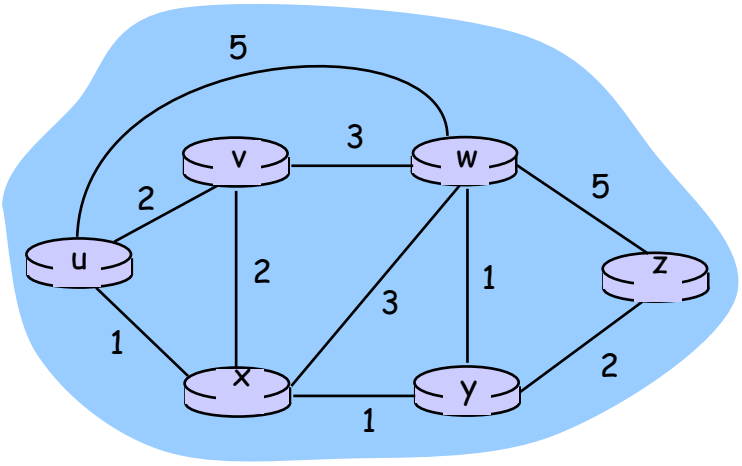
1. What is the difference between routing and forwarding? (10%)
2. What is the Head-of-the-Line (HOL) blocking? (b) Draw a figure to show it. (10%)
3. (a) Describe how packet loss can occur at input ports. (b) Describe how packet loss at input ports can be eliminated. (10%)
4. (a) Describe the assumption and purpose of the Dijkstra's shortest-path algorithm. (5%) (b) Show how the algorithm works by computing a table. (6%) (c) Show the forwarding table of the source node. (5%) (note:如你的學號最後一位數除以 5 的餘數為 0，source node 為 v; 餘數為 1，source node 為 w; 餘數為 2，source node 為 x; 餘數為 3，source node 為 y; 餘數為 4，source node 為 z。數值有變動時需按照演算法寫出計算過程，數值相同時，優先選字母順序較前者。不按照規定，不計分。16%)



5. 針對 IPv4 Class B 網路 (18%)
   a. 求出最後一個 Class B 網路 ID? (2%) 可用 IP 範圍？ (4%) 共有幾個 IP 可用？(2%) （以十進位表示，要寫完整過程）
   b. 將最後一個 Class B 網路分成 3 個 subnet，subnet mask 的值為何？ (2%) 請列出第一個 subnet 的 ID (2%) 可用 IP 範圍？(4%) 共有幾個 IP 可用？(2%)（以十進位表示，要寫完整過程）
6. (a) What is the main motivation of the NAT? (3%)
   (b) How to implement NAT at the router? (6%) (9% total)
7. Describe the goal of DHCP (2%) and draw a figure and describe the four-message flow of DHCP. (8%) (要說明過程，10% total)
8. (a) What are the three motivations of IPv6? (3%)
   (b)Draw a figure to explain how to tunnel IPv6 datagrams between two IPv4 routers? (8%) (要說明過程，11% total)
9. What are two main functions of ICMP to communicate network-level information by hosts & routers? (6%)

只寫答案而沒有解釋說明，扣一半分數

1. (10%)

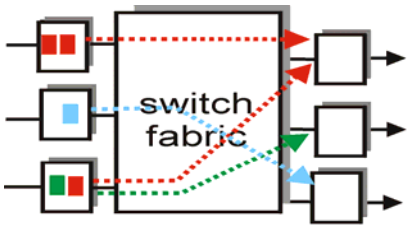
(a) Forwarding is about moving a packet from a router's input link to the appropriate output link. (5%)

(b) Routing is about determining the end-to-end routes between sources and destinations. (5%)

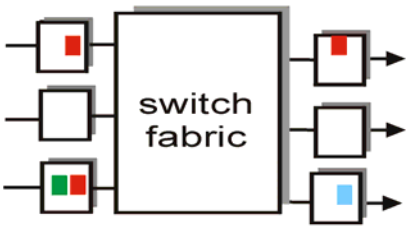
2.

(a) HOL blocking – a queued packet in an input queue must wait for transfer through the fabric because it is blocked by another packet at the head of the line. (5%)

(b) (5%)



output port contention at time t - only one red packet can be transferred



green packet experiences HOL blocking

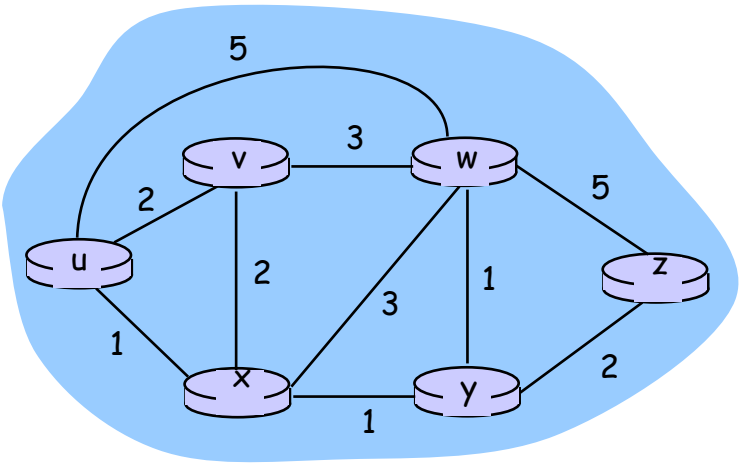
3.

