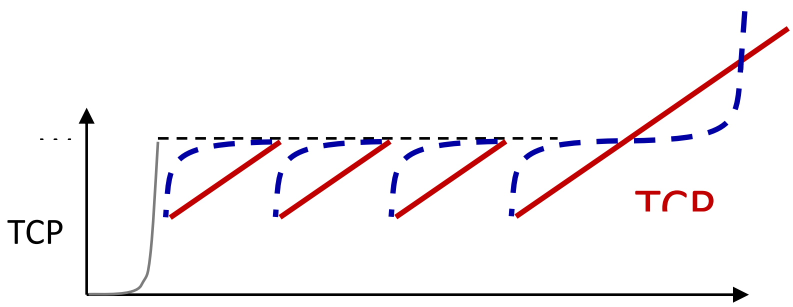
Question 1: CLO-01 **[2x5=10 points]**

a) Network Congestion is one of the top most research topics in Computer Networks. Is there a better way than Additive Increase Multiplicative Decrease (AIMD) to "probe" for usable bandwidth?

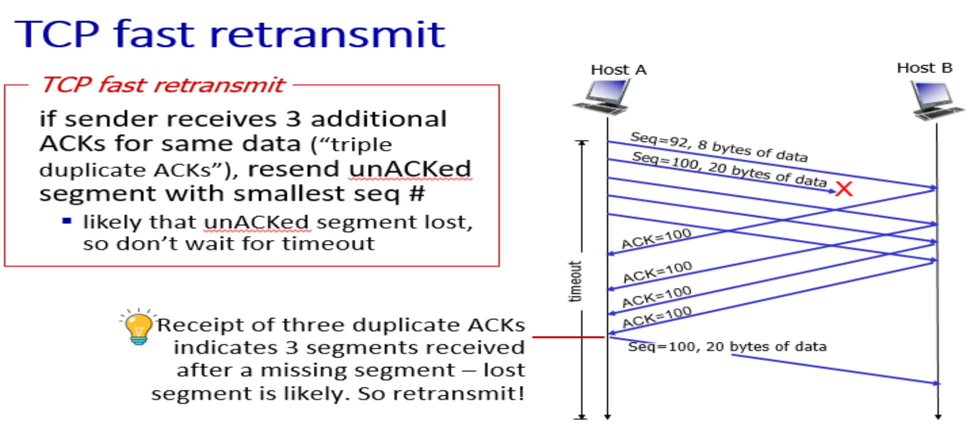
Solution:

- W_{max}: sending rate at which congestion loss was detected
- congestion state of bottleneck link probably (?) hasn't changed much
- after cutting rate/window in half on loss, initially ramp to to W_{max} *faster*, but then approach W_{max} more *slowly*
- K: point in time when TCP window size will reach W_{max}
- K itself is tuneable
- increase W as a function of the *cube* of the distance between current time and K
- larger increases when further away from K
- smaller increases (cautious) when nearer K



b) With the help of Windo timing diagram, explain the phenomenon of TCP Fast Re-transmit.

Solution:



Question 2: CLO-01 **[2x5=10 points]**

a) How a link-state routing protocol works differently from a distance vector protocol? Explain this difference using a comparison chart.

Solution:

Link State Protocol	**Distance Vector Protocol**
1. Table update process (3 points)	
Routers exchange Link state advertisement to collect **global** knowledge at each router. Each advertisement has router IDs and cost of connected interfaces.	Each router process **local** knowledge (cost of its own interfaces and directly connected neighbors) using DV algorithm (bellman-ford) and create distance vectors (DV).
construct least-cost-path tree by tracing predecessor nodes ties can exist (can be broken arbitrarily)	**iterative, asynchronous:** each local iteration caused by: local link cost change DV update message from neighbor
each router must broadcast its link state information to **other n routers**	
efficient (and interesting!) broadcast algorithms: O(n) link crossings to disseminate a broadcast message from one source	**distributed, self-stopping**: each node notifies neighbors only when its DV changes neighbors then notify their neighbors – only if necessary no notification received, no actions taken!
2. message complexity (1 point)	
n routers, O(n2) messages sent	exchange between neighbors; convergence time varies
3. speed of convergence (1 point)	
O(n2) algorithm, O(n2) messages may have oscillations	convergence time varies may have routing loops count-to-infinity problem
4. robustness: what happens if router malfunctions, or is compromised? (1 point)	
router can advertise incorrect link cost each router computes only its own table	DV router can advertise incorrect path cost (“I have a really low cost path to everywhere”): black-holing each router’s table used by others: error propagate thru network

b) Consider the network graph shown in figure 1 with nodes A to F. Apply Dijkstra’s algorithm to find the least cost path from Node A to all other nodes.

