$= 3000$ kbps

P8. Suppose users share a 3 Mbps link. Also suppose each user requires 150 kbps when transmitting, but each user transmits only 10 percent of the time. (See the discussion of packet switching versus circuit switching in **Section 1.3** .)

a. When circuit switching is used, how many users can be supported? $\frac{3000 \text{ kbps}}{150 \text{ kbps/user}} = 20$ users
b. For the remainder of this problem, suppose packet switching is used. Find the probability that a given user is transmitting. 0.1
c. Suppose there are 120 users. Find the probability that at any given time, exactly *n* users are transmitting simultaneously. (*Hint*: Use the binomial distribution.)
d. Find the probability that there are 21 or more users transmitting simultaneously.

c. $X \sim \text{Binomial}(120, 0.1)$

$$P(X=n) = \binom{120}{n} (0.1)^n (0.9)^{120-n}$$

d. $P(X \geq 21) = 1 - P(X \leq 20)$

$$= 1 - \sum_{n=0}^{20} \binom{120}{n} p^n (1-p)^{120-n}$$

$p = 0.1$

$\mu = 120 \times 0.1 = 12$

$\sigma^2 = 120 \times 0.1 \times (1 - 0.1)$

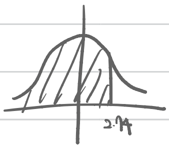
$= 120 \times 0.1 \times 0.9$

$= 10.8$

$\sigma = \sqrt{10.8} \simeq 3.28$.

$P(X \geq 21) = 1 - P(X \leq 20)$

$$Z = \frac{X - \mu}{\sigma} = \frac{21 - 12}{3.28} = \frac{9}{3.28} \simeq 2.74$$



$P(X \leq 20) \simeq P(Z \leq 2.74)$.

$P(X \geq 21) = 1 - P(Z \leq 2.74)$

$= 1 - 0.997$

$= 0.003$

$\therefore 0.003$, 0.3%

P14. Consider the queuing delay in a router buffer. Let *I* denote traffic intensity; that is, I=La/R. Suppose that the queuing delay takes the form IL/R(1−I) for I<1.

a. Provide a formula for the total delay, that is, the queuing delay plus the transmission delay.

b. Plot the total delay as a function of *L/R*.

a. queuing delay $= \dfrac{IL}{R(1-L)}$ → total delay $= \dfrac{IL}{R(1-I)} + \dfrac{L}{R} = \dfrac{L}{R}\left(\dfrac{I}{1-I} + 1\right)$

Transmission delay $= \dfrac{L}{R}$

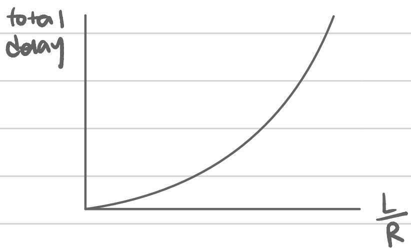
$$= \frac{L}{R}\left(\frac{\cancel{I}+1-\cancel{I}}{1-I}\right) = \frac{L}{R}\left(\frac{1}{1-I}\right)$$

$$= \frac{L}{R(1-I)}$$

b. total delay $= \dfrac{L}{R} \cdot \dfrac{1}{1-\frac{La}{R}}$

$\dfrac{L}{R} = x$ → $\dfrac{x}{1-ax}$

x approaches $\dfrac{1}{a}$



P18. Perform a Traceroute between source and destination on the same continent at three different hours of the day.

VideoNote

Using Traceroute to discover network paths and measure network delay

a. Find the average and standard deviation of the round-trip delays at each of the three hours.

b. Find the number of routers in the path at each of the three hours. Did the paths change during any of the hours?

c. Try to identify the number of ISP networks that the Traceroute packets pass through from source to destination. Routers with similar names and/or similar IP addresses should be considered as part of the same ISP. In your experiments, do the largest delays occur at the peering interfaces between adjacent ISPs?

d. Repeat the above for a source and destination on different continents. Compare the intra-continent and inter-continent results.

```
:\Users\easy1>tracert www.targethost.com

|대 30홉 이상의
ww.targethost.com [104.21.80.1](으)로 가는 경로 추적:

 1   209 ms     3 ms     1 ms  10.50.35.254
 2     *        *        *     요청 시간이 만료되었습니다.
 3     6 ms     2 ms     1 ms  10.1.0.2
 4     5 ms     3 ms     6 ms  203.246.85.254
 5     3 ms     3 ms     8 ms  115.92.253.185
 6     2 ms     2 ms     3 ms  10.243.48.181
 7    33 ms    11 ms    13 ms  1.208.180.5
 8     *       14 ms    10 ms  1.208.107.189
 9     *        *        *     요청 시간이 만료되었습니다.
10     7 ms     4 ms     5 ms  1.208.165.9
11    38 ms    39 ms    38 ms  61.43.235.130
12    60 ms    60 ms    81 ms  100.67.30.98
13    40 ms    44 ms    79 ms  13335.hkg.equinix.com [36.255.56.48]
14    40 ms    43 ms    41 ms  103.22.203.71
15    40 ms    40 ms    40 ms  104.21.80.1

추적을 완료했습니다.
```

a. Mean = $\dfrac{209+3+1+6+2+1+5+3+6+3+3+8+2+2+3+33+11+13+17+4+5+38+39+38+60+60+81+40+44+79+40+43+41+40+40+40}{36}$

$= 29.25$ ms

Standard deviation 38.17 ms

b. total hops : 15

c. four and more ISPs were involved.

