- We can optimize reccomendations using cookies

  Drawbacks: privacy, security

CH:02 (completed)

CH:03 Transport Layer

- Application Layer handovers data to lower layer i.e transport layer.
- Transport layer provides a logical comunication end-to-end connection b/w different application processes running on different hosts.
- Multiplexing → have to send data from several paths/networks/links to a single destination / channel.
- TCP is complex as compared to UDP. The choice

b/w them is made according to the requirements.

- Multiplexing /De-multiplexing → same concept used in FDM & TDM.

- address of process identified by port number, address of host identified by IP address.

- socket have it's own unique port number. Uniqueness of port number is in the machine only. A machine has it's own IP address.

- UDP → User Datagram Protocol.

- Implementation of transport layer is fixed.

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Lecture-11

Mid-1 solution

Q2

A) 1) $0.2(1-0.2)^{N-1}$. ($p(1-p)^{N-1}$) transmitting, not transmitting

4) N = 11 users

$^{11}C_3 * p^3 * (1-p)^8$ (any 3)

B) 64 Kbps (1.536/24)

Lecture NO.12

TCP sockets identified by:

- source IP address
- destination IP address
- source port number
- destination port number

- UDP is a protocol that provides unreliable data transfer. (connectionless: no handshake)

Checksum

Ex: → add two 16-bit integers

```
  1110 0110 0110 0110   sender
  1101 0101 0101 0101
(1)1011 1011 1011 1011
carry                 1 → carry
add
  1011 1011 1011 1100
1st complement
  0100 0100 0100 0011
↳ checksum
```

→ Transport layer provides reliability.

1 1 1 0 0 1 1 0 1 1 1 0 0 1 1 0

1 1 0 1 0 1 0 1 0 1 0 1 0 1 0 1

receiver

$\boxed{1}$ 1 0 1 1 1 1 0 0 0 0 1 1 1 0 1 1

1

1 0 1 1 1 1 0 0 0 0 1 1 1 1 0 0

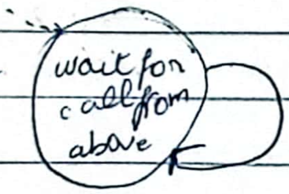
1st complement

0 1 0 0 0 0 1 1 1 1 0 0 0 0 1 1 → checksum 2

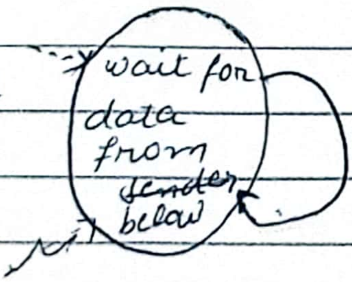
checksum 1 ≠ checksum 2 (indicating an error)

→ rdt 1.0

sender



receiver

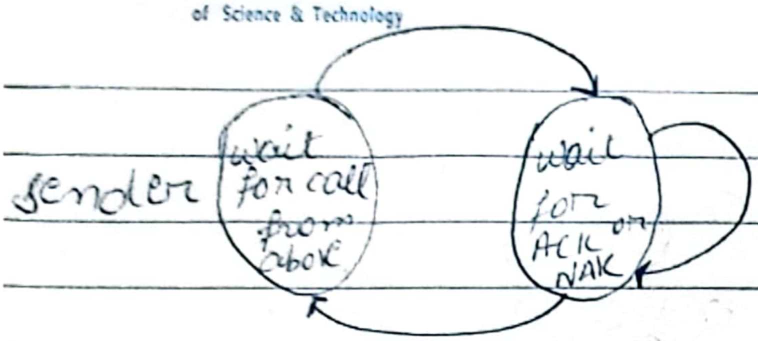


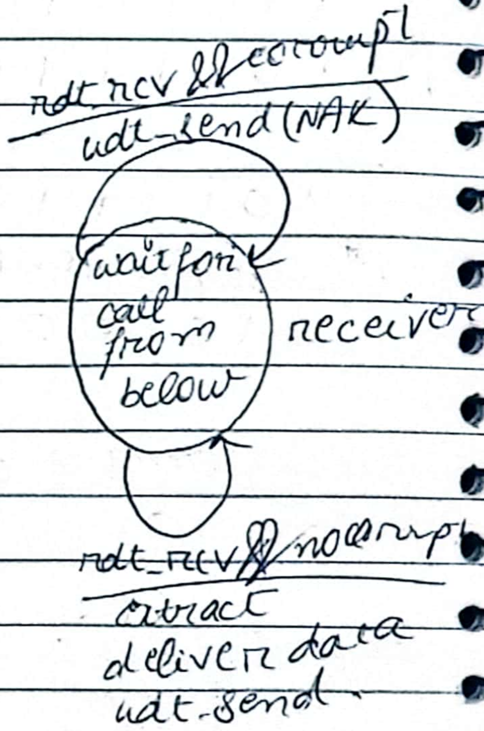
extract packet data (extract (packet.data)) and deliver it (deliver-data (data))