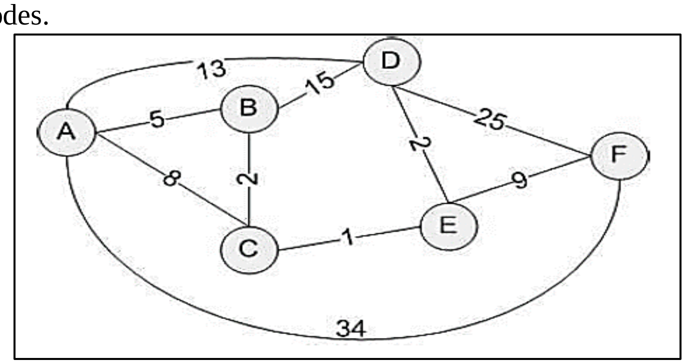


Figure 1: A network graph

Solution:

Step	S	D(B),p(B)	D(C),p(C)	D(D),p(D)	D(E),p(E)	D(F),p(F)
0 (Initialization)	A	5,A	8,A	13,A	∞	34,A
1	AB		7,B			
2	ABC				8,C	
3	ABCE			10,E		17,E
4	ABCED					
5	ABCEDF					

Question 3: CLO-01 **[2x5=10 points]**

Imagine that a sender uses RDT 3.0 with stop-and-wait. This sender sends packets of length 10 KB over a link of 1 Mbps. The average round trip time RTT is equal to 250ms.

a) Calculate the channel utilization and then explain the result.

Solution:-

The packet size is L=10KB=10*8*Kbits=80 Kbits

The bandwidth is R=1Mbps=1000 kbps = 1024kbps

The transmission time is calculated as:

L/R=80 Kb/1000 kbps =0.08 sec=80 ms = 0.078 = 78ms

Thus, the Utilization is determined as follows:

U = (L/R)/(RTT+L/R) = 80/80+250=0.24 = 78/78+250 = 0.2378 = 24%

The channel is underutilized as it is effective only 24% of its maximum capacity.

b) How the channel utilization may be increased?

Solution:-

The problem is the low utilization of the system which could be solved by pipelining protocol

Question 4: CLO-01 **[5x2=10 points]**

Write the difference, in maximum 30 words each (answer will not be marked after 30 words)

a) (In Forwarding table computing/learning) process at switches versus routers

Solution:-

routers: compute tables using routing algorithms, IP addresses

switches: learn forwarding table using flooding, learning, MAC addresses

b) intra-AS routing versus intra-domain routing

Solution:-

No difference.

c) Time-to-Live field of IPv4 Header versus Hop-Limit field of IPv6 Header

Solution:-

No difference, same function, just different naming convention.

d) Flow control mechanism in link layer versus flow control in transport layer

Solution:-

On the link layer, pacing between adjacent sending and receiving nodes on a link is handled, while on transport layer, overflow at the final destination node is avoided.

