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① point to point communic^n
② end to end "

→ Wireless connec^n : possible only when devices are in the vicinity of each other.

→ Medium only allows analog signal
→ Comp. provides o/p in 0's & 1's
So, to convert digital → analog : we need a Modem
(vice-versa : Demodulation)

↓ How to convert

→ Content - based Networking
→ Info. - centric N/W : take very quick decisions & transmit your packets at dest^n.

cable TV • changing channel ? requesting STB to switch to another frequency

→ cable connection : Had booster to have good quality of video
↓ is a
Repeater (Re) → amplifies the signal (improves quality)
Physical level layer device

• For point - to - point connec^n : we require
Switch / Bridge / Hub (Data link level layer devices)
↓
connected to Router

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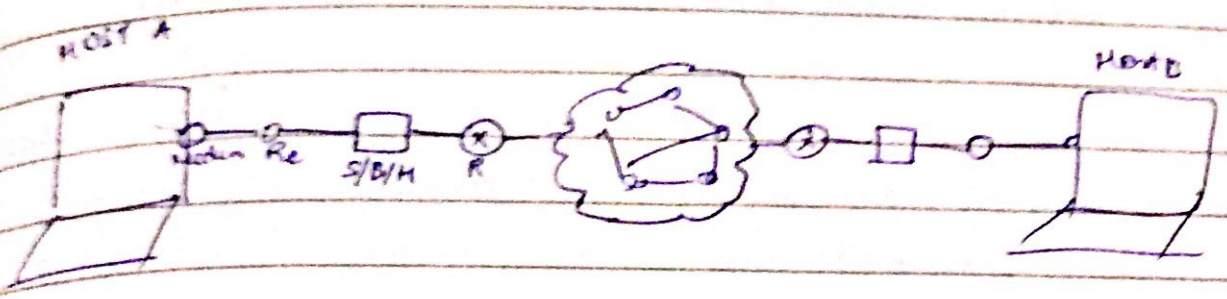
1) Centralized
2) DC
3) Distributed

- Right now, we only use switches — layer 2 (works for DL layer)
  layer 3 (works for NW layer)



App" layer : end-to-end connec".

- Original msg : Text form

→ Appl" layer : Convert text to hypertext form { have to match interpretes in all OSs }
(so that it works on all OS)

(need

Protocols : HTTP / FTP / HTTPS / SMTP / SNMP etc.

Transfer protocols

Trp : layers in TCP/IP : end-to-end connec" (logical connec"s .....)

→ ① Transfer msg to some form so that it works on our n/w.

→ URLs (can remember) mapped to addresses (N/W needs this Add.)
Many servers are available When you write a URL, whichever server is available will provide connec" to you.

DNS

→ Hierarchial add. scheme exists

.in
.ac.in .gov.in

DNS :→ . URL request reaches DNS server, checks db & forwards corresponding IP add to your system.

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Wireshark

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→ Till now, we don't know dest^n.

1st, logical connec^n needs to be established by Xport layers

TCP ✓ UDP

Objective of Xport layer : (logical connec^n)

① To establish an end-to-end connec^n — connection oriented (Ack received) TCP; Connectionless (No Ack) UDP

Accessing Wi-fi : UDP

" Bank ... : TCP

② Flow control → Goback N, selective Repeat, etc...

↓

May have different bandwidths

Otherwise, data may be lost

③ Congestion control

Intermediate nodes may be connected to other n/w also (↑ traffic) ⇒ Congestion may occur.

④ Reliable and Unreliable Connection

Reliable → Banking Services (TCP)

Unreliable → e-mail (UDP)

* → Port Add (depends on app^{n}s) : 16 bits

~~Network~~

* 3 add is n/w

TL : Port Add : 16 bits

HTTP : 80
HTTPS : 483

Network layer : Takes care to forward data

Objectives :

① Router : Has multiple interfaces

Func^{n}s at NL : 1) Send 2) Receive 3) Forward 4) Drop

Router :

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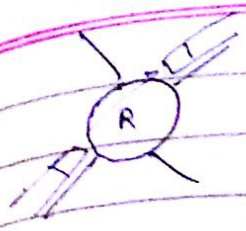

Each interface generally maintains 2 queues.
→ Have 3 interfaces to fwd the packet
↓
select acc. to packet add

delays
* 1) processing
* 2) Propog"
* 3) Transmission
4) Queuing

③ Quality of Service (QoS)
→ Talk about Wired & Wireless at N/w layer.