→ rdt 2.0 (channel with bit errors)

- ACKs
- NAKs.

rdt 2.0: FSM specification





Lecture - 13

rdt 3.0 (not a standard protocol)

reliable data transfer, but the resource utilization is low

(stop-and-wait) → only 1 packet

Resource/user utilization = $\frac{L/R}{RTT + L/R}$

$U_{sender} = \frac{0.008}{30.008} =$

→ Pipelining: (more than 1 packet)
(increased utilization)

Ex: $U_{sender} = \frac{3L/R}{RTT + L/R} = \frac{0.0024}{30.008} = 0.00081$ → 3 packet pipelining utilization increase utilization by a factor of 3!

• utilization is increased but it also increases the complexity

• Window Size: how many packets can be in a pipeline in 1 minute.

• Sequence Number Range: $0 \rightarrow 2^k - 1$
(mod 2^k arithmetic)
↳ simple words → wraparound

→ Go-Back-N has only 1 timer.
↳ if there is packet loss, then there are many overheads.

* To avoid overheads, follow selective repeat approach

individual act

to repeat selective piece/packet

have to maintain a logical timer for every packet

Ex: $N = 3,\ K = 3 = 2^3 - 1 = 7\ (0-7)$

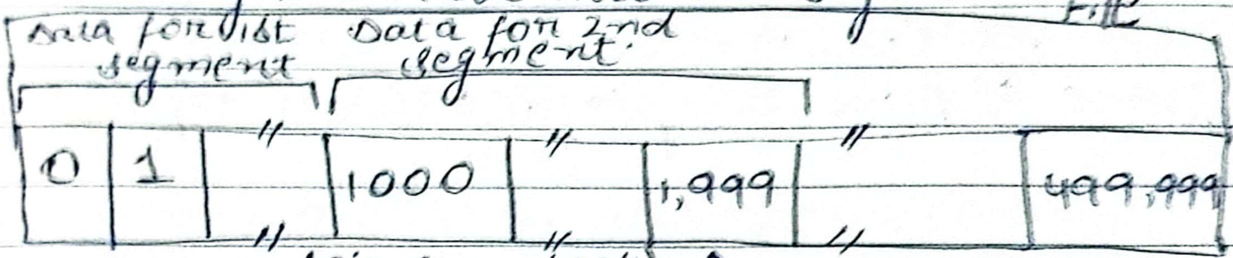
→ TCP is designed following all the above discussed guidelines.

Lecture - 11

→ TCP overview (basic features)

- Message from application layer is transferred to transport layer and a header (UDP/TCP) is appended.
- The IP address is not needed in the header

→ Dividing File data into TCP segments



(Fig from book)

- 500,000 data is divided into segments of data with each segment consisting of 1000 bytes

→ Sequence Number → Number of first byte in the segment's data

→ Acknowledgements → sequence no. of next byte expected from other side.

→ Receiver has an idea of what sequence number/acknowledge will be sent by the sender.

•) Timeout should > RTT

- Sample RTT: measured time from segment transmission until ACK receipt. is not constant.

•) $\text{Estimated RTT} = (1-\alpha) * \text{EstimatedRTT} + \alpha * \text{Sample RTT}$.

- Exponential Weighted Mean Average (EWMA)
- typical value $\alpha = 0.125$
- influence of past sample decreases exponentially fast.

•) $\text{TimeOutInterval} = \text{EstimatedRTT} + \underbrace{4 * \text{DevRTT}}_{\text{safety margin}}$

•) $\text{DevRTT} = (1-\beta) * \underbrace{\text{DevRTT}}_{\text{initial}} + \beta * |\underbrace{\text{SampleRTT} - \text{EstimatedRTT}}_{\text{Absolute error}}|$

initial will be given or assumed.