e) Connectionless link versus Unreliable link

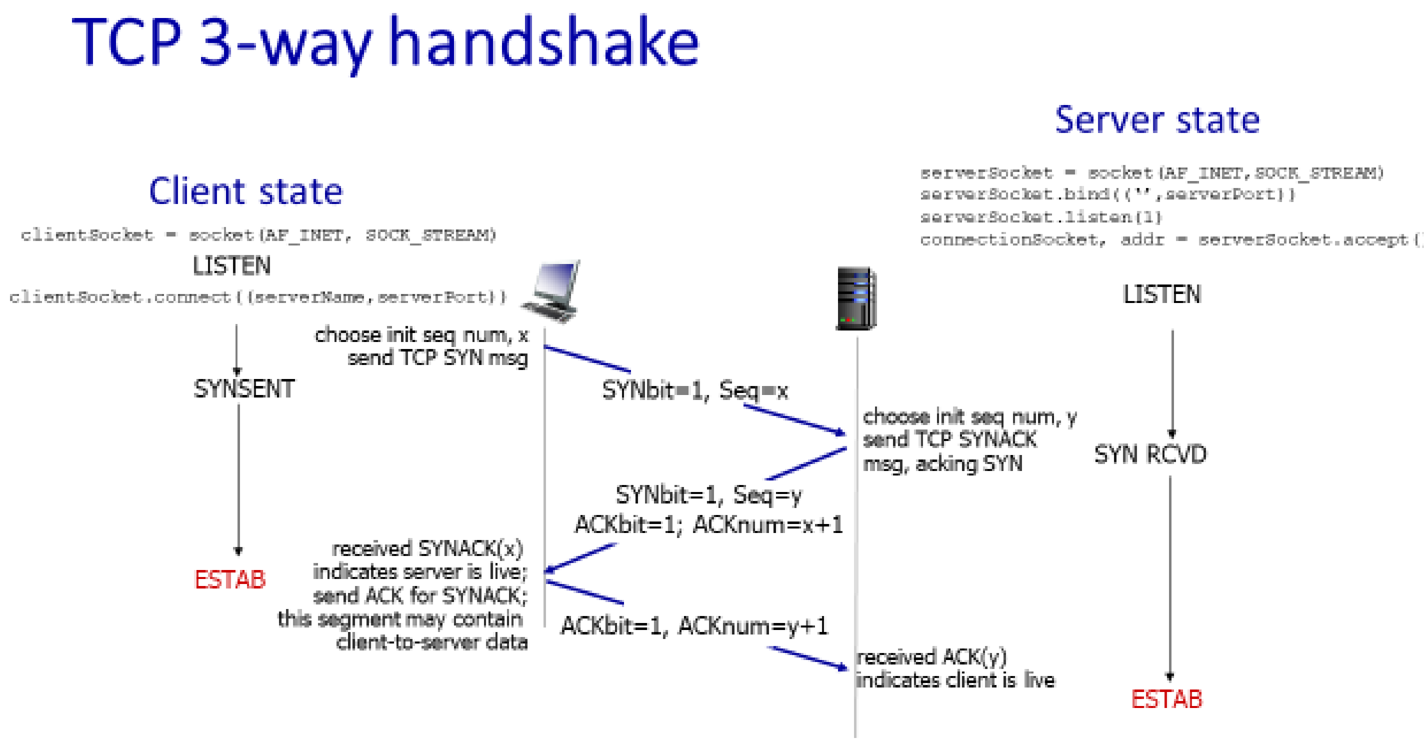
Solution:-

Connection-less: no handshaking between sending and receiving NICs

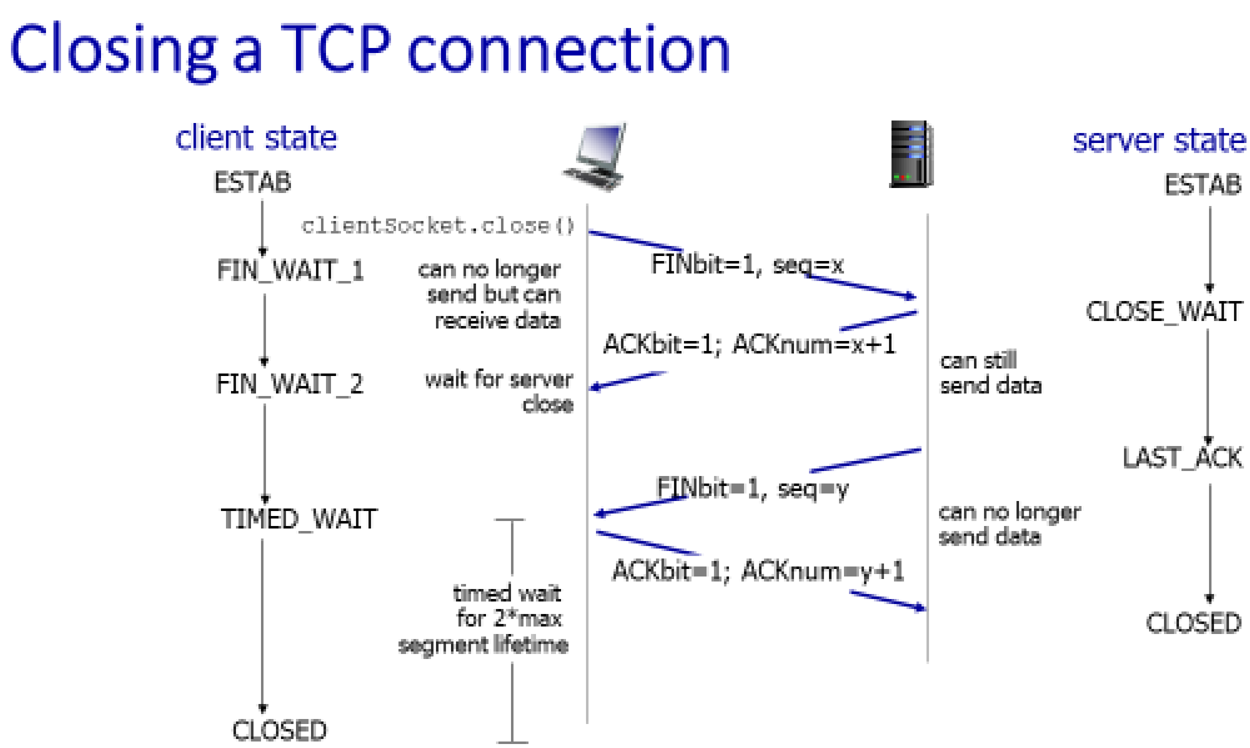
Unreliable: receiving NIC doesn't send ACKs or NAKs to sending NIC

Question 5: **CLO-01** **[2x5=10 points]**

In TCP connection management, a three-way handshake is used to establish a TCP connection. With the help of a sequence diagram, describe in detail the three-way handshake process and TCP connection termination process. Your description should include the details of actual sequence and acknowledgement number.