Appl" Layer

Services : DNS (Name service), HTTP (Web), SMTP, POP, IMAP (E Mail), FTP (File Transfer)

HTTP (Port No. 80 / 8080)

Data Center : Many servers
Problem : How to replicate data from 1 server to another

Cookies → can't find if it is http or not (if we use IP add → can identify IPV4/V6)

HTTP by default is a stateless protocol
↳ nothing is stored. (No state info is stored)

We Cookies to store state info. Client forwards the add"al info along with Request msg by reading cookie

Gmail : if you don't log out, next time you'll directly see your inbox.

• Gmail sends 1 cookie to you. 1 cookie stores

generally, social media ac's cookies : active till 15 days.

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Anonymyzer. ✕

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After 15 days, if you log in, you're to enter username and pswd.

→ Session Hijacking Attack : If you're active session, he may steal the info from cookie & further communicate with server

↓ SOT"

One Time Password (OTP)

↳ Now, people are attacking on this also.

HTTP Proxy

→ Use of Proxy server : To access some blocked site, you bypass the proxy server.

DNS

↳ Assign unique names to an IP add.

→ DHCP assigns IP add. to host system.
↓
dynamic host config" protocol

↳ 2 hosts have same IP add. connected to WLAN.
They won't be connected to Internet (because server will be confused) → IP conflict.
↓
That's why, have to maintain unique IP names.

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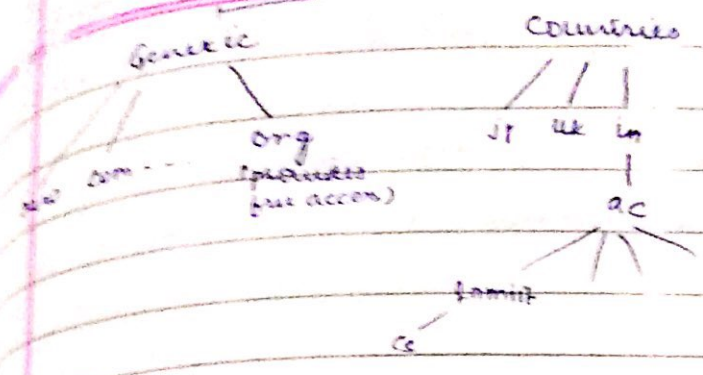
DNS



→ maintain hierarchical addressing

Domain Resource Records

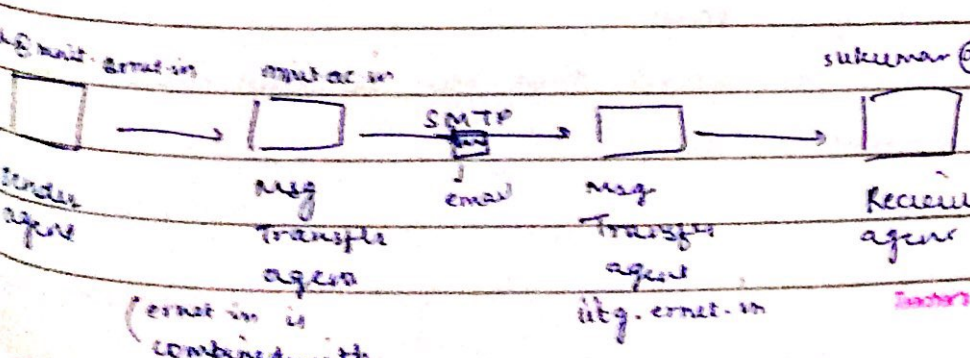
- domain_name : case insensitive comp name ≤ 63 characters & full path ≤ 255 char.
- Time_to_live : Time for which server is active (if inactive, has to contact → ac → in> if active directly committ will give response)
- Class : Normally IN - Internet Resources
- Type : Type of record
- Value : Value of record (IP add for A record type)
  - A record → IPV4 add.

