Minor

● Graded

Student

Saharsh Laud

Total Points

42.5 / 75 pts

Question 1

Q1

3 / 3 pts

- ✔ **+ 0.5 pts** First Design:
  Cost: Cheaper since it has fewer links
- ✔ **+ 0.5 pts** Second Design:
  Cost: Expensive as it requires more links
- ✔ **+ 0.5 pts** First Design:
  Resilience: Moderately Resilient, if one link fails connectivity can still be maintained but if two if simultaneous link fails ,corresponding node if cut off.
- ✔ **+ 0.5 pts** Second Design:
  Resilience: More Resilient as multiple alternative path exits. However hostels still have 2 links , If both of them fail then hostel can be cut off.
- ✔ **+ 0.5 pts** First Design:
  Capacity: It shares bandwidth across fewer links so congestion can occur under heavy load
- ✔ **+ 0.5 pts** Second Design:
  Capacity: Higher Capacity since multiple Independent Path exist between hostel and Interet
- **+ 0 pts** Wrong/Not Answered

Question 2

Q2

2 / 4 pts

- **− 0 pts** Correct
- ✔ **− 2 pts** Incorrect/Incomplete E(x)
- **− 1 pt** Not mentioned that E(x) should be divisible by G(x) for error to go undetected
- **− 1 pt** Not mentioned x and G(x) are co-prime so G(x) must divides B(x)
- **− 1 pt** Incorrect/Incomplete conclusion to show G(x) does not divide B(x)
- **− 4 pts** Not Attempted/Incorrect

Question 3

Q3

0 / 4 pts

+ 1.5 pts Correct encoding 2B/3B

+ 0.5 pts Mention NRZ signal encoding

+ 1 pt Advantage

+ 1 pt Disadvantage

✔ **+ 0 pts** Not attempted/Wrong

Question 4

Q4

2 / 4 pts

− 0 pts Correct

− 1 pt Not mentioned Tt >= 2 *(d/s)

− 1 pt Mentioned 10x increase in speed

✔ **− 1 pt** Not mentioned 10x decrease in length

− 1 pt Mentioned increase in speed or decrease in length

− 2 pts Incorrect/Not Attempted part A

✔ **− 1 pt** Incorrect A's average throughput

− 1 pt Incorrect B's average throughput

− 0.5 pts Incorrect value of p

− 2 pts Incorrect/Not Attempted part B

− 1 pt Incomplete solution

− 4 pts Incorrect/Not Attempted

Question 5

Q5

4 / 5 pts

✔ **+ 1 pt** Correct part A

+ 2 pts Correct part B

✔ **+ 1 pt** Partially correct B

✔ **+ 2 pts** Correct part C

+ 1 pt Partially correct part C

+ 0 pts Incorrect answer/ Not attempted

Question 6

Q6

2.5 / 3 pts

- ✔ **+ 1 pt** A. Correct Byte-count format
- **+ 0.5 pts** A. Partially Correct Byte-count format
- ✔ **+ 1 pt** B. Correct byte stuffing
- **+ 0.5 pts** B. Partially correct byte stuffing
- **+ 1 pt** C. Correct bit stuffing
- ✔ **+ 0.5 pts** C. partially correct bit stuffing
- **+ 0 pts** Wrong answer / Not attempted

Question 7

Q7

3 / 4 pts

- **– 0 pts** Correct
- **– 4 pts** Incorrect / Not attempted
- **– 1 pt** Incorrect Spanning Tree / Not attempted
- **– 0.5 pts** Incorrect Root Ports / Not Attempted
- **– 0.5 pts** Incorrect Designated Ports / Not Attempted
- ✔ **– 0.5 pts** Incorrect Blocked Ports / Not Attempted / Both ports on the link were marked as blocked, preventing any traffic from traversing the link.
- ✔ **– 0.5 pts** Vague Explanation / Did not correctly explain how connection S4-S2 gets established after S2-S3 goes down
- **– 1 pt** No / Incorrect Explanation of how new spanning tree is constructed after S2-S3 goes down
- **– 0.5 pts** Incorrect spanning tree after link goes down / Not attempted

Question 8

Q8

3 / 3 pts

- ✔ **+ 1 pt** Routing: Process of computing the best path for data packet to travel from a source to destination across network
- ✔ **+ 1 pt** Forwarding:While Routing selects the best path, Forwarding is the Process of moving a packet from input interface to output interface based on forwarding table
- ✔ **+ 1 pt** Switching: It is a Mechanism inside devices(router/switches) to transfer the packet from input port to output port effectively
- **+ 0 pts** Wrong/Not attempted

