Open system Interconnection (OSI)

DataLink Layer

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Sliding Window Protocol

- Sliding window protocol is a flow control protocol.
- It allows the sender to send multiple frames before needing the acknowledgments.
- Sender slides its window on receiving the acknowledgments for the sent frames.
- This allows the sender to send more frames.
- It is called so because it involves sliding of senders window.
- Maximum number of frames that sender can send without acknowledgment = Sender window size
- **Optimal Window Size**
  In a sliding window protocol, optimal sender window size = 1 + 2a

Derivation

- As we know $\eta = \frac{T_t}{T_t+2xT_p}$
- To get 100% efficiency, we must have-
  - $\eta = 1$
    $1 = \frac{T_t}{T_t+2xT_p}$
    $T_t = T_t + 2xT_p$
  - Thus
    - To get 100% efficiency, transmission time must be $T_t + 2T_p$ instead of T_t.
    - This means sender must send the frames in waiting time too.
    - Now, let us find the maximum number of frames that can be sent in time $T_t + 2T_p$.
  - We have-
    - In time T_t, sender sends one frame.
    - Thus, In time $T_t + 2T_p$, sender can send $(T_t + 2T_p)/T_t$ frames i.e. $1 + 2a$ frames.
    - Thus, to achieve 100% efficiency, window size of the sender must be 1+2a.

Required Sequence Numbers

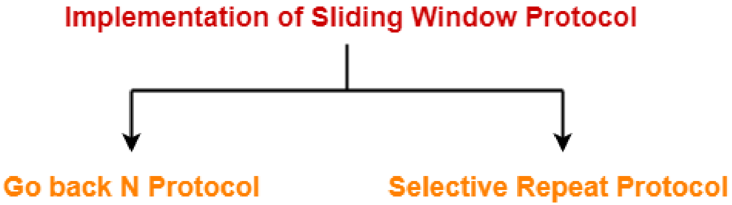
- Each sending frame has to be given a unique sequence number.
- Maximum number of frames that can be sent in a window $= 1 + 2a$.
- So, minimum number of sequence numbers required $= 1 + 2a$.
  - To have 1+2a sequence numbers, Minimum number of bits required in sequence number field $= \lceil log_2(1 + 2a) \rceil$
- **Note:**
  - When minimum number of bits is asked, we take the ceil.
  - When maximum number of bits is asked, we take the floor

Choosing a Window Size

- The size of the senders window is bounded by-
- **Receivers Ability**
  - Receivers ability to process the data bounds the sender window size.
  - If receiver can not process the data fast, sender has to slow down and not transmit the frames too fast.
- **Sequence Number Field**
  - Number of bits available in the sequence number field also bounds the sender window size.
  - If sequence number field contains n bits, then 2n sequence numbers are possible.
  - Thus, maximum number of frames that can be sent in one window = 2n.
- For n bits in sequence number field,
  Sender Window Size = min (1+2a , 2n)

Implementations of Sliding Window Protocol

- The two well known implementations of sliding window protocol are-
  - Go back N Protocol
  - Selective Repeat Protocol



Implementations of Sliding Window Protocol

- Efficiency of any flow control protocol may be expressed as-

$$\text{Efficiency } (\eta) = \frac{\text{Number of frames sent in one window}}{\text{Total number of frames that can be sent in one window}}$$

OR

$$\text{Efficiency } (\eta) = \frac{\text{Sender Window Size in the Protocol}}{\text{Optimal Sender Window Size}}$$

OR

$$\text{Efficiency } (\eta) = \frac{\text{Sender Window Size in the Protocol}}{1 + 2a}$$

- In Stop and Wait ARQ, sender window size $= 1$.
  $\textit{Efficiency of Stop and Wait ARQ} = \frac{1}{1+2a}$

PRACTICE PROBLEMS BASED ON SLIDING WINDOW PROTOCOL-

Q1 If transmission delay and propagation delay in a sliding window protocol are 1 msec and 49.5 msec respectively, then-

1. What should be the sender window size to get the maximum efficiency?
2. What is the minimum number of bits required in the sequence number field?
3. If only 6 bits are reserved for sequence numbers, then what will be the efficiency?

- **Solution**- Given- **Transmission delay = 1 msec**, **Propagation delay = 49.5 msec**
  To get the maximum efficiency,
  sender window size= $1 + 2$a$= 1 + 2x\frac{49.5msec}{1msec} = 100$
  For maximum efficiency, sender window size $= 100$

PRACTICE PROBLEMS BASED ON SLIDING WINDOW PROTOCOL-

- Minimum number of bits required in the sequence number field= $\lceil log_2(1+2a) \rceil = \lceil log_2(100) \rceil$
- If only 6 bits are reserved in the sequence number field, then-
  Maximum sequence numbers possible $= 2^6 = 64$
- Now,
  Efficiency$= \frac{Sender \;\; window \;\; size \;\; in \;\; the \;\; protocol}{Optimal \;\; sender \;\; window \;\; size} = \frac{64}{100} = 64\%$

PRACTICE PROBLEMS BASED ON SLIDING WINDOW PROTOCOL-

Q2 If transmission delay and propagation delay in a sliding window protocol are 1 msec and 99.5 msec respectively, then-

1. What should be the sender window size to get the maximum efficiency?
2. What is the minimum number of bits required in the sequence number field?
3. If only 7 bits are reserved for sequence numbers, then what will be the efficiency?