Absolute error → not constant

$\boxed{\text{typically: } \beta = 0.25}$

- Probabilistic Measures (It is possible that the sender's assumption is not correct).
- Fast retransmission is helpful in many cases.
-

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CH: 03

P31

Sample RTT 1 = 106 ms $\alpha = 0.125$
" 2 = 120 ms Estimated RTT = 100 ms
" 3 = 140 ms $\beta = 0.25$
" 4 = 90 ms Dev RTT = 5 ms
" 5 = 115 ms

For sample RTT 1 (106)

EstimatedRTT $= (1-0.125)\times 100 + \cancel{0.250}\ 0.125\times 106$

$= 87.5 + 13.25$

$= 100.75$

DevRTT $= (1-0.25)\times 5 + 0.25\times |106 - 100.75|$

$= 5.0625$

TimeOut Interval $= 100.75 + 4\times 5.0625$

$= 121$

For Sample RTT 2 (120)

EstimatedRTT $= (1-0.125)\times 100.75 + 0.125\times 120$

$= 103.2$

DevRTT $= (1-0.25)\times 5.0625 + 0.25\times |(120 - 103.2)|$

$= 7.99 \Leftarrow 8$

TimeOut Interval $= 103.2 + 4\times 7.99$

$= 135.16$

(same process for next samples)

network by nature is un-reliable

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• SS threshold = slow start

Lecture-15

Fast retransmit → saves time

• Application Layer & Transport layer have the same/shared buffer.

• Received window shows the no. of bytes, the receiver is willing/allowing to accept.

→ Congestion:

• Too many sources sending too much data too fast for network to handle.

Manifestations:
- Long delays
- Packet Loss

• a different from ~~mate~~ model:
•) ~~Buffer...~~ Overflow

→ congestion control Approach: AIMD
→ we have congestion window for congestion control.

•) LastByteSent − LastByteAcked $\leq$ cwnd ↓ congestion window

•) TCP rate = $\dfrac{cwnd}{RTT}$ (byte/sec)

(CH:03 → finished

• AIMD → Additive Increase & Multiplicative Decrease

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Lecture-16

States/Phases of TCP: (Congestion Control)

i). Slow Start

ii)

iii).

Solving TCP Reno

PU0

a) (1-6), (23-26) → slow start

b) (6-16), (17-22)

↳ fast recovery

↓

congestion avoidance

c) triple duplicate ACK

d) Timeout

e) 32 (value of ssthresh)

cwnd/2, cw ssthresh + 3

f) 42/2 = 21+3 = 24 (new congestion window)

ssthresh

g) 30/2 = 15 → ssthresh, congestion window = 1

h) By the end of 7th RTT, transmission of 96 packets was done. We needs to transmit 70.

i) 8/2 = 4+3 = 7 (new congestion window)

↓

ssthresh

• Sending Rate = $\frac{MSS}{RTT}$

MSS → Max segment size

RTT → Round Trip Time.

CH:04 → Data Plane
CH:05 → Control Plane

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Lecture-17
Network Layer:
Data Plane

→ Network Layer Functions

forwarding   routing

- A router must have atleast 2 interfaces.
- Network Layer provides un-reliable service
- In this layer, the packet/segment is called datagram after the header is added.
- Internet "best effort" service model.

→ NO gurantee on
- successful datagram delivery to destination
- timing/order of delivery
- bandwidth available to end-end flow.

→ Subnet:
Device interfaces that can physically reach each other without passing through an intervening router

→ IP addresses have Structure

subnet part   host part

IP

assign to host

- We cannot make a IP address which consists of all 0's or all 1's

- subnet mask will not change.

→ CIDR (Classless Inter Domain Routing)

- changing 1 bit changes the subnet mask.

→ DHCP (Dynamic Host Configuration Protocol)

→ ICANN (Internet corporation for Assigned Names & Numbers)

→ NAT (Network Address Translation)

NETWO

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Lecture - 18

→ Sub-net part also known as prefix.

200.23.16/23 → prefix/subnet prefix
200.23.16.0/23 → subnet mask.

→ IP addresses
public private.

→ It is not possible that 2 systems on the internet have same IP address. If it is like that, then "IP conflict" error occurs.

→ NAT (Network Address Translation) → example of openflow
→ In LANs subnet part is same
Local Area Network (public home etc)
• Private
not of internet.