Why DNS uses UDP ?

- UDP is much faster. TCP req. handshake time. It'll create traffic
- DNS request & responses are very small & fits well within 1 UDP segment.
- UDP is unreliable. In DNS reliability is ensured at Appl" layer.

E-mail

- 3 agents
  - User
  - Transfer



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[codec] → email header info

to see origin of e-mail (shows server agent)

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SMTP (Simple Mail Transfer Protocol) → RFC 821, RFC 5321
↳ (Port No. : 25)

MIME → Multipurpose Internet Mail Extension
↳ Use multi-language & multimedia contents inside a mail.

↳ ~~content driven~~

↳ need to maintain 2 sockets. At your side, at the server's side
(Port no.: any random no.) <1024 (Port no. : 25)

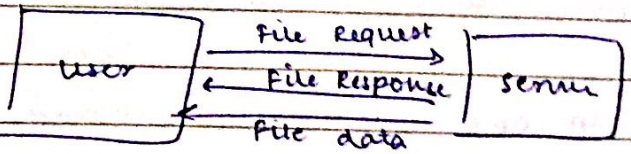
stateful protocols

POP 3 (Post Office Protocol V3) → earlier protocol for email delivery

IMAP V4 (Internet Message Access Protocol)
↳ uses port no. : 143

FTP (File Transfer Protocol) [IP Messenger : send upto 1GB]
↳ Port no. : 21

→ built on client-server model



Performance Metrics in CN

- Bandwidth (Throughput)
  - ↳ Width of freq. band
  - ↳ No of bits per second that can be transmitted over a communication link

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many users ~~using~~ listening RedFM at a time. Have to allot diff bandwidth to each user.

BOOK : CN by Kurose & Ross

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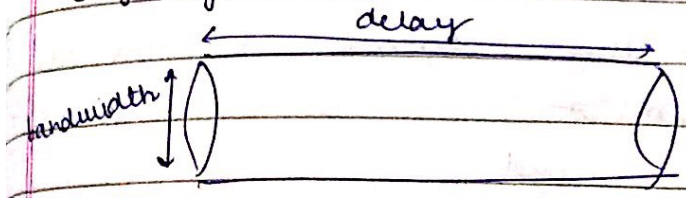
1 Mbps = 10^6 bits / sec = 1×2^{20} bits / sec

10^{-6} sec to transmit each bit or each bit occupies ~~for~~ 1 μs space.

- Latency = Propogation + transmit + queue (3 delays)
  - ↓ RTT/2 (generally)
- Propogⁿ = distance / speed of light
- Transmit = size / bandwidth

1 bit transmission : propgⁿ imp

large bytes : bandwidth imp.



BDP :

large file transfer : ~~cattle~~ bandwidth is critical

small : latency " "

Infinite bandwidth

- Throughput = Transfer size / time
- Transfer time = RTT + 1 / (bw x Transfer size)
- RTT dominates

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Q. Calculate total time to transfer a 1.5 MB file in following cases, assuming a RTT of 80ms, a pkt size of 1 KB data & an initial 2×RTT of "handshaking" before data is sent.

(a) The bandwidth is 10 Mbps, & data pkts can be sent continuously

(b) " " " " , but after we finish sending each data pkt we must wait 1 RTT before sending next

(c) The link allows infinitely fast transmit, but limits bandwidth s.t. only 20 pkts can be sent per RTT

(a) Before data is sent : $2 \times 80 = 160$ ms

Total no. of pkts : $\frac{1.5 \times 1024 \text{ KB}}{1 \text{ KB}} = 1536$

~~Time~~ Propogation time : 40 ms (1 side ka)

~~Total Time = 160 ms~~

bandwidth ↑ ↓

10 Mb → 1 second

1.5 MB → 0.15 second = 150 ms

Total Time = 160 + 150 = 310 ms

(b) 160 + 150 + 80 (1536) = 123190 ms

= 123.2 s

(c) $\frac{1536}{20} = 76.8$

77 × 80 ms = 6160 ms = 6 sec

(a) $160 + \frac{1258912}{10000000} + \frac{RTT}{2}$ (Propg) $\simeq 1.458$ sec.