Question 9

Q9

3 / 3 pts

- ✔ **+ 1.5 pts** Large Files transfer consume bandwidth and buffer space in routers/switches causing queuing delay and increasing latency for small packets
- ✔ **+ 1.5 pts** Scheduling Mechanisms:
  Weighted Fair Queueing
  or
  Priority Queueing
  etc
- **+ 0 pts** Wrong/Not Attempted

Question 10

Q10

2.5 / 6 pts

- **− 6 pts** Not Attempted/Incorrect
- **− 0 pts** Correct (2+1+3)
- ✔ **− 1 pt** Incorrect/Incomplete advertisements for 1c
- **− 0.5 pts** 2 advertisements mentioned for 1b
  Only Correct advertisement: **AS3 IPx; 3b**
- ✔ **− 0 pts** Correct next hop for 1b is **3b** not 1c
- **− 1 pt** Incorrect/4 Advertisements mentioned for 1b
- **− 1 pt** b) Correct Answer: Setting higher LOCAL PREF
- ✔ **− 3 pts** c) Not attemted/ Incorrect
  Correct answer: **Advertising more specific IP**
- **− 2 pts** c) Missing both IP advertisements
- **− 1 pt** c) Missing IP advertisements **8.8.8.0/25** or **8.8.8.128/25**
- **+ 0.5 pts** part a

Question 11

Q11

1 / 3 pts

- **− 0 pts** Correct
- ✔ **− 1 pt** (a) To all, customers, peers, providers
- **− 1 pt** (b) Only to Customers
- ✔ **− 1 pt** (c) Only to Customers
- **− 3 pts** Not Attempted/Incorrect

Question 12

Q12

3 / 8 pts

- **− 0 pts** Correct
- **− 8 pts** Incorrect / Not attempted
- ✔ **− 1.5 pts** Part (a) - Incorrect / Not attempted
- ✔ **− 1.5 pts** Part (b) - Incorrect / Not attempted
- **− 3 pts** part (c) - Incorrect / Not attempted
- ✔ **− 1 pt** part (c) - Incorrect / No explanation
- **− 0.5 pts** part (c) - Vague Explanation
- ✔ **− 1.5 pts** part (c) - Incorrect number of message exchanges / Not attempted
- **− 2 pts** part (d) - Incorrect / Not attempted
- **+ 0.5 pts** In part (a) all the announcements of x to u till network gets stabilised have to be written

Question 13

Q13

2 / 6 pts

- ✔ **+ 2 pts** $A.)$ Correct answer

  Mentioned the major challenge is **Scalability**.

  Explained MAC addresses are **flat identifiers** (unique but not hierarchical), so routing tables would need an entry for every single device in the world. IP addresses are **hierarchical** (network + host parts), which allows aggregation into prefixes, making routing feasible across the Internet.

- **+ 1 pt** $A.)$ Partially correct answer

- **+ 2 pts** $B.)$ Correct answer

  Message complexity of initial convergence = 2.(N.E) = **O(N*E)**

  Message complexity of update = 4*E = **O(E)**

  Where N = Number of nodes/routers in the network, E = Number of edges/links in the network.

- **+ 1 pt** $B.)$ Partially correct answer

- **+ 1 pt** $C.i$ Correct answer

  The datagram passes through 5 input interfaces + 5 output interfaces = **10 interfaces total**.

- **+ 0.5 pts** $C.ii$ Correct answer

  With 4 routers, there are exactly 4 lookups in total. Therefore, **4 forwarding tables will be indexed**.
  5 is also a possible answer if you consider a lookup at the source host.

- **+ 0.5 pts** $C.iii$ Correct answer

  Each router decrements the TTL by 1 when it forwards a packet. At each one of the 4 routers, the TTL is decremented by 1 before forwarding it, so the packet arrives at the destination host with **TTL = k − 4**.

- **+ 0 pts** No correct answer / Not attempted

Question 14

Q14

4 / 8 pts

Part A:

+ 1 pt First Packet - 2L/C
Second Packet 3L/C

+ 0.5 pts Partially correct

✔ **+ 0 pts** Both Wrong

Part B:

+ 5 pts Assumes correctly that
if R>C - cannot determine ISP rate properly
if R<C:
Send 2 ping packets to ISP Server/Packets with TTL=2 back-to-back; measure time to receive both responses.