Solution:



Question 6: CLO-02 **[4x2.5=10 points]**

Consider the LAN scenario in figure 2 and answer the following:

a) Which protocol is used to resolve IP to MAC addresses?

Solution:

Address Resolution Protocol (ARP)

b) Which broadcast address is used in an ARP request frame?

Solution:

Broadcast MAC address: FFFF.FFFF.FFFF

The frame contains the IP address of the destination and the broadcast MAC address, FFFF.FFFF.FFFF.

c) PC-A has sent a frame addressed to PC-B. What will the switch SW1 do with the frame if address of PC-B is not present in the MAC address table of SW1?

Solution:

The switch SW1 will forward the frame to all ports.

d) PC-C is trying to send a packet to a PC-D on a remote LAN segment, but there are currently no mappings in its ARP cache. How will the PC-C obtain a destination MAC address?

Solution:

PC-C will send an ARP request for the MAC address of the default gateway i-e E6-E-00-17-BB-4B.

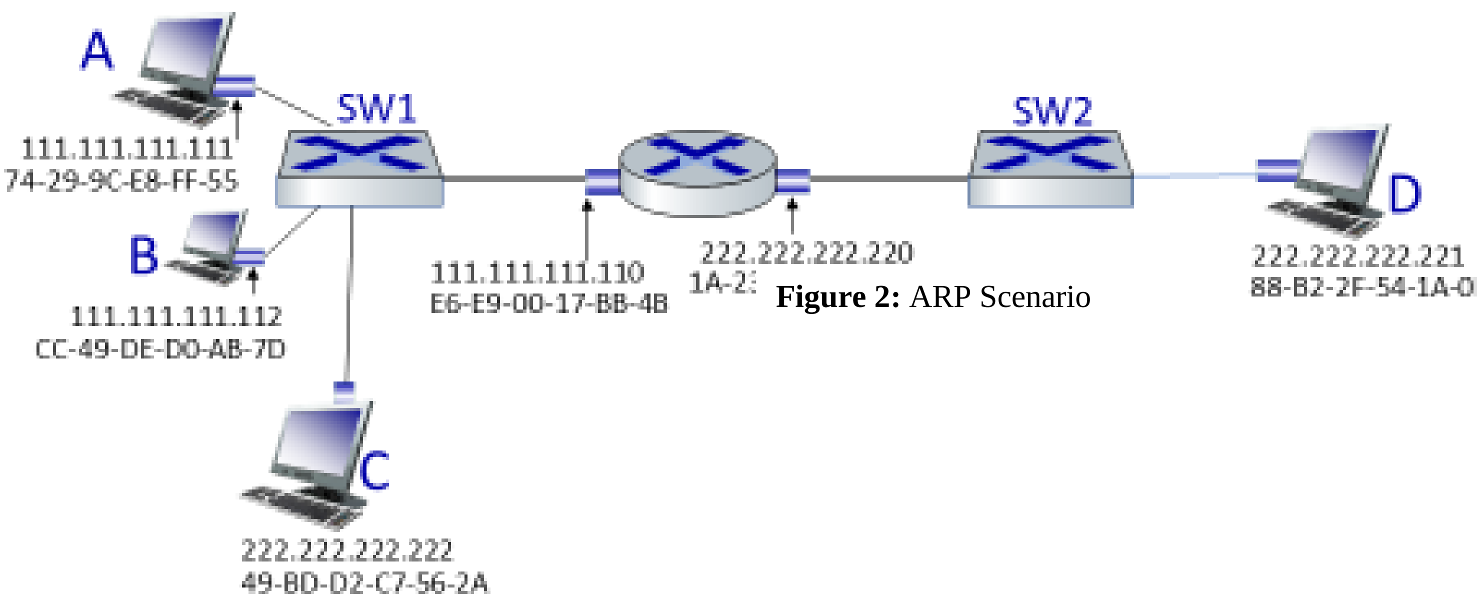


Figure 2: ARP Scenario

Question 6: CLO-02 **[5x2=10 points]**

A University uses the address block of 192.168.9.0/24 for its network. Now your task is to assign IP addresses to the different department's LAN as shown in network figure 3. The network has the following addressing requirements.

- The Computer Science (CS) department LAN-1 will require 50 host IP addresses.
- The Computer Science (CS) department LAN-2 will require 120 host IP addresses.
- The Electrical (EE) department LAN-1 will require 10 host IP addresses.
- The Electrical (EE) department LAN-2 require 18 host IP addresses.
- The Head Quarter (HQ) LAN-1 will require 28 host IP addresses.