Ans:

(a) Packet loss occurs if queue size at the input port grows large because of slow switching fabric speed and thus exhausting router's buffer space. (5%)

(b) It can be eliminated if the switching fabric speed is at least ***n*** times as fast as the input line speed, where ***n*** is the number of input ports. (5%)

4. (a) Describe the assumption and purpose of the Dijkstra's shortest-path algorithm. (5%) (b) Show how the algorithm works by computing a table. (6%) (c) Show the forwarding table of the source node. (5%) (note:如你的學號最後一位數除以 5 的餘數為 0，source node 為 v; 餘數為 1，source node 為 w; 餘數為 2，source node 為 x; 餘數為 3，source node 為 y; 餘數為 4，source node 為 z。數值有變動時需按照演算法寫出計算過程，數值相同時，優先選字母順序較前者。不按照規定，不計分。)



(a) (5%)

- net topology, link costs known to all nodes (2%)
  - accomplished via “link state broadcast”
  - all nodes have same info
- computes least cost paths from one node (‘source”) to all other nodes (2%)
  - gives forwarding table for that node (1%)

(b) 以 v 為起點 (一欄 1%, 6%)

Step	N’	D(u), p(u)	D(w), p(w)	D(x), p(x)	D(y), p(y)	D(z), p(z)
0	v	2, v	3, v	2, v	∞	∞
1	vu		3, v	2, v	∞	∞
2	vux		3, v		3, x #1	∞
3	vuxw				3, x	8, w #2
4	vuxwy					5, y #3
5	vuxwyz					

#1 D(y) = min(D(y) , D(x) + C(x , y)) = min(∞, 2+1) = 3

#2 D(z) = min(D(z) , D(w) + C(w , z)) = min(∞, 3+5) = 8

#3 D(z) = min(D(z) , D(y) + C(y , z)) = min(8, 3+2) = 5

Forwarding table (一個 1%, 5%)

Destination	Next hop (output link)
u	u
w	w
x	x
y	x
z	x

以 w 為起點

Step	N’	D(u), p(u)	D(v), p(v)	D(x), p(x)	D(y), p(y)	D(z), p(z)
0	w	5, w	3, w	3, w	1, w	5, w
1	wy	5, w	3, w	2, y #1		3, y #2
2	wyx	3, x #3	3, w			3, y
3	wyxu		3, w			3, y
4	wyxuv					3, y
5	wyxuvz					

#1 D(x) = min(D(x) , D(y) + C(y , x)) = min(3, 1+1) = 2

#2 D(z) = min(D(z) , D(y) + C(y , z)) = min(5, 1+2) = 3

#3 D(u) = min(D(u) , D(x) + C(x , u)) = min(5, 2+1) = 3

Forwarding table

Destination	Next hop (output link)
u	y
v	v
x	y
y	y
z	y

以 x 為起點

Step	N'	D(u), p(u)	D(v), p(v)	D(w), p(w)	D(y), p(y)	D(z), p(z)
0	x	1, x	2, x	3, x	1, x	∞
1	xu		2, x	3, x	1, x	∞
2	xuy		2, x	2, y #1		3, y #2
3	xuyv			2, y		3, y
4	xuyvw					3, y
5	xuyvwz					

#1 D(w) = min(D(w) , D(y) + C(y , w)) = min(3, 1+1) = 2
#2 D(z) = min(D(z) , D(y) + C(y , z)) = min(∞, 1+2) = 3

Forwarding table

Destination	Next hop (output link)
u	u
v	v
w	y
y	y
z	y

以 y 為起點

Step	N'	D(u), p(u)	D(v), p(v)	D(w), p(w)	D(x), p(x)	D(z), p(z)
0	y	∞	∞	1, y	1, y	2, y
1	yw	6, w #1	4, w #2		1, y	2, y
2	ywx	2, x #3	3, x #4			2, y
3	ywxu		3, x			2, y
4	ywxuz		3, x			
5	ywxuzv					

#1 D(u) = min(D(u) , D(w) + C(w , u)) = min(∞, 1+5) = 6
#2 D(v) = min(D(v) , D(w) + C(w , v)) = min(∞, 1+3) = 4
#3 D(u) = min(D(u) , D(x) + C(x , u)) = min(6, 1+1) = 2
#4 D(v) = min(D(v) , D(x) + C(x , v)) = min(4, 1+2) = 3