First packet: 2L/R + 2L/C
L/C + L/R + L/R + L/C

Second Packet: 3 L/R + 2 L/C
(L/C + L/R) "waiting for first packet" + L/R + L/R + L/C

The difference between the second and first packet responses: L/R

Since we know L (length of packet) - estimate R

+ 3.5 pts Idea Described but no Math shown

✔ **+ 2 pts** Mentions any partially correct idea

+ 0 pts Incorrect/Not attempted

Part C:

✔ **+ 1 pt** Send back-to-back high-priority and low-priority requests

✔ **+ 1 pt** If there is high sibling traffic, there will be significant lag between the two packets

+ 1 pt Partially correct

+ 0 pts Incorrect

+ 0 pts Fully incorrect/ Not attempted

Question 15

Q15

3 / 4 pts

- ✔ **+ 2 pts** Mentioned **rules/policies** must be placed in both gateway routers, which are used to identify the traffic between the two campus area networks, i.e packets with source IP in one network and destination IP in the other.

- ✔ **+ 2 pts** Mentioned the **tunnelling of packets** between the two networks at the **gateway routers**. This means a packet which is sent from a host in one of the campus networks to a host in another campus network is **encapsulated** at its gateway router into another packet with **src-ip = Internet interface IP of the router** and **dst-ip = Internet interface IP of the gateway router of the other campus network**. At the destination router, the outer packet is **decapsulated**, the router then checks the actual dst-ip and then forwards it to the correct host in its network.

- **+ 0 pts** Incorrect Mechanism / Not Attempted

- **− 1 pt** Your general mechanism is correct. But if you change the source IP to the IP of the gateway router, how will you remember the original IP at the destination router?

  Check out the rubrics for the correct implementation.

1 I don't think you correctly understand how NAT works. NAT is not applicable here.

Question 16

Q16

4.5 / 7 pts

Part A:

- ✔ **+ 1 pt** Circuit switching has simpler data plane complexity. Once setup is done, per packet forwarding is trivial
- **+ 1 pt** Packet switching has more complexity – lookup, headers, queuing
- ✔ **+ 0 pts** Incorrect/Not Attempted

Part B.i:

- ✔ **+ 2 pts** 40 ns with proper steps
- **+ 1 pt** Correct steps but wrong answer
  or
  Direct Answer without steps
- **+ 0 pts** Incorrect/Not attempted

Part B.ii:

- ✔ **+ 1 pt** IPv6header is 128 bits.
  Worst case 128 lookups: 128x1ns = 128ns;
  128ns > 40 ns Not feasible
- **+ 0 pts** Incorrect/Not attempted

Part B.iii

- **+ 2 pts** A source node adds a (random) 20 bit flow label to packets going to the same destination

  Allows other routers to identify and forward packets based on flow label rather than using expensive lookups
- **+ 0.5 pts** Only mentions use of flow label bits to forward packets without lookups
- ✔ **+ 0 pts** Incorrect/ Not attempted

- **+ 0 pts** Fully incorrect/not attempted
- **+ 0.5 pts** Adjustment for part A.

Name: SAHARSH LAUD   Entry Number: 2024 MCS 2002

Minor Exam

COL334/672: Computer Networks

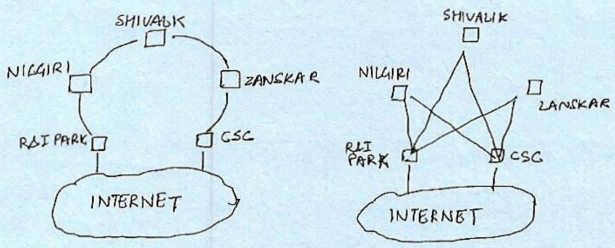
Sem I, 2025-26

There are 16 questions and 17 pages in this exam booklet (including this page). There are **75 total points**, and you have **120 minutes** to answer the questions.

- **Feel free to think outside the box but write inside the box**
- **Write concise answers**
- **Do not start the exam until instructed to do so**

I Link Layer

1. [3 points]: Consider the two design approaches below for connecting IITD hostels to the Internet using optical fiber. Compare these designs in terms of their cost, resilience, and capacity? Explain briefly.