Determine the following.

a) Number of Bits Borrowed
b) Total Number of Subnets
c) Total Number of Host Addresses
d) Number of Usable Addresses
e) Custom Subnet Mask & Subnet Range (Network & Broadcast address)

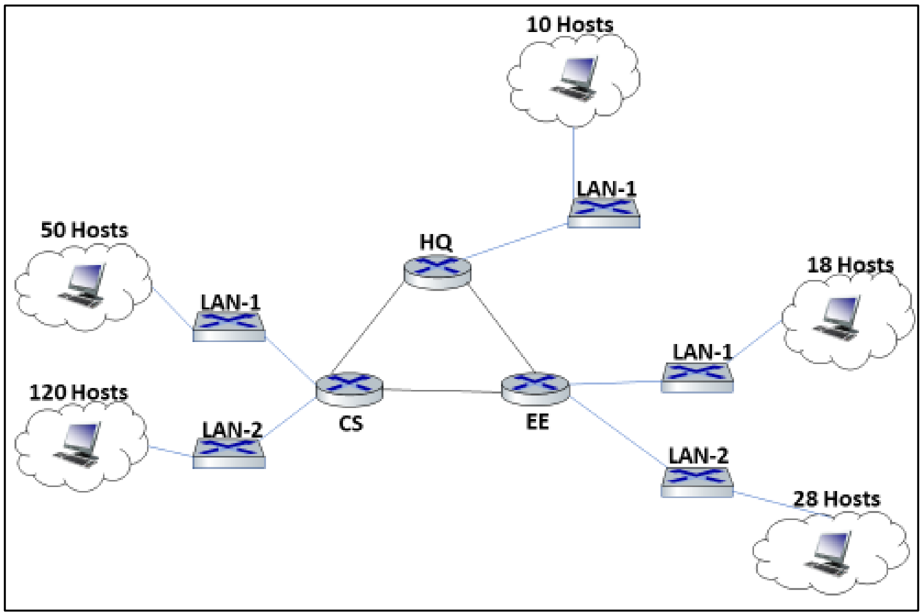


Figure 3: A LAN subnet

Solution:

The Department-1 LAN-1 will require 50 host IP addresses.

Determine the following.

a) Number of Bit Borrowed= 2
b) Total Number of Subnets= $2^2 = 4$
c) Total Number of Host Addresses= 64
d) Number of Usable Addresses=62
e) Custom Subnet Mask= 255.255.255.192
   Subnet Range (Network & Broadcast address)
   192.168.9.0 ---192.168.9.63 192.168.9.64 ---192.168.9.127
   192.168.9.128---192.168.9.191 192.168.9.192 ---192.168.9.255

The Department-1 LAN-2 will require 120 host IP addresses.

Determine the following.

a) Number of Bit Borrowed= 1
b) Total Number of Subnets= $2^1 = 2$
c) Total Number of Host Addresses= 128
d) Number of Usable Addresses= 126
e) Custom Subnet Mask= 255.255.255.128
Subnet Range (Network & Broadcast address)
192.168.9.0 ---192.168.9.127 192.168.9.128 ---192.168.9.255

The Department-2 LAN 1will require 10 host IP addresses.
Determine the following.

a) Number of Bit Borrowed= 4
b) Total Number of Subnets= $2^4 = 16$
c) Total Number of Host Addresses= 16
d) Number of Usable Addresses= 14
e) Custom Subnet Mask= 255.255.255.240
Subnet Range (Network & Broadcast address)

192.168.9.0 ---192.168.9.15 192.168.9.16 ---192.168.9.31
192.168.9.32---192.168.9.47 192.168.9.48 ---192.168.9.63
192.168.9.64 ---192.168.9.79 192.168.9.80 ---192.168.9.95
192.168.9.96 ---192.168.9.111 192.168.9.112 ---192.168.9.127
192.168.9.128 ---192.168.9.143 192.168.9.144 ---192.168.9.159
192.168.9.160 ---192.168.9.175 192.168.9.176 ---192.168.9.191
192.168.9.192 ---192.168.9.207 192.168.9.208 ---192.168.9.223
192.168.9.224 ---192.168.9.239 192.168.9.240 ---192.168.9.255

The Department-2 LAN 2will require 18 host IP addresses.
Determine the following.

a) Number of Bit Borrowed= 3
b) Total Number of Subnets= $2^3 = 8$
c) Total Number of Host Addresses= 32
d) Number of Usable Addresses= 30
e) Custom Subnet Mask= 255.255.255.224
Subnet Range (Network & Broadcast address)

192.168.9.0 ---192.168.9.31 192.168.9.32 ---192.168.9.63
192.168.9.64---192.168.9.95 192.168.9.96 ---192.168.9.127
192.168.9.128 ---192.168.9.159 192.168.9.160 ---192.168.9.191
192.168.9.192 ---192.168.9.223 192.168.9.224---192.168.9.255

The MD LAN-1 will require 28 host IP addresses.
We can assign any of the remaining subnet from part (d).