→ NAT translation table

Wan side address	LAN side address

•) It goes against the rule of encapsulation but works correctly technically, despite having system overheads.

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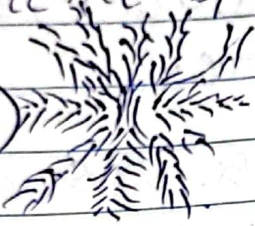
(longest prefix match)

P8 (a)

Prefix	Link
11100000000	0
(16-bits)	1
(7-bits)	2
~~Otherwise~~	3

→ Major difference b/w IPv4 and IPv6 is the range

→ IPv6 (2^{128})



00 interface → 0

00,000000 through 00,111111

010,00000 " 010,11111

011,00000 " 011,11111

10,000000 " 10,111111

11,00000 " 11,111111

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Lecture-19

PS

(b) Link 3 , Link 2, Link 3

→ Open Flow
  ↳ match + action
  • Outstreched table can create network-wide behaviour

→ NAT (Network Address Translation) is not a part of network architecture..

→ Middle Boxes: NAT, Firewalls, IDS; Load Balancer, Application specific, caches

CH:04 → complete

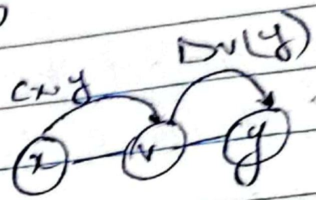
Lecture NO. 21

Link State Algorithm (Dijextra Algorithm)

•) Traffic generated on Router "x" is less than the traffic generated on Router "y"

→ Distributed Routing Algorithm

Based on ↳ Distance Vector Algorithm



$$D_x(y) = \min_v \{c_{x,v} + D_v(y)\}$$

→ Bell-man Ford Equation

• $D_x(y)$ → cost of least cost path from x to y.

Ex:

∞ → undefined

$\cancel{D_b(a) = \min(8, 1+1+1)} = \min(8,3) = 3$

$\cancel{D_b(}$

$D_b(a) = \min(c_{b,a} + D_a(a),\ c_{b,c} + D_c(a),\ c_{b,e} + D_e(a)\} =$
$\min(8, \infty, \infty) = 8$

$D_b(c) = \min(\cancel{c_{b,c} + D_c(a)}, c\ 1, \infty, \infty) = 1$

$D_b(d) = \min(9, 2, \infty) = 2$

$D_b(f) = \min(\infty, \infty, 2) = 2$

$D_b(e) = \min(\infty, \infty, 1) = 1$

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$\Delta b(g) = \min(\infty, \infty, \infty) = \infty$
$\Delta b(h) = \min(\infty, 2, \infty) = 2$ (Example in slides not in book)

- we cannot find/estimate/determine "t" as it depends on certain constraints like network size.

- No fixed complexity
- Dont have to have all the info of the network

→ Advantages of Distributed

~~→ # BG~~

policy-based routing → focused more on performance.

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Lecture NO·22

$Dx(y) = min(2+0, 7+1) = min(2,8) = 2$
$Dx(z) = min(2+1, 7+0) = min(3,7) = 3$
$Dy(x) = min(2+0, 1+7) = min(2,8) = 2$
$Dy(y)$

·) We advertize whole network instead of advertising each node in the network

→ ICMP : Internet control message Protocol.
↳ ~~we sometimes consider it a transport layer protocol.~~
→ application ; trace-route.

·) TTL = 0 → message is discarded and warning is sent to the server/user.

Time-To-Live

·) TTL is decremented by 1 per router.

·) BGP → Border Gateway Protocol

(iBGP) Internal BGP
↓
not used for inside routing

External BGP (eBGP)

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- Transport layer provides end-to-end reliability

Lecture NO. 23

Link Layer
↳ individual links
(how individual links are designed)

- In transport layer, the internal network is transparent.

- datagram + link layer header + trailer = frame.
- transferring data from 1 node to another using communication/physical link.

→ we can have different protocols on different links.

- We need reliability in link layer because every link may have different characteristics. We need reliability if link layer is wired. In case of wireless, we dont need it.

- NIC (Network Interface Card)

→ Even Parity → no. of 1's should be even / make it
→ odd " → no. of 1's " " odd

- Two-dimensional Parity → detection is not 100% correct.
  - ↳ detecting & correcting single bit errors.