Ans: Design 1: Circular	Design 2: Mesh
Cost: Simpler Design, Cheaper as only 6 links	Cost: complex design; Costlier as 8 links.
Resilient: Less Resilient if one node fails network gets disconnected.	Resilient: multiple links so more resilient if one node fails can connect via other nodes.
Capacity: Low capacity as single circular path for data transfer so multiple requests cannot be handled	Capacity: More links so multiple paths and multiple requests can be sent simultaneously so more capacity.

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2. [4 points]: Consider a CRC generator polynomial: $G(x) = x^{16} + x^{12} + x^5 + 1$. A burst error of length L is an error pattern where the corrupted bits are confined to exactly L consecutive positions, with errors in the first and last of those positions. Prove that any burst error of length $L \leq 16$ is always detected by this CRC polynomial.

Ans: we know that:

A polynomial $C(x)$ divides $B(x)$ if degree of $B(x)$ > degree of $C(x)$

Given: $G(x) = x^{16} + x^{12} + x^5 + 1$ ⇒ Degree = 16

Also a polynomial $C(x)$ divides $B(x)$ exactly once if degree $B(x)$ = degree $C(x)$

As per given burst errors → Error polynomial will have degree $L \leq 16$ with

$E(x) = x^k \; --- \; x^0$ and $x^k = 1$ and $x^0 = 1$

Since $E(x)$ will always have degree ≤ 16 so $G(x)$ will always have a degree greater than or equal to $E(x)$.

So $G(x)$ will never divide $E(x)$ fully and we will always get some remainder

~~G(x) %~~ $E(x) \% G(x) \; != 0$

Hence any Burst Error of Length $L \leq 16$ will be always detected.

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3. [4 points]: Recall that Manchester encoding uses two signals to represent a single bit. Alternatively, this can be viewed as a two-step process:

Step 1. Bit encoding: $1 \rightarrow 10$, $0 \rightarrow 01$.

Step 2. Signal encoding: The encoded bits are transmitted using NRZ scheme ($0 \rightarrow$ low, $1 \rightarrow$ high)

Let's call this scheme as 1B/2B encoding as 1 bit is encoded using 2 bits. Given this context, answer the following questions:

A. Design a 2B/3B encoding scheme such that a signal transition occurs at least once every 4-bit times. Explain both the bit-encoding and signal-encoding steps.

B. For a general nB/$n+1$B encoding scheme, discuss one advantage and one disadvantage of using a large value of n for such encoding.

A: Signal encoding
00 → low
01 → low med
10 → high med
11 → High

Since 2 bits so 4 options possible

Bit encoding
000 → 00
001 → 01
010 → 10
011 → 11
100 → 00
101 → 01
110 → 10
111 → 11

The Bit encoding ensures signal transition occurs atleast once every 4 bits

B) Advantage → More precision since Large range

Disadvantage → longer delays in attaining same level again.

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4. [4 points]: Answer the following questions:

A. Recall that the minimum frame size on 10 Mbps Ethernet is 64 bytes. Assume a new version of Ethernet called *Fast Ethernet* that uses the same medium access control as Ethernet. If we want to keep the minimum frame size the same, what should a network designer ensure for correct MAC operation? Fast Ethernet speed 100 Mbps.

B. Consider two nodes, A and B, that use the slotted ALOHA protocol to contend for a channel. Suppose node A's transmission probability is p, while node B's transmission probability is 2p. Provide a formula for A's average throughput. In addition, find p such that ~~A~~'s B's throughput is thrice of ~~B~~'s A's throughput.

3/8

A. $\frac{64 \times 8}{100 \times 10^6} = 5.12$ microsec = Transmission Time

MAC designer should ensure $2 \times RTT$ should be ~~more~~ less than 5.12 μsec

Basically propagation delay should be atleast 256 μsec.

B. Avg Throughput A = $\frac{p(1-2p)}{2}$

Avg Throughput B = $\frac{2p(1-p)}{2}$

~~3B = A~~ B = 3A

$\Rightarrow \frac{2p(1-p)}{2} = 3 \times p(1-2p)$

$3(p - 2p^2) = 2p - 2p^2$

$3p - 6p^2 = 2p - 2p^2$

$p = 4p^2$

$1 = 4p$ $\boxed{p = \frac{1}{4}}$

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5. [5 points]: Consider a wireless network with three nodes: A, B, and C. A and B can hear each other, B and C can hear each other.