Question 7: CLO-03 **[5x2=10 points]**

Suppose that the Alice as a client wants to retrieve the www.google.com home page but has no information about the www.google.com web server IP address:

a) Describe the process of the Alice client obtaining the IP address for the hostname www.google.com under the assumption that it is not cached at the local DNS server and that the local DNS server has not cached an entry for the .com DNS server. (Describe this for the non-recursive case)

Solution:

Alice client contacts local DNS, local DNS contacts root DNS, gets info on .com DNS back. Local DNS contacts .com DNS gets IP for www.google.com.

b) After Alice, a second client Bob (connect to the same network as the first client Alice) also wants to obtain the IP address for www.google.com. Describe the process of the client Bob obtaining the IP address in this case.

Solution:

Client Bob contacts local DNS, local DNS has entry cached and returns it to client Bob.

c) Assume that the round-trip time between local DNS server and DNS root server is 3RTT, between local DNS server and DNS TLD server is 2RTT, and between the clients and the local DNS server is RTT. How long does it take for Alice to obtain the IP address for www.google.com? How long for Bob?

Solution:

It takes 6RTT for the Alice to obtain the IP address for google.com

It takes RTT for the Bob client (as the IP address is already in local domain server)

d) How many types of Resource Records (RR) are there?

Solution:

There are 4 types of RR: A, CNAME, NS, and MX.

e) What would be the type for the Resource Record that contains the hostname of the mail server?

Solution:

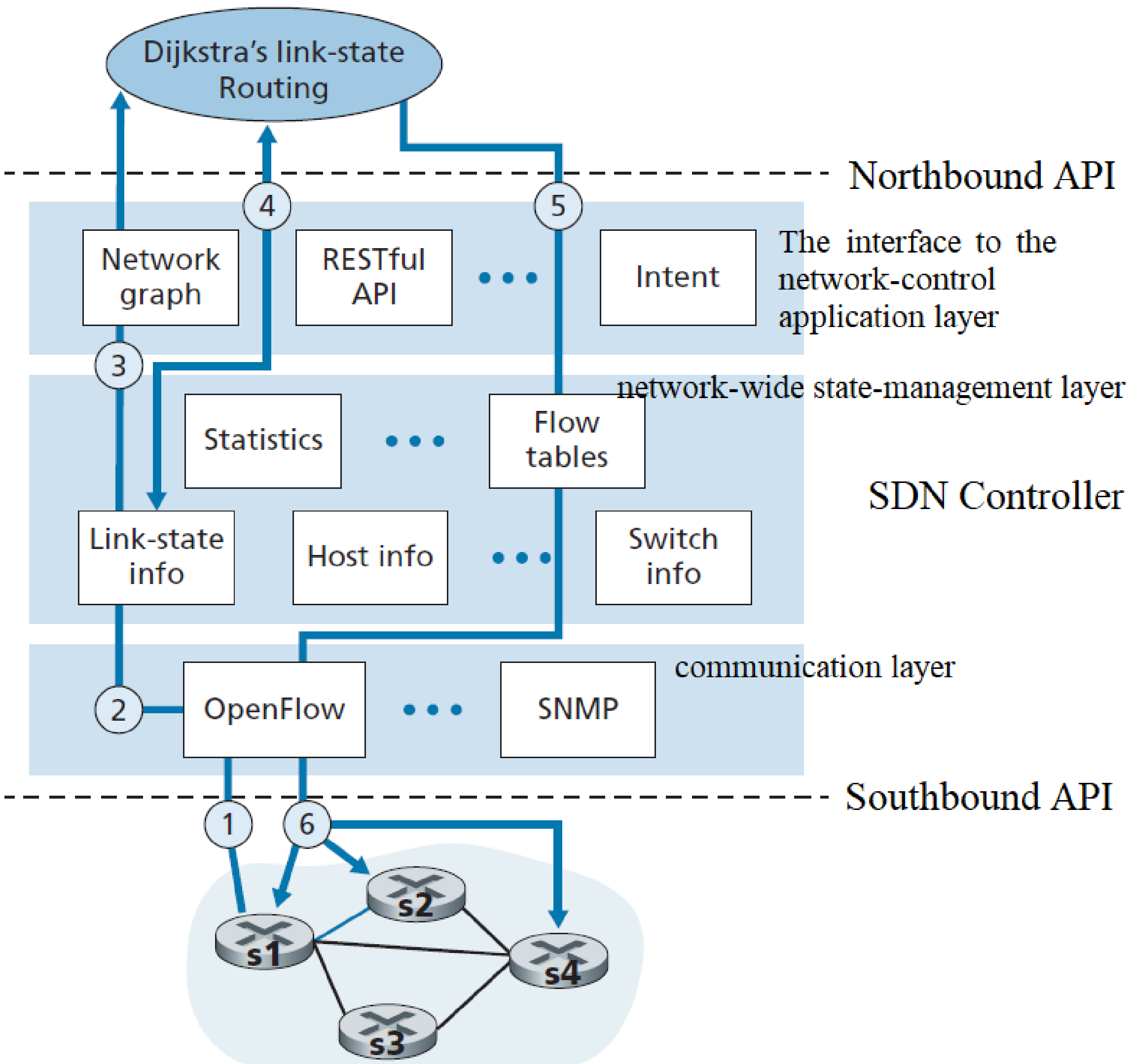
The MX record is used to map the mail server's hostname to its IP address