(b) $1.458 + 122.8 = 124.258$

(c)

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Transport layer

HTTP header → has get & POST Method.
" data →

Protocols
- UDP
- TCP

1st obj : TO provide end-to-end communic" (for both)

UDP	TCP
↳ Unreliable	↳ Reliable
↳ Conn" less	↳ Conn" Oriented
	↳ Flow & congestion Control
	↳ Ordered Pkt Delivery.

↳ Ad Audio/Video : always require ordering of frames

Connec" Establishment : Req + Ack (2-way handshake)

⇓

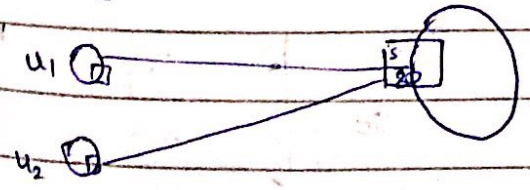
Problem : ↳ Some pkts get lost
↳ Whether ~~server~~ client is reponding or not : can't identify.

↳ How it server differentiate whether Req is new or duplicate of old one ?

Ans: Use Throwaway Transport Add (Port No)

↳ Don't use a port no. if it has been already - delayed duplicate pkts 'll never find their way to a tranport procss

↳ Is it feasible ?



all are connected to http. Same 80 will provide service to all users with diff. procs
We can't delete 80. as it is providing services to many users.

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Sol^n 2 : Give each conn^n a unique identifier chosen by the initiating party & put in each statement.

- Problem :

Sol^n 3 : Devise a mechanism to kill off aged pkts that 're still hobbling about, Restrict the pkts timeline.

3 ways

1.) Prevent pkts from looping

* 2.) Putting hop count in each pkt - decrement at each hop (initialize to max value)

3.) Time stamping : in real life, sync. is always a problem

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We 've 2 types of conn's → that's why we 've 2 protocols

① Conn^n Oriented :

How to establish conn^n ?

1.) 3 - way handshaking

2.) 2 - way "

4 Most of appl^n services → HTTP (& TCP)

4 First you type URL → sent to DNS → returns IP add. to your system → contact the server. → server responds back.

Cases possible :

1.) Request is lost → How client will get his answers ?

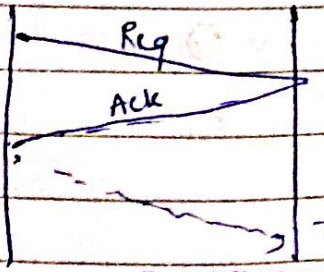
Sol^n

Timeout

doesn't recieve any response by server, wait upto RTT (sending + receiving time) & ~~wait~~ ~~opt~~ send request again

Acknowledgement

TO



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DOS attack : like TCP, 3-way handshaking

within timeout, you've to recieve ack. Else → send request again

2-way handshaking
↓ disadv:

how to authenticate really connected to the client ?

(how server will authenticate whether a frame is original or duplicate (sent again)) → (if ACK not sent within timeout / if ACK is lost, etc)

• server never maintains any timeout. Timeout is only maintain by clients.

→ ARQ (Automatic Requests)

2 things we want to achieve
1) Reliability
2) Flow control

5 Objectives (in general)
1) End-to-end comm"
2) Reliability
3) Flow Control
4) Congestion Control
5) Reliable Transmission