A. Explain why A and C cannot transmit simultaneously using CSMA/CD.

B. Explain why this issue does not arise in wired Ethernet networks.

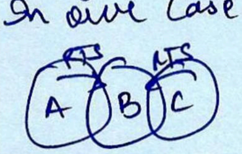
C. Sketch a MAC protocol that solves this problem in the wireless scenario.

A. Using CSMA/CD A sends a signal to B and C sends a signal to B but there is no way for A to send signal to C directly since they are not in each others range. This is called Hidden Tower Problem and A & C ~~can~~ transmitting simultaneously can lead to collision because both think channel is free.

B. In wired ethernet the Blocking signal propogates through the entire channel i.e. through all links so if A is sending & collision occurs C also gets notified & it can sense the transmission. Basically in wired Ethernet since devices are physically connected through links no node is Hidden and collisions are detected.

C. The CSMA/CA (Collision Avoidance) protocol uses two special packets: RTS (Request to send); CTS (Clear to send) so Before transmitting a sender send RTS packet and only sends after receiving CTS.

In our Case:-



1.) Case 1: B sends CTS back to either A or C and either one transmits.

2.) Case 2: B doesn't send CTS and Both A & C Backoff and Wait.

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6. [3 points]: The following character encoding is used in a data link protocol:
A: 01000111 B: 11100011 FLAG: 01111110 ESC: 11100000
Show the bit sequence transmitted for the four-character frame A B ESC FLAG when each of the following framing methods is used:

A. Byte count

B. Flag bytes (or sentinel approach) with byte stuffing

C. Flag bytes (or sentinel approach) with bit stuffing

Feel free to report Part A and Part B in terms of symbols, while Part C should be shown in binary bits.

A: send Byte count ahead of the message:- A B ESC FLAG = 4 Bytes

Bit sequence: $\underbrace{00000100}_{\text{Byte Count}=4}$ $\underbrace{01000111}_{A}$ $\underbrace{11100011}_{B}$ $\underbrace{11100000}_{ESC}$ $\underbrace{01111110}_{FLAG}$

B:
Byte stuffing: send Flag to show start & end & ESC for FLAG & ESC

FLAG A B ESC ESC ESC FLAG FLAG

01111110 01000111 11100011 11100000 11100000 111 00000 01111110 01111110

C: Bit stuffing: Stuff 0 when we see 5 consecutive 1's

A B

~~01000111 110100011 0111110101 11100000~~

A B ESC FLAG

01000111 110100011 11100000 0111111010

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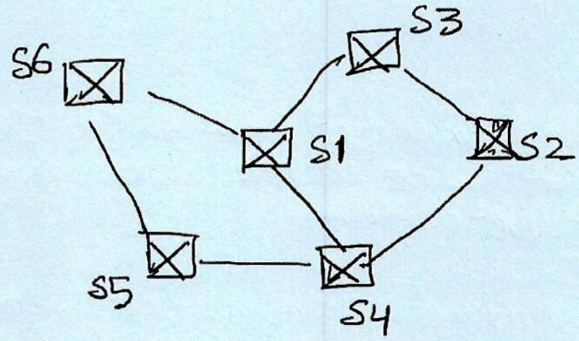
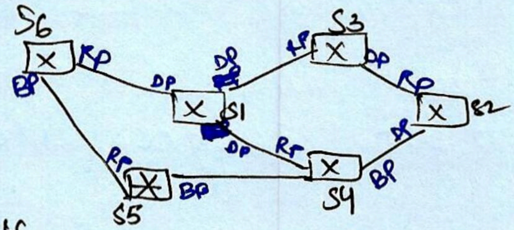
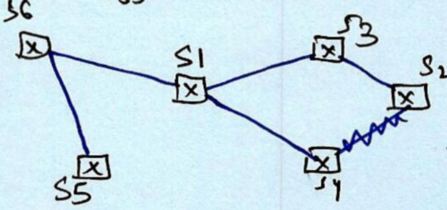


7. [4 points]: For the given Layer-2 network topology, draw the spanning tree generated by the Spanning Tree Protocol (STP). Clearly indicate the root port, designated ports, and blocked ports. What changes occur in the spanning tree when the link between S2 and S3 goes down? In particular, show the new spanning tree and explain how it is constructed.