Forwarding table

Destination	Next hop (output link)
u	x
v	x
w	w
x	x
z	z

以 z 為起點

Step	N'	D(u), p(u)	D(v), p(v)	D(w), p(w)	D(x), p(x)	D(y), p(y)
0	z	∞	∞	5, z	∞	2, z
1	zy	∞	∞	3, y #1	3, y #2	
2	zyw	8, w #3	6, w #4		3, y	
3	zywx	4, x #5	5, x #6			
4	zywxu		5, x			
5	zywxuv					

#1 D(w) = min(D(w) , D(y) + C(y , w)) = min(5, 2+1) = 3
#2 D(x) = min(D(x) , D(y) + C(y , x)) = min(∞, 2+1) = 3
#3 D(u) = min(D(u) , D(w) + C(w , u)) = min(∞, 3+5) = 8
#4 D(v) = min(D(v) , D(w) + C(w , v)) = min(∞, 3+3) = 6
#5 D(u) = min(D(u) , D(x) + C(x , u)) = min(8, 3+1) = 4
#6 D(v) = min(D(v) , D(x) + C(x , v)) = min(6, 3+2) = 5

Forwarding table

Destination	Next hop (output link)
u	y
v	y
w	y
x	y
y	y

5. (18%)

a.

最後一個 Network ID 為 191.254.0.0，Network ID 表示為 10111111.11111110.00000000.00000000; (2 分)

Host ID 表示為 10111111.11111110.XXXXXXXX.XXXXXXXX, 所有 16 個 bit 的 X 不可以全為 0 或 1，因此第一個可用 Host ID 為 10111111.11111110.00000000.00000001 = 191.254.0.1 (2 分)

最後一個可用 Host ID 為 10111111.11111110.11111111.11111110 = 191.254.255.254 (2 分)

->共有 2^{16}-2=65534 個可用 Host ID (2 分)

b.

將最後一個 Class B 網路分成 3 個 subnet，加上全為 0 與全為 1 的兩個不能用的 subnet ID，最少需要 3+2=5 subnet mask 的值 => 需要 Host ID 的前 3 個 bits 當作 subnet ID。所以新的 subnet mask 是由原本 Class B 的 default subnet mask 255.255.0.0 來改，改成 11111111. 11111111. 11100000.000000000 => 255.255.224. 0 (2 分)

subnet 的 ID 要從最後一個 Class B Network ID 10111111.11111110.00000000.00000000 來改，需要 Host ID 的前 3 個 bits 當作 subnet ID，不可全為 0 或 1。因此第一個 subnet ID 為 10111111.11111110. 00100000. 00000000 => 191.254.32.0 (2 分)
Host ID 表示為 10111111.11111110. 001XXXXX.XXXXXXXX, 所有 13 個 bit 的 X 不可以全為 0 或 1，因此第一個可用 Host ID 為 10111111.11111110. 00100000. 00000001 = 191.254.32.1 (2 分)
最後一個可用 Host ID 為 10111111.11111110. 00111111.11111110 = 191.254.63.254 (2 分)
->共有 2^{13}-2=8190 個可用 Host ID (2 分)

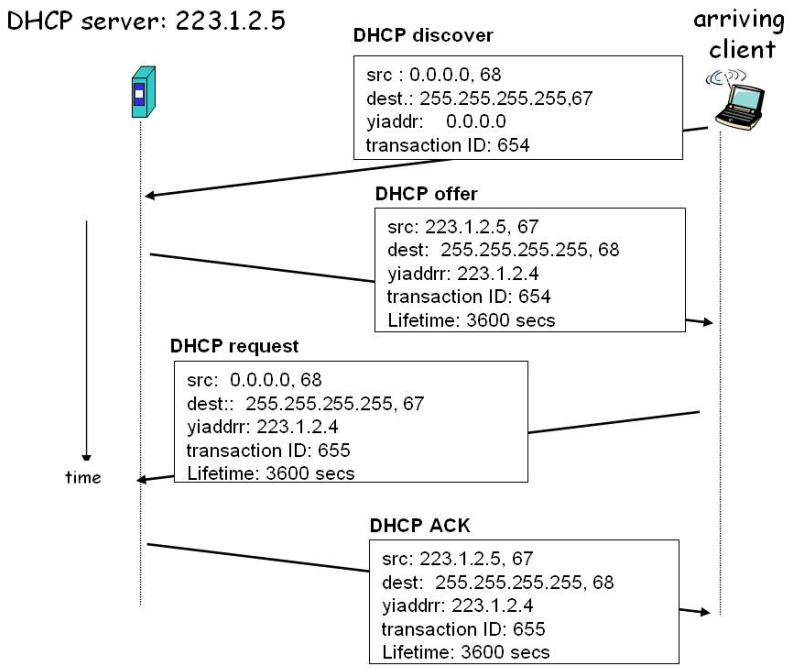
6. (a) (3%)
range of addresses not needed from ISP: just one IP address for all devices