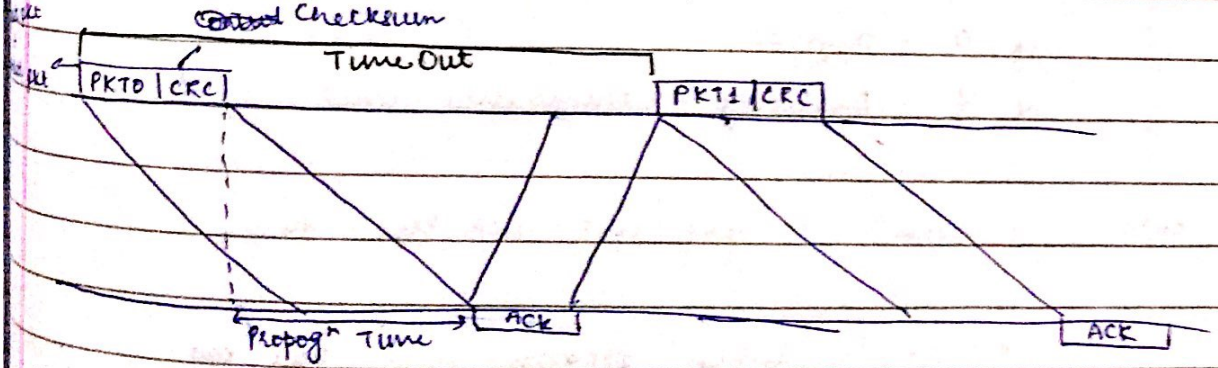
• Here, Flow Control & Reliable transmission are closely binded.

↳ For this, need to maintain 2 things.
• Ack
• Time Out

→ 3 Protocols in ARQs (Flow Control Mechanisms) → need to study same at DLL also.

1) Stop & wait (Binary sync mech) 2) Go back N (X Modem mechanism) 3) Selective Repeat (TCP Mech) → Used in this mechanism

1) Stop & Wait — wait for response from server side.



data pkt + control pkt
↓ ↓
payload header portion

CRC : also of control pkt

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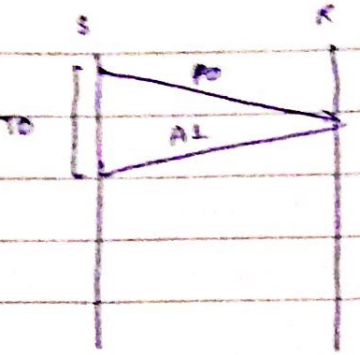
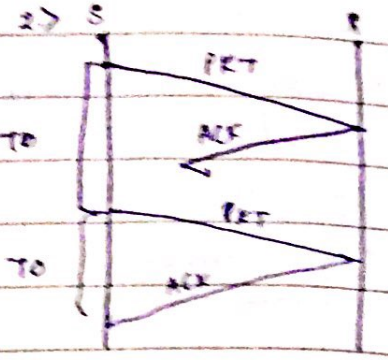
Flow control : also determines whether pkt is corrupted or correct

↓ correct : you get correct ACK else not

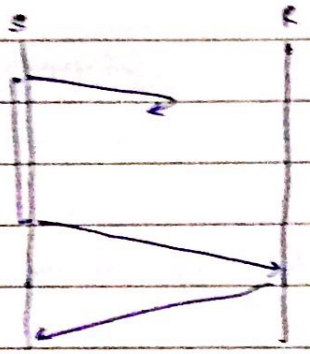
Diff scenarios Possible

1) 

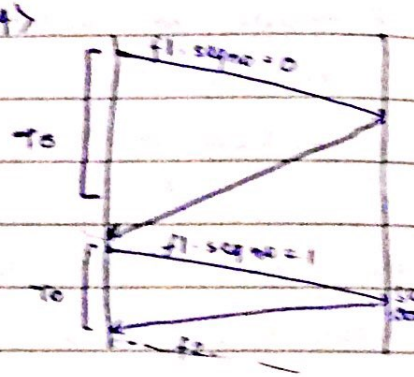
- You forwarded correct pkt.

2) 

- ACK lost, Resend the same pkt & get ack within TO

3) 

- Pkt lost, resend the same pkt & get ack within TO

4) 

→ ACK sent within TO, but received after TO.

Sender must think if he already forwarded ack, why to do it again?

That's why we need these.