Ans

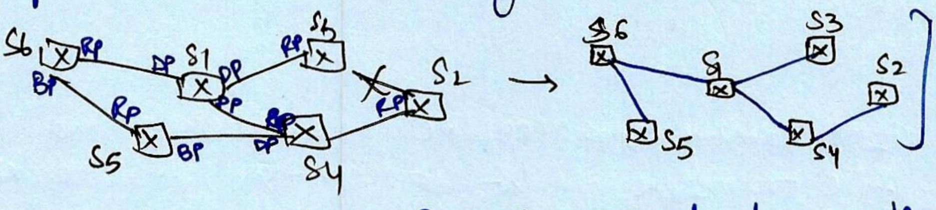
Root = S1





spanning tree

If link between S2 & S3 goes down :-



New Spanning Tree

Since link between S2 & S3 went down the port from S2 to S4 which was earlier DP & Blocked at 4 Now Becomes Root Port and the S2-S4 edge gets added so Spanning Tree structure changes.

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II Network Layer

8. [3 points]: Explain the difference between routing, forwarding, and switching.

Routing: Moving data packet from source IP address to Destination IP address within same or different Network.

Forwarding → Forwarding the packet from input port to correct output port ~~[illegible]~~ based on MAC address.

Switching → ~~Forw~~. Moving data packet to correct output interface inside L2 switch.

9. [3 points]: Explain how large file transfers could degrade the latency observed by both a gaming application and small file transfers. Suggest a scheduling mechanism that could mitigate this problem.

~~Both~~ Gaming apps require low latency and large file transfer might hog up the network and monopolize. Also small file behind a large file can lead to unnecessary blocking similar to Belady's effect where ~~small~~ small file could be transmitted fast but has to wait due to large file transferring taking more time.

→ Round Robin & Weighted fair queue can solve this by doing fair scheduling.

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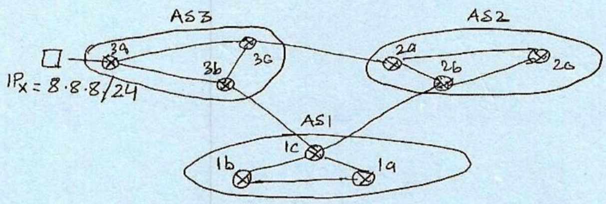
→ Large file transfer can hog up the network for longer time due to which queuing delay for gaming app packets will increase leading to degradation of latency.

10. [6 points]: Consider the network topology below. $AS3$ is the origin AS for IP prefix $IP_x = 8.8.8.8/24$. Assume all routers are BGP routers. Answer the following questions:



a. Assuming synchronous updates, list all the announcements for IP_x received at BGP routers $1c$ and $1b$. Be sure to include both the AS path and the next hop.

b. Case 1: Suppose $AS1$ wants to route traffic to IP_x via $AS2$. How can it achieve this?

c. Case 2: Suppose $AS2$ wants the traffic from AS1 to IP_x to pass through its network (e.g., $AS2$ is a malicious AS trying to surveil $AS1$'s traffic). Design a mechanism to accomplish this using only BGP. (Hint: Consider the IP lookup process.)

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a.) Announcements :—

1c: (8.8.8/24, AS3, 3b)

1b: (8.8.8/24, AS3, 1C)

b.) It can do so by setting a higher LOCAL_PREF value for AS2 routing so that the packets are routed from AS2 through 1c - 2b.

c.) AS2 can disguise itself as DNS server and set one of server address to this so that AS 3 and AS1 ~~Route~~ route its traffic through AS2 for IP lookup since it will be posing itself as server address for IP lookup.

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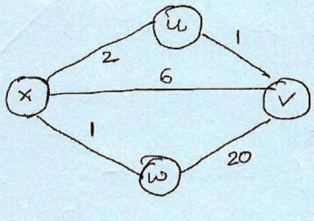
11. [3 points]: Recall that in interdomain routing, a link between two ASes can represent one of three business relationships: customer-provider, provider-customer, or peer-peer. As a network operator, you must configure BGP export policy – i.e., decide which neighbours (peers, customer, providers) should be forwarded a route advertisement – while ensuring that the policy respects the underlying economic relationships. For each of the following cases, specify the correct export policy:

a. route was learned from a customer
b. route was learned from a provider
c. route was learned from a peer

a.) Route advertisement to ~~cus~~ providers
b) Route advertisement to customers
c) Route advertisement to peers.

