{ bps}$

$(0.0000512 \text{ bps} \times 10^6) \Rightarrow 51.2\ \mu s$

IPv4 → 32 bits
IPv6 → 126 bits
MAC → 48 bits
Port → 16 bits

Ethernet Transmitter Algorithm

The algorithm is commonly called Ethernet's Media Access control (MAC), which is implemented in Hardware on the network adapter.

Access method of Ethernet: CSMA/CD
CSMA → Carrier Sence Multiple Access with
CD → Collision Detection

Encoding Method: Manchester Encoding Technique for coverting data bits into signals. Ethernet cable carries data as electrical signal.

Algorithm: when the adapter (host computer) has a frame to send & the line is idle, it transmits the frame immediately.

The upper bound of 1500 bytes in the message means that the adapter can occupy the line for a fixed length of time.

When the adaptor has a frame to send & the line is busy, it waits for the line to go idle & then transmits immediately.

The ethernet is said to be CSMA 1-persistent protocol because an adaptor with a frame to send transmits with probability 1 whenever a busy line goes idle.

☆ since there is no centralized control it is possible for two (or more) adaptors to begin transmitting at the same time, either because both found the line to be idle or both had been waiting for a busy line to become idle.

এই অবস্থাকে বলা হয় two or more frames are collide on the network.

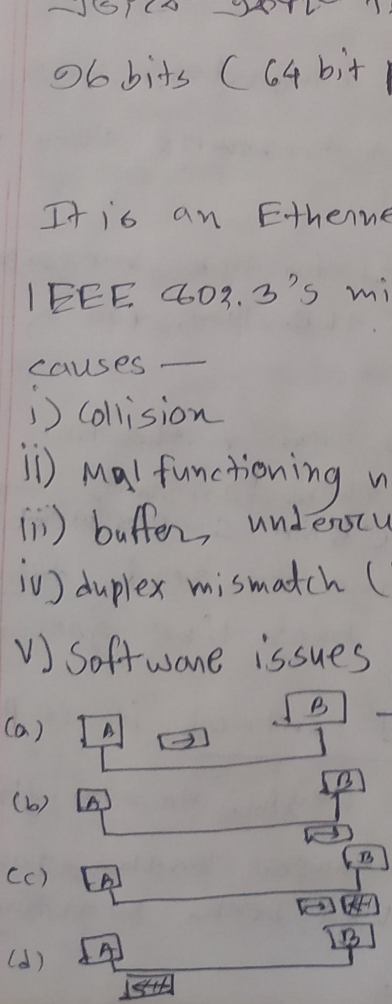
Ethernet supports collision detection,
So প্রতিটি sender জানে কলিশন হচ্ছে।
Adapter যখন detect করবে যে collide হচ্ছে তখন transmit করবে 32-bit jamming sequence এবং ট্রান্সমিশন বন্ধ হয়ে যাবে। কে বন্ধ করবে → host computer

এক্ষেত্রে প্রতিটি transmitter minimally send করবে 96 bits (64 bit preamble + 32 bit jamming sequence)

Runt frame

It is an Ethernet frame that is less than the IEEE 802.3's minimum length of 64 bytes.

causes —
i) Collision
ii) Malfunctioning network card
iii) buffer underrun
iv) duplex mismatch (half (half-duplex), half (full-duplex) runs)
v) Software issues



Worst-case scenario

(a) a situation where A sends a frame at time t.
(b) A's frame arrives at B at time t+d (Propagation + transmission delay)
(c) B begins transmitting at time t+d and collides with A's frame.
(d) B's runt (32-bit) frame arrives at A at time t+2d

Exponential Backoff

Used by the ethernet to reduce the probability of collision.

Adaptor যখন collision detect করে, transmission off করে এবং কিছুক্ষণ অপেক্ষা করে আবার চেষ্টা করে। আবার চেষ্টা করে ব্যর্থ হলে দ্বিগুণ সময় অপেক্ষা করে।

অর্থাৎ

১ম চেষ্টা → ১ সেকেন্ড অপেক্ষা

২য় " → ২ "

৩য় " → ৪ "

৪র্থ " → ৮ "

— — —

The strategy of doubling the delay interval between each retransmission attempt is known as Exponential Backoff.