→ Use 1 bit sequence no here:

if 0 : original

if 1 : Duplicate (retransmitted one)

3 cond" : pkt lost, ack lost, delay

in case : when resending, send pkt seq no. 1 ⇒ R will send ACK (R will think S has not received ack)

0 ⇒ R will reject pkt

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drawbacks :

① Huge timeouts → very inefficient

Efficiency of stop & wait ;

Transmitted segment size = 1000 bits. Link speed = 1.5 Mbps segment transm^n & recep^h time is 40 ms. a) How many no. of bits can be propogated over this channel. b) Find efficiency of channel

a) 1.5 Mbps Time = 40 ms

40 ms → 1000 bits

1 s → $\frac{1000}{40} \times 1000 = 25000$ bits / sec

b) $\frac{25000 \text{ bits/sec}}{1.5 \times 1024 \times 1024 \text{ b/sec}} = 0.01589$

a.) $40 \times 10^{-3} \times 1.5 \times 10^{6} \Rightarrow$ bits transmitting in 1 sec

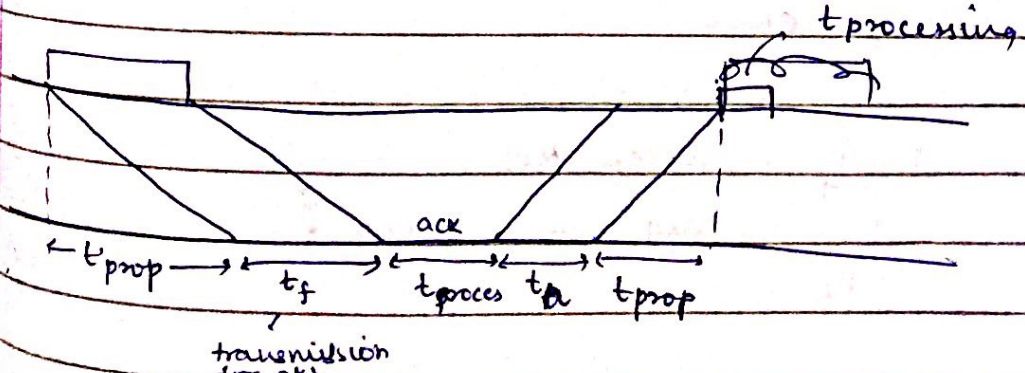
$= 60000$

b) efficiency :

we're transmitting only 1000 bits

$\text{eff} = \boxed{\frac{1000}{60000}}$

for Stop & Wait :



t_0 (delay time for pkt 0) $= 2 \times t_{prop} + t_f + t_a + 2 \times t_{proc}$

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Bandwidth delay efficiency

n_f → transmitting this much
R → have this much capacity

no. of bits in f_0

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$$t_0 = 2(t_{prop} + t_{proc}) + \frac{n_f}{R} + \frac{n_a}{R}$$

(t_f, t_a; R → bit rate of the channel)

$$R^{\circ}_{eff} = \frac{\text{No of bits delivered to dest}^n}{\text{Total time req to deliver the info bits}}$$

→ only need data bits (not overhead wala part) → n_0

$$R^{\circ}_{eff} = \frac{n_f - n_0}{t_0}$$

(n_0 : overhead bits)

* Transmission effeciency of : Ratio of R°_{eff} to R.

$$\eta_{sw} = \frac{R^{\circ}_{eff}}{R} = \frac{(n_f - n_0)/t_0}{R} = \left(\frac{n_f - n_0}{R}\right)\left[\frac{1}{2(t_{prop}+t_{proc}) + \frac{n_f}{R} + \frac{n_0}{R}}\right]$$

(η_{sw} (effeciency of sliding window))

$$= \left(\frac{n_f - n_0}{R}\right)\left[\frac{R}{2R(t_{prop}+t_{proc}) + n_f + n_a}\right]$$

$$= \frac{n_f - n_0}{n_f + n_a + 2R(t_{prop}+t_{proc})}$$

$$\eta_{sw} = \frac{1 - \frac{n_0}{n_f}}{1 + \frac{n_a}{n_f} + \frac{2(t_{prop}+t_{proc})R}{n_f}}$$

($\frac{n_0}{n_f}$ → loss of transm^n effeciency; denominator → loss of)

↳ We need both η_{sw} & R°_{eff}

↳ Here, we've not considered any error.