12. [8 points]: Consider the following network topology using distance vector routing with poisoned reverse, i.e., if A routes to X through neighbor B, A does not share its distance to X with B. Answer the following questions:



a. Give x's distance vector announcements to u.

b. Give a link-cost change for either $c(v,w)$ or $c(v,u)$ such that v will *not* inform its neighbors of a new minimum cost-path to any destination to its neighbors.

c. Suppose that $c(x,w)$ increases to 40. Will there be a count-to-infinity problem? If no, explain why. If yes, how many messages will be exchanged between x and v before the network stabilizes again?

$c(x,v)$

d. How do you modify $c(x,y)$ such that there is no count-to-infinity problem at all if $c(x,w)$ changes from 1 to 40?

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a.) x : (x,0) ; (u,2) ; (v,6) ; (w,1)

b) Change c(v,u) → 5

~~c) Yes there will be count to infinite problem.~~

~~c) No it will not be a problem because~~
~~First x will advertise:- & v hears~~

~~x : (x,0) (u,2) (v,6) (w,40)~~

~~Then v advertises:~~

~~v : (v,0) (u,1) (x,6) (w,20)~~

~~x will hear this and will get to know that a new shorter path exists and it will change~~

~~x : (x,0) (u,2) (v,6) (w,26)~~

~~so count to infinity wont occur~~

c) Yes Count to infinite occurs
After 7 messages it stabilizes

d.) set distance (x,v) to 40 so that both paths are same cost (x,v) (x,w)

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13. [6 points]: Answer the questions below. Write concise answers.

A. Suppose the network layer were to perform routing based on Ethernet MAC addresses instead of IP addresses. What is the major challenge with this approach?

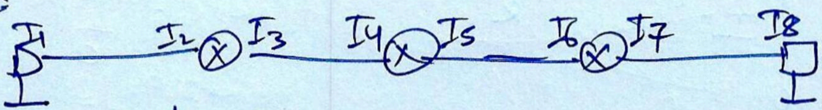
B. Message complexity is the total number of control messages exchanged (including forwarded copies) until convergence. What is the message complexity of the link state routing algorithm? Suppose a link cost changes, what is the message complexity of the update?

C. Suppose there are four routers between a source host and a destination host. Ignoring fragmentation, an IP datagram sent from the source host to the destination host will travel over how many interfaces? How many forwarding tables will be indexed to move the datagram from the source to the destination? Suppose the TTL at the source was k, what is the TTL at the destination?

A. Ethernet MAC's are fixed so large Routing tables since one entry for each device. and also no subnetting.

B. If there are n links → n messages
If link updates n-1

C:



- 8 interfaces
- ~~6 Tat~~ 3 Tables indexed.
- k-3 Final TTL

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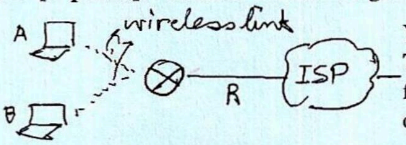
III Design Questions

14. [8 points]: Consider the following scenario:



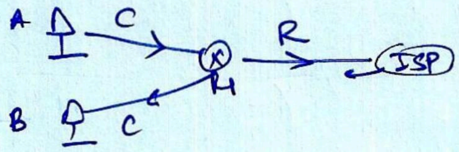
You and your sibling are connected to your home router via WiFi. The WiFi router supports simultaneous uplink and downlink traffic at a rate of C Mbps each. Your Internet plan provides a rate of R Mbps in both directions. Answer the following questions:

A. You (A) send two packets back-to-back, each of size L, destined for your sibling's machine (B). Assume the packets are routed via your WiFi router. Calculate the arrival times of the first and second packet at your sibling's machine. Assume propagation, processing, and link-layer delays are negligible, and there is no other traffic.

B. Suppose you want to verify that the rate you are receiving from your ISP is close to your subscribed rate. Sketch a measurement technique you could use as an end host. You cannot modify your home router and have access only to your machine.

C. You notice significant lags in your video conferencing call and suspect that your sibling is sending a large amount of data over the Internet. You want to verify this independently. Your router supports priority queuing with high and low priority queues, and by default, data is sent at low priority. Sketch a measurement technique to determine if there is significant cross-traffic on your router.

A.