Question 8: CLO-03 **[10 points]**

How the Dijkstra's link state routing can be used in an SDN controller scenario. Explain using the help of a detailed diagram that takes into consideration following points:

- The Dijkstra's algorithm is executed as a separate application, outside of the packet switches **(1).**
- Packet switches send link updates to the SDN controller and not to each other **(1).**
- A controller's functionality can be broadly organized into three layers **(5)**
  - Name each layer
  - Name different components of an SDN controller within each layer
- The two APIs used for communicating between (1) application plane and control plane and (2) control plane and data plane **(1).**
- The sequence of operations (number them) between different SDN modules/planes, to implement Dijkstra **(2).**

Solution:-



Question 9: **CLO-03** **[2x5=10 points]**

a) Why IP fragmentation was implemented in IPv4?

Solution:-

Each IP datagram need to fit in a frame at the source PC using its MTU size (e.g. ~1400). If it encounters a MTU size of < 1400 while passing through Internet (a mesh connection of routers) the router with lower MTU interface fragment IP datagram into two or more datagram. These datagrams travels the Internet without change (if they haven't encounter another lower MTU) and are assembled back by the destination network layer.

b) ISPs are slowly changing their IP networks to IPv6. This means they have to interconnect between groups of routers running IPv4 with other groups running IPv6. Suppose a scenario shown in figure 4, where IPv6 packets need to traverse an IPv4 tunnel. How is this tunnel practically implemented?

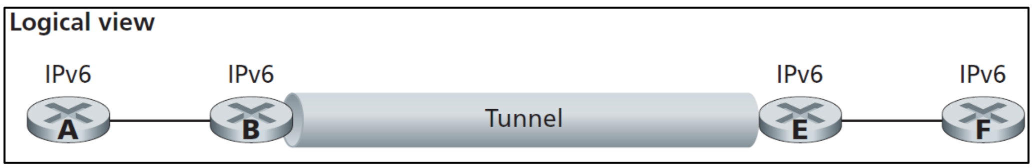
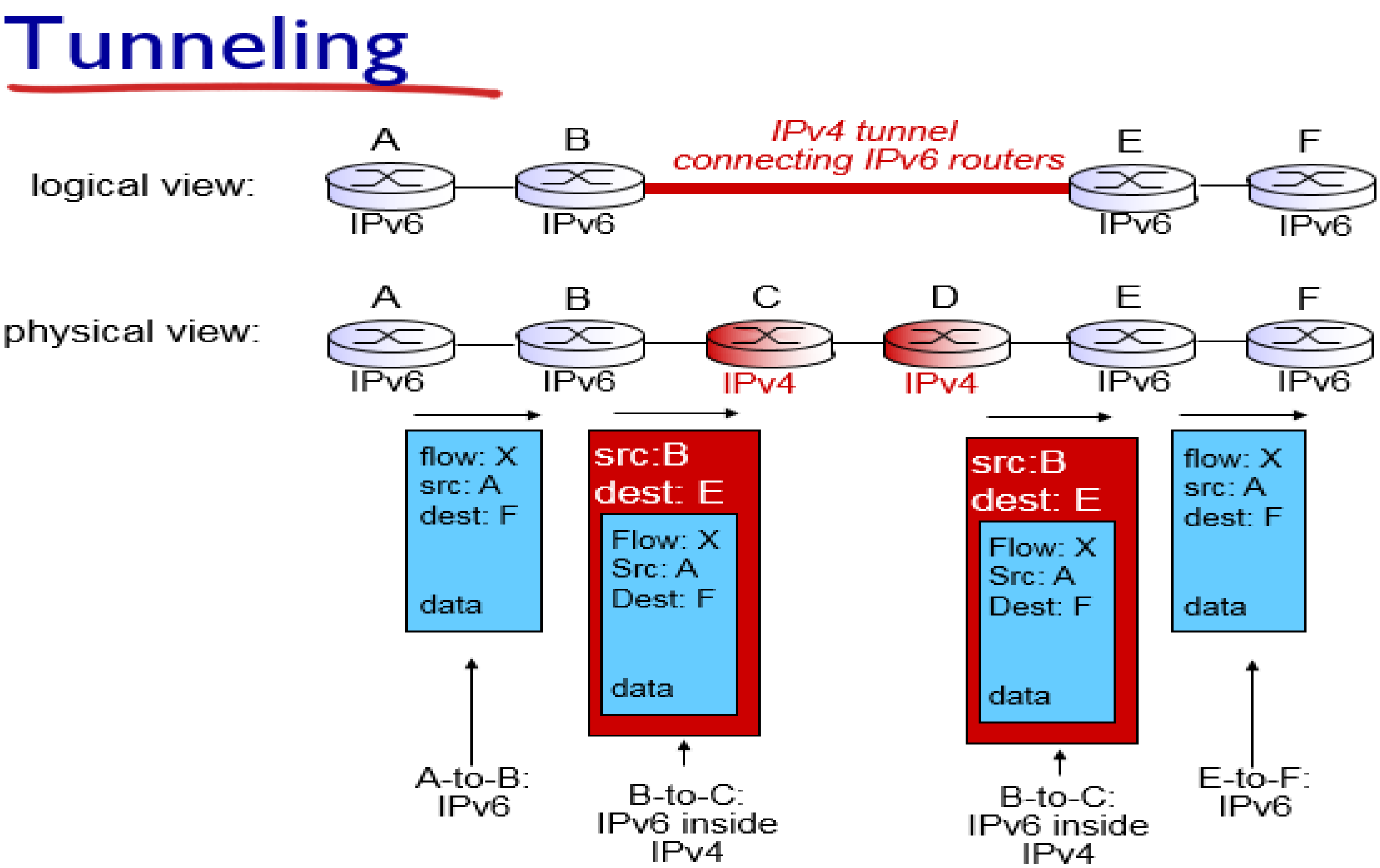