- **Solution**- Given- **Transmission delay = 1 msec, Propagation delay = 99.5 msec**

1: To get the maximum efficiency, **sender window size=1+2a**

2: Minimum number of bits required in the sequence number field

3: Efficiency = Sender window size in the protocol / Optimal sender window size

PRACTICE PROBLEMS BASED ON SLIDING WINDOW PROTOCOL-

Q3 A 3000 km long trunk operates at 1.536 Mbps and is used to transmit 64 byte frames and uses sliding window protocol. If the propagation speed is 6 μsec / km, how many bits should the sequence number field be?

- **Solution**- Given- **Distance = 3000 km Bandwidth = 1.536 Mbps Packet size = 64 bytes Propagation speed = 6 μsec / km**
- **Calculating Transmission Delay-**
  $Transmission\ delay(T_t) = \frac{Packetsize}{Bandwidth} = \frac{(64x8bits)}{(1.536x10^6 bitspersec)}$
- **Calculating Propagation Delay**
  $For\ 1km\, propagation\ delay = 6\mu sec$
  $For\ 3000\ km,\ propagation\ delay = 3000x6\mu sec = 18000\mu sec$
- **Calculating Value Of a-**
  $a = \frac{T_p}{T_t} = \frac{18000\mu sec}{333.33\mu sec}$

PRACTICE PROBLEMS BASED ON SLIDING WINDOW PROTOCOL-

- **Calculating Bits Required in Sequence Number Field-**
  Bits required in sequence number field $= \lceil log_2(1 + 2a) \rceil$
  - Thus, Minimum number of bits required in sequence number field $= 7$
  - With 7 bits, number of sequence numbers possible $= 128$
  - We use only $(1+2a) = 109$ sequence numbers and rest remains unused.

PRACTICE PROBLEMS BASED ON SLIDING WINDOW PROTOCOL-

Q4 Compute approximate optimal window size when packet size is 53 bytes, RTT is 60 msec and bottleneck bandwidth is 155 Mbps.

- **Solution** Given- **Packet size = 53 bytes, RTT = 60 msec, Bandwidth = 155 Mbps**
- **Calculating Propagation Delay**
  $Propagation delay(T_p) = \frac{Round Trip Time}{2} = 30 msec$
- **Calculating Value of a-**
  $a = \frac{T_p}{T_t}$
- **Calculating Optimal Window Size-**
  $Optimal\ window\ size = 1 + 2a$

Q5 : A sliding window protocol is designed for a 1 Mbps point to point link to the moon which has a one way latency (delay) of 1.25 sec. Assuming that each frame carries 1 KB of data, what is the minimum number of bits needed for the sequence number?

- **Solution** Given- Bandwidth = 1 Mbps, Propagation delay (T_p) = 1.25 sec, Packet size = 1 KB
- **Calculating Transmission Delay**
  $Transmission\ delay(T_t) = \frac{Packetsize}{Bandwidth} = \frac{(2^{10} x 8 bits)}{(10^6 bitspersec)}$
- **Calculating Value of a**
  $a = \frac{T_p}{T_t} = \frac{1.25sec}{8.192msec}$
- **Calculating Bits Required in Sequence Number Field**
  Bits required in sequence number field = $\lceil log_2(1 + 2a) \rceil$
- With 9 bits, number of sequence numbers possible = 512.

Q6: Host A is sending data to host B over a full duplex link. A and B are using the sliding window protocol for flow control. The send and receive window sizes are 5 packets each. Data packets (sent only from A to B) are all 1000 bytes long and the transmission time for such a packet is 50 μs. Acknowledgment packets (sent only from B to A) are very small and require negligible transmission time. The propagation delay over the link is 200 μs. What is the maximum achievable throughput in this communication?

- **Solution** Given-
  Sender window size = Receiver window size = 5, Packet size = 1000 bytes, Transmission delay (Tt) = 50 μs, Propagation delay (Tp) = 200 μs
- **Calculating Bandwidth**
  $Transmissiondelay = \frac{Packetsize}{Bandwidth}$
  $Bandwidth = \frac{PacketSize}{Transmissiondelay(T_t)} = \frac{(1000x8bits)}{(50x10^{-6}sec)}$

- **Calculating Value of a-**
  $a = \frac{T_p}{T_t}$
- **Calculating Optimal Window Size-**
  $Optimal window size = 1 + 2a$
- **Calculating Efficiency-**
  $Efficiency(\eta) = \frac{Sender\ \ window\ \ size}{Optimal\ \ window\ \ size}$
- **Calculating Maximum Achievable Throughput-**
  $Maximum\ achievable\ throughput = Efficiency(\eta) x Bandwidth$

Q7: Station A uses 32 byte packets to transmit messages to station B using a sliding window protocol. The round trip delay between A and B is 80 msec and the bottleneck bandwidth on the path between A and B is 128 Kbps. What is the optimal window size that A should use?

- **Solution** Given- Packet size = 32 bytes, Round Trip Time = 80 msec, Bandwidth = 128 Kbps
- **Calculating Transmission Delay-**
  Transmission delay (Tt)=$\frac{Packetsize}{Bandwidth} = \frac{(32x8bits)}{(128x103bitspersec)}$
- **Calculating Propagation Delay-**
  Propagation delay (Tp) =$\frac{RoundTripTime}{2}$
- **Calculating Value of a-**
  $a = \frac{T_p}{T_t}$
- **Calculating Optimal Window Size-**
  Optimal window size=$1 + 2a$

Thank You