How to introduce error ?

P_f ← error rate prob.

$1 - P_f$: success prob.

$\frac{1}{1-P_f}$: avg. success prob.

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[6.0 MCQs]

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n_f

Q. segment sizes are : 1250 bytes & 25 byte overhead & 25 byte ack R = 1 Mbps $2 \times (t_{prop} + t_{proc})$ = i) 1 ms, ii) 10 ms, iii) 100 ms. Try for R = 1 Gbps also. Find efficiency of stop & wait protocol.

i) R_{eff} = $\frac{n_f - n_o}{2 \times (t_{prop} + t_{proc}) + \frac{n_f}{R} + \frac{n_a}{R}}$

= $\frac{1250 - 25}{1\,ms + \frac{(1250 + 25) \times 8}{1 \times 10^6}}$ = $\frac{1225 \times 8}{1\,ms + 10.2\,ms}$

= $\frac{B75}{} \times 10^3$

η_{sw} = $\frac{1250 - 25}{1250 + 25 + 1\,ms\,(1 \times 10^6)}$ = $\frac{12.25 \times 8}{12.5 \times 8 + 1000}$

= $\frac{9800}{11200}$ = 0.875

ii) 10 ms

R_{eff}

⟹ Considering with errors :

- The effect of Transmission Errors on the efficiency of S & W ARQ

1) If a frame / segment incured errors during transm^n, the time out Mech will cause retransm^n of frame / segment. In that case, t_o is the transmi^n / retransm^n time (sec)

P_f → probability of segment transmitted has errors & it needs retransm^n

Then,

Avg. succesfull Retransm^n = $\frac{1}{1 - P_f}$ (1 in 10 segments)

t_{sw} = $\frac{t_o}{1 - P_f}$ = $t_o\left(\frac{1}{1 - P_f}\right)$ —— ①

time for stop & wait

$$\eta_{sw} = \frac{(n_f - n_o / t_{sw})}{R}$$

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same values as prev ques^n, for 1 ms only.
$P_f = 10^{-6}, 10^{-5}, 10^{-4}$ → Bit error rate

If $P_f = 10^{-6}$

$$t_{sw} = \frac{t_o}{1-10^{-6}} = 2 \times (t_{prop} + t_{proc}) + n_f/R + n_o/R \left[\frac{1}{1-10^{-6}}\right]$$

To calculate the Transm^n efficiency for S & W ARQ:
We need to calculate an avg. total time req. to deliver correct frame

Let n_t → i transm^n's are req. to deliver correct segment/pkt
→ (i-1) retransm^n's are req. → (i-1) TO are req.

$$P[n_t = i] = (1-P_f) \cdot P_f^{\,i-1} \quad \text{for } i = 1, 2, 3 \ldots$$

↳ i-1 times, need timeout

$$E[t_{sw}] = t_o + \sum_{i=1}^{\infty} (i-1)\, P[n_t = i]\, t_{out}$$

expected t_{sw} time

$$= t_o + \sum_{i=1}^{\infty} (i-1)\, t_{out}\, (1-P_f)\, P_f^{\,i-1}$$

$$= t_o + \frac{t_{out}\, P_f}{1-P_f}$$

If $t_{out} = t_o$:

$$E[t_{sw}] = \frac{t_o}{1-P_f}$$ → that's how we get t_{sw} in ①

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Concurrent & parallel Computing → Pipeline

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A system approach : CN by Peterson & David

Ques: Bandwidth = 50 Kbps
1 way transmn time = 250 ms. Find out Bandwith delay product (BDP).
Window size = W = 2 (Bandwidth delay) + 1
Find link utilization

delay = 250 ms +

↳ Drawbacks:
- For single pkt, we're waiting
- TO very huge

↓ sol^n

Use pepelining concept

⇓

need not to wait till a task is completed. can be introduced while a task is going on.
Need to choose a buffer which will be transmitted

- Sliding window Protocol : used in GO Back N & Selective Repeat

↓ Problem

Whenever error, whatever successful pkt have been sent needs to be retransmitted

↓

send ack for pkt which is lost.

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