Ethernet - pros:

i) Most widely used wired LAN technology.

ii) Inexpensive.

iii) All nodes have same privileges (অধিকার), it does not follow client-server architecture.

iv) Maintanance & administration are simple.

v) Ethernet is reliable (Cable used to connect systems in ethernet is robust (মজবুত) to noise, so the data transfer quality is good.

vi) Latest gigabit ethernet version -এ Gbps speed -এ transfer possible.

Ethernet cons:

i) Under heavy loads, too much of the network's capacity is wasted by collisions.

ii) Not good for real-time/interactive application.

iii) Not suitable for a client-server architecture, it cannot set priority for the packets (who? network)

iv) For interactive application, dummy data have to be fed to make the frame size 46B which is mandatory. যদি 1bit data হয় তাহলে padding bit add করে তাকে 46bit বানাতেই হবে।

v) After receiving a packet, the receiver doesn't send any acknowledgement. Because it uses CSMA/CD technology.

Category:	Shielding	Max. transmission speed (At 100 meters)
Cat 3 →	UTP →	10 Mbps
Cat 5 →	UTP →	10/100 Mbps
Cat 5e →	UTP →	1000 Mbps / 1 Gbps
Cat 6 →	STP/UTP →	1000 Mbps / 1 Gbps
Cat 6a →	STP →	10,000 Mbps / 10 Gbps
Cat 7 →	STP →	10,000 Mbps / 10 Gbps
Cat 8 →	STP →	up to 40 Gbps

Q1// Determine the maximum length of the cable (in km) for transmitting data at a rate of 500 Mbps in an Ethernet LAN with frames of size 10,000 bits. Assume the signal speed in the cable to be 2,00,000 Km/s. (GATE CS 2003)

Ans: Transmission time $\geq$ round trip time of 1 bit

$\geq$ 2× propagation time

[Transmission time = $\frac{\text{message size}}{\text{bandwidth}}$

Propagation time = $\frac{\text{Length}}{\text{propagation speed}}$

So, $\frac{\text{Message size}}{\text{bandwidth}} \geq \frac{2 \times \text{length}}{\text{propagation speed}}$

$\Rightarrow \frac{10{,}000 \text{ bits}}{500 \text{ Mbps}} \geq \frac{2 \times \text{length}}{2{,}00{,}000 \text{ km/sec}}$

$\Rightarrow \frac{10^4 \text{ bits}}{500 \text{ Mbps}} \geq \frac{\cancel{2} \times \text{length}}{\cancel{2} \times 10^5 \text{ Km/sec}}$

$\Rightarrow \frac{10^4 \text{ bits} \times 10^5 \text{ km/sec}}{500 \text{ Mbps}} \geq L$

$\Rightarrow \frac{10^4 \text{ bits} \times 10^5 \text{ Km/sec}}{500 \times 10^6 \text{ bps}} \geq L$

$\Rightarrow 2 \text{ Km} \geq L$ **Ans.**

Q2// A network with CSMA/CD protocol in the MAC layer is running at 1 Gbps over a 1 km cable with no repeaters. The signal speed in the cable is 2×10^8 m/sec. The minimum frame size for the network?

Ans: Transmission time $\geq$ round trip time of 1 bit

$\geq$ 2× propagation time

So, $\frac{\text{Message size}}{\text{Bandwidth}} \geq \frac{2 \times \text{length}}{\text{propagation speed}}$

$\Rightarrow \frac{\text{Message size}}{1 \text{ Gbps}} \geq \frac{2 \times 1 \text{ km}}{2 \times 10^8 \text{ m/sec}}$

$\Rightarrow \text{Message size} \geq \frac{2 \times 1 \text{ km} \times 10^9 \text{ bps}}{2 \times 10^8 \text{ m/sec}}$

$\Rightarrow \text{Message size} \geq \frac{2 \times 1 \times 10^3 \times 10^9 \text{ bps}}{2 \times 10^8 \text{ m/sec}}$

$\Rightarrow \text{Message size} \geq \frac{2 \times 10^3 \times 10^9 \text{ bits}}{2 \times 10^8}$

$\geq 10^4$ bits

$\geq 10{,}000$ bits

Ans.