(b) NAT router must: (6%)

- *outgoing datagrams: replace* (source IP address, port #) of every outgoing datagram to (NAT IP address, new port #) (2%)
  remote clients/servers will respond using (NAT IP address, new port #) as destination addr.
- *remember (in NAT translation table)* every (source IP address, port #) to (NAT IP address, new port #) translation pair (2%)
- *incoming datagrams: replace* (NAT IP address, new port #) in dest fields of every incoming datagram with corresponding (source IP address, port #) stored in NAT table (2%)

7. DHCP: (10%)
Goal: allow host to *dynamically* obtain its IP address from network server when it joins network (2%)
Flow: (8%)

- host broadcasts "DHCP discover" msg (1%, 1%)
- DHCP server responds with "DHCP offer" msg
- host requests IP address: "DHCP request" msg
- DHCP server sends address: "DHCP ack" msg

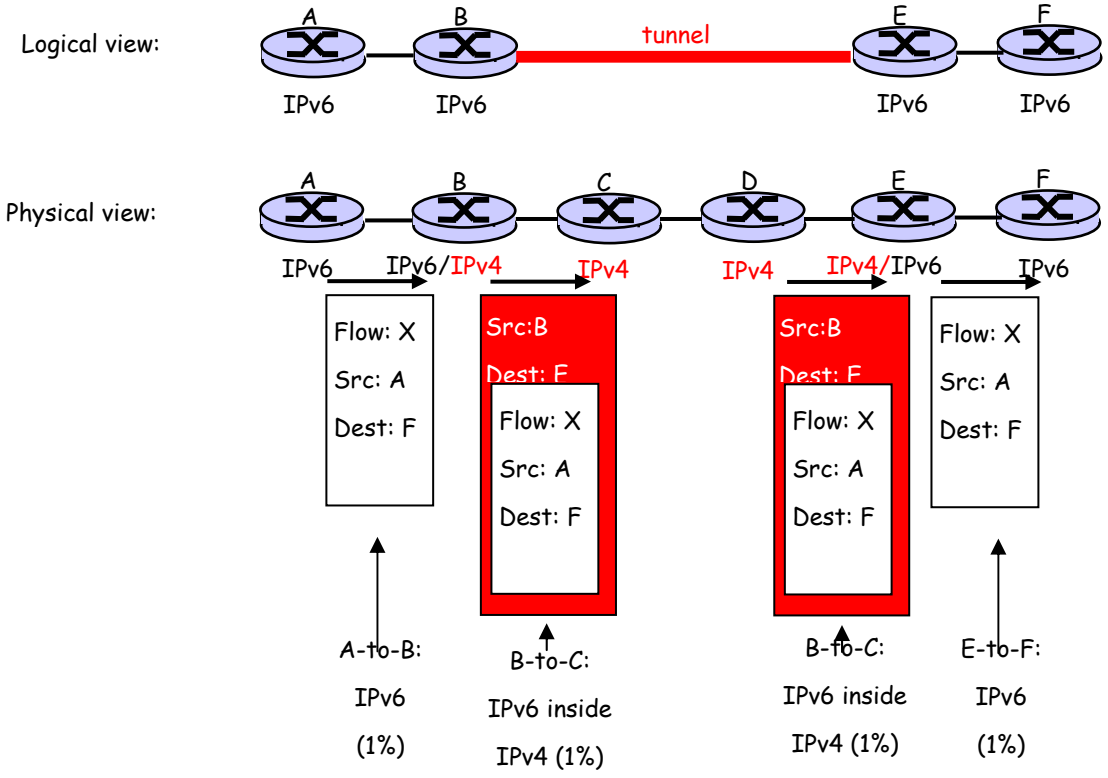


8. (11%)

(a) (3%)

- 32-bit address space soon to be completely allocated.
- header format helps speed processing/forwarding
- header changes to facilitate QoS

(b) How to tunnel IPv6 datagrams between two IPv4 routers? (8%)



- the source IPv4 router encapsulates the new IPv4 datagram by including the original IPv6 datagram as its payload and IPv4 addresses of the two IPv4 routers as the new source and destination IP addresses in the new IPv4 header. (2%)
- the new IPv4 datagram is decapsulated in the destination IPv4 router and the original IPv6 datagram is further transmitted through IPv6. (2%)

9. What are two main functions of ICMP to communicate network-level information by hosts & routers? (6%)

Ans:

- error reporting: unreachable host, network, port, protocol (3%)
- echo request/reply (used by ping) (3%)