Finding even parity

1	0	1	0	1	1
1	1	1	1	0	0
0	1	1	1	0	1
0	0	1	0	1	0

if 1 bit is flipped

1	0	1	0	1	1
1	0	1	1	0	1
0	1	1	1	0	1
0	1	1	0	1	

parity error (row)

parity error (column)

→ CRC (Cyclic Redundancy check)

← d data bits → | ← r CRC bits →

D	R

$$\langle D, R \rangle = D * 2^r \text{ XOR } R$$

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→ If no bit is corrupted, remainder would be 0

Ex:

$\overbrace{1\ 0\ 0\ 1}^{G}$ 1 0 1 1 1 0 R = 4 − 1 = 3.

1 0 1 1 1 0 0 0 0 ← $D * 2^r$

```
           1 0 1 0 1 1
1 0 0 1 | 1 0 1 1 1 0 0 0 0
          1 0 0 1 ↓ ↓
              1 0 1 0
              1 0 0 1
                    0
```

Answer 011 → Remainder.

Final Result = ____________________

•) 32-bit standard generator (also 8, 16 etc)

Types of Links

Point-to-Point

Broadcast (shared wire / medium)

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MAC Protocols: taxonomy

- channel partionning
- random access
- "taking turns"

TDMA → time-division multiple access

FDMA → frequency division multiple access

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Lecture NO. 24
Slotted Aloha

→ Efficiency

Suppose "n" nodes with many frames to send, each transmits in slot with probability "p"

- $p(1-p)^{N-1}$
  ↳ prob that given node has success in a slot
- $Np(1-p)^{N-1}$
  ↳ prob that any node has a success
- ~~p* the maximiz~~ max efficiency:
  find p^* that maximizes $Np(1-p)^{N-1}$
  ↓
  Optimal value
- Max efficiencity = 37%
  ↳ when you have large no. of nodes

→ Pure Aloha
↳ just removed "slot" condition of ALOH.
It's efficiency is half of the efficiency of Slotted Aloha. Slotted Aloha came after pure ALOHA.

What is the value of η so that efficiency is maximized.

Lecture NO. 25

$$\eta = NP(1-P)^{N-1}$$

$$\frac{d\eta}{dp} = \cancel{(N-1)}\left(N\cdot(1-P)^{N-1} - NP(N-1)(1-P)^{N-2}\right)$$

$$\frac{d\eta}{dp} = 0$$

$$N\cdot(1-P)^{N-1} - NP(N-1)(1-P)^{N-2} = 0$$

$$N\cdot(1-P)^{N-1} = NP(N-1)(1-P)^{N-2}$$

$$1 = \frac{NP(N-1)(1-P)^{N-2-1}}{\cancel{N}\cancel{(1-P)^{N-1}}}$$

$$1 = P(N-1)(1-P)^{-1}$$

$$1 = \frac{P(N-1)}{(1-P)} \quad - \quad 1-P = P(N-1)$$

$$\frac{1-P}{P} = N-1$$

$$\frac{1}{P} - \frac{\cancel{P}}{\cancel{P}} = N-1 \Rightarrow \frac{1}{P} = N-1$$

$$\frac{1}{N-} \cdot \frac{\cancel{S}}{\cancel{P}} \cdot \frac{1}{N-1} = P$$

$$\frac{1}{N-1} = P = \frac{1}{N-1} = \frac{1}{N}.$$

$$P = \frac{1}{N}.$$

$$\frac{1}{N-1} - \frac{1}{N} = 0 \Rightarrow \frac{N-(N-1)}{N(N-1)} = 0 \rightarrow \frac{1}{N} - \frac{1}{N-1} = 0$$

$$= \frac{\cancel{N}-\cancel{N}+1}{N(N-1)} = 0$$

$$p^* = \frac{1}{N}$$

$$\eta^* = N \times \frac{1}{N}\left(1 - \frac{1}{N}\right)^{N-1}$$

$$\eta^* = \left(1 - \frac{1}{N}\right)^{N-1}$$

$$\lim_{N \to \infty} \eta^* = \lim_{N \to \infty}\left(1 - \frac{1}{N}\right)^{N-1}$$

$$= \frac{1}{e} \quad R$$

efficiency

→ Collissions are detected only on receiver side

→ DHCP (local area network)

→ DNA (network-wide)