$A \to H = \frac{L}{C}$

$R_1 \to ISP = \frac{L}{R}$

$ISP - R_1 = \frac{L}{R}$

$H - B = \frac{L}{C}$

Total Time: $2\left(\frac{L}{R}+\frac{L}{C}\right)$

- 1st packet Arrival time $= 2L\left(\frac{R+C}{RC}\right)$

- 2nd Packet →

Wait $\frac{L}{C}$ At A → Then $\frac{L}{C}$ to $R_1 = \frac{2L}{C}$ at R_1

Then $R_1 \to ISP \to H = \frac{2L}{R}$ So $\frac{2L}{C}+\frac{2L}{R}$ back at R_1

$H \to B \to \frac{L}{C} \Rightarrow \frac{2L}{C}+\frac{2L}{R}+\frac{L}{C}$

2nd Packet Arrival time $= \frac{3L}{C}+\frac{2L}{R}$

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B. Flood the network with as much data as i can send in T time measure it as D. Then the amount of data I could send in T time ie. D tells network Rate as →

$$\text{Rate} = \frac{D}{T}$$

This is done in speed test.

~~C. Send 2 packets with higher priority so that it's gets placed in higher priority queue and wait for the Acknowledgement~~

c) Send 2 packets one with higher priority and one with lower priority. Note time for both packets to return. If the return time for high priority is lesser than low priority this means heavy amount is being sent over this higher queue which is causing low priority queue packets to have more queueing delay and lesser throughput since more time is being spent in servicing higher amount downloads in higher priority queue.

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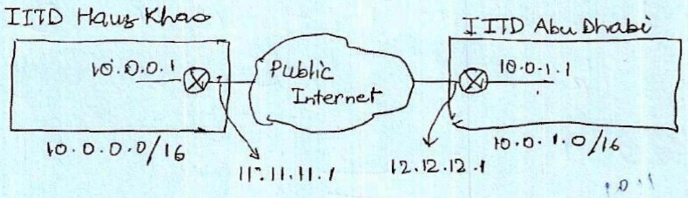
15. [4 points]: Consider the following scenario: The hosts in IITD Hauz Khas campus are in the private network 10.0.0.0/16, while hosts in IITD Abu Dhabi campus are in the private network 10.0.1.0/16. Assume that there is 1 border router in each campus that connects it to the public Internet as shown below. As a network operator, you want to enable seamless communication between hosts in the two campuses *using their private IP addresses*. Design a mechanism that achieves this without requiring any participation from the end hosts.



We can use NAT (Network Address Translation) wherein a middlebox NAT Translator keeps a NAT Table. Whenever ~~an~~ request comes from private network host NAT maps it as
(Private IP, Port) ⟶ (IITD Router Public IP, New Port No.)
or
(Private IP, Port) ⟶ (IIT Abu Dhabi Public IP, New Port)
NAT sits at each public end of each Router and does this translation through a NAT table storing these mappings & New Port number so that it seems traffic is coming from different hosts without any end host participation.

16. [7 points]: Answer the following questions:

A. Recall that the data plane is the part of a network device responsible for forwarding data. Compare circuit switching and packet switching in terms of data plane complexity.

B. Consider the following scenario:

i. A backbone network has routers processing packets at 100 Gbps. Assume the average packet size is 500 bytes. What is the maximum budget for different forwarding plane functions?

ii. Consider IPv6 routing that performs lookups using unibit tries with an SRAM lookup time of 1 ns. Would it be possible to ensure that the data plane overhead remains within the maximum budget calculated earlier? Explain.

iii. Recall that IPv6 includes a 20-bit flow label in its header. How could this header be used to design a faster data plane?

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A. Circuit Switching	Packet switching
1.) Dedicated path is estabilished and packets can be forwarded in this path with full bandwidth guarantee for entire duration so no congestion control needed	1.) Path is shared so multiple packets might get collided & it also does best effort delivery so congestion Control mechanisms needed.
2.) Forwarding is simple	2.) Forwarding is Complex.

B 1.) → Size = 500 bytes Speed = 100 Gbps

Time to transmit = $\frac{500 \times 8}{100 \times 10^9}$ = 40 nanoseconds

∴ Budget is 40ns

2.) No, it wouldn't be possible since IPv6 is 128 bit in worst case 128 lookups in unibit tries = 128 ns > 40 ns so maximum budget crossed.

3.) Flow table can be used to show the flow of data & reduce checksum & error checks leaving it for higher layers like Transport and Link layers Thereby decreasing latency & a Faster data plane.

$1 \rightarrow 10$

$0 \rightarrow 01$

$000 \rightarrow 00$

$001 \rightarrow 01$

$010 \rightarrow 10$

$011 \rightarrow 11$

$100 \rightarrow 00$

$101 \rightarrow 01$

$110 \rightarrow 10$

$111 \rightarrow 11$