Figure 4: IP Tunneling

Solution:-

It is implemented using tunneling. IPv6 datagram carried as payload in IPv4 datagram among IPv4 routers as shown below.



Question 10: CLO-03 **[3 + 3 + 4 = 10 points]**

For the network shown in Figure 5, suppose that the desired forwarding behavior is that packets from h5 or h6 destined to h3 or h4 are to be forwarded from s3 to s1, and then from s1 to s2 (thus completely avoiding the use of the link between s3 and s2).

a) Write down the flow table entry for s3, so that datagram sent from h5 or h6 are forwarded to s1 over interface 3.

b) Write down the flow table entry for s1, so that datagram arriving at port 1 of s1, from s3, are forwarded to s2 over outgoing interface 4.

c) Finally write down the flow table entry for s2, for forwarding to required destinations.

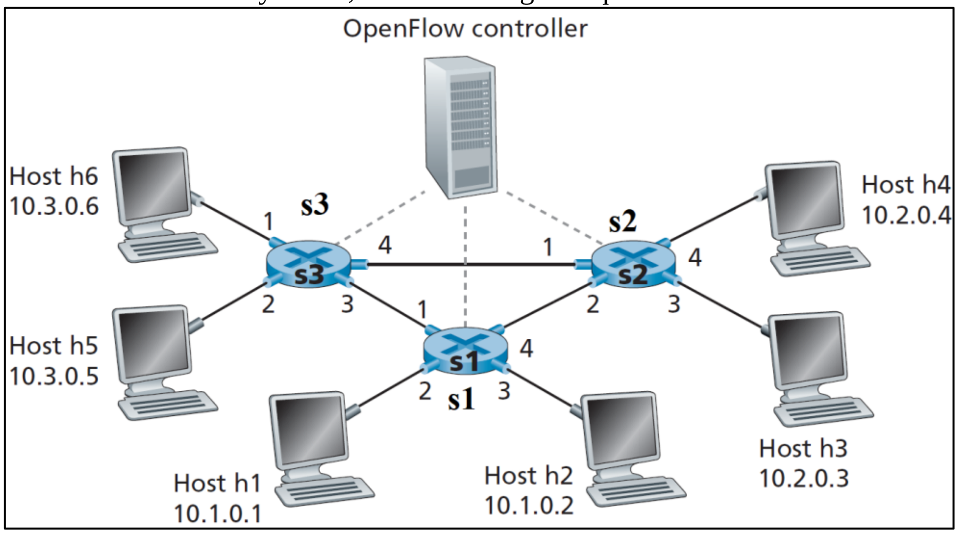


Figure 5. An SDN network, consisting of 3 OpenFlow Switches, 6 Hosts and an OpenFlow Controller

Solution:

(a)

Match	**Action**
IP Src = 10.3.*.* ; IP Dst = 10.2.*.*	Forward(3)

(b)

Match	**Action**
Ingress Port = 1 ; IP Src = 10.3.*.* ; IP Dst = 10.2.*.*	Forward(4)

(c)

Match	**Action**
Ingress port = 2 ; IP Dst = 10.2.0.3	Forward(3)
Ingress port = 2 ; IP Dst = 10.2.0.4	Forward(4)

-------Thank You-------