Major ISPs

- Domestic 203.246.85.254, 115.92.253.185 — Significant delay increase after Hop 7
- International 61.43.235.130 — Notable RTT rise at Hop 12.
- Equinix data center (Hong kong) — Equinix data center Hop 13 stabilizes the RTT
- cloud flare (104.21.80.1. Final destination)

RTT increase significantly at ISP peering points
The most significant delays occur at international ISP handovers,
which is expected in cross-border connection.

d. Intra-Continent traceroute
- Hop count : 5-10
- Average RTT : 20-30 ms
- Peering delays : minimal

Inter Continent Traceroute.
(Korea → Hong kong → USA)
Hop count 15
Average RTT : 40-70 ms
Peering delays : Significant at international ISP transitions (Hop 7, 12)

P25. Suppose two hosts, A and B, are separated by 20,000 kilometers and are connected by a direct link of R=2 Mbps. Suppose the propagation speed over the link is 2.5·108 meters/sec.

a. Calculate the bandwidth-delay product, R·dprop.

b. Consider sending a file of 800,000 bits from Host A to Host B. Suppose the file is sent continuously as one large message. What is the maximum number of bits that will be in the link at any given time?

c. Provide an interpretation of the bandwidth-delay product.

d. What is the width (in meters) of a bit in the link? Is it longer than a football field?

e. Derive a general expression for the width of a bit in terms of the propagation speed *s*, the transmission rate *R*, and the length of the link *m*.

$m = 20000 \times 10^3 m = 2.0 \times 10^7$

$R = 2Mbps = 2 \times 10^6 bps$

$s = 2.5 \times 10^8 \ m/sec$

a. $d_{prop} = \frac{m}{s} = \frac{2.0 \times 10^{\cancel{7}}}{2.5 \times 10^{\cancel{8}}} = \frac{4}{5} \times \frac{1}{10} = \frac{8}{100} = 0.08$ sec

$R \cdot d_{prop} = 2 \times 10^6 \times 0.08 = 160000$ bits

b. 160,000 bits

c. The bandwidth-delay product represents the maximum number of bits can be transit within the link

d. Bit width $= \frac{s}{R} = \frac{2.5 \times 10^8 \ m/s}{2 \times 10^6 \ bps} = 125$ meters.

one bit in this link is longer than football field.

e. $\frac{s}{R}$

P31. In modern packet-switched networks, including the Internet, the source host segments long, application-layer messages (for example, an image or a music file) into smaller packets and sends the packets into the network. The receiver then reassembles the packets back into the original message. We refer to this process as *message segmentation*. **Figure 1.27** illustrates the end-to-end transport of a message with and without message segmentation. Consider a message that is 8·106 bits long that is to be sent from source to destination in **Figure 1.27** . Suppose each link in the figure is 2 Mbps. Ignore propagation, queuing, and processing delays.

a. Consider sending the message from source to destination *without* message segmentation. How long does it take to move the message from the source host to the first packet switch? Keeping in mind that each switch uses store-and-forward packet switching, what is the total time to move the message from source host to destination host?

b. Now suppose that the message is segmented into 800 packets, with each packet being 10,000 bits long. How long does it take to move the first packet from source host to the first switch? When the first packet is being sent from the first switch to the second switch, the second packet is being sent from the source host to the first switch. At what time will the second packet be fully received at the first switch?

c. How long does it take to move the file from source host to destination host when message segmentation is used? Compare this result with your answer in part (a) and comment.

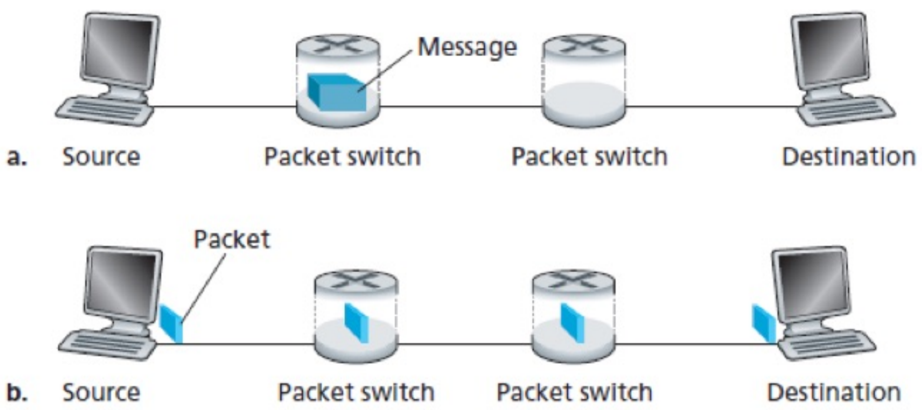


Figure 1.27 End-to-end message transport: (a) without message segmentation; (b) with message segmentation

d. In addition to reducing delay, what are reasons to use message segmentation?

e. Discuss the drawbacks of message segmentation.

a. Transmission time $= \frac{\text{Message size}}{\text{Transmission Rate}} = \frac{8 \times 10^6 \text{ bits}}{2 \times 10^6 \text{ bps}}$

$= 4$ sec

source $\rightarrow$ 1st switch $\rightarrow$ 2nd Switch $\rightarrow$ destination

4 4 4

4sec $\times$ 3 = 12sec

$\therefore$ 12 seconds

b. Transmission time per packet $= \frac{\text{Packet size}}{\text{Transmission Rate}} = \frac{10000 \text{ bits}}{2 \times 10^6 \text{ bps}} = \frac{1}{200} = 0.005$

$0.005 \times 2 = 0.01$

$\therefore$ 0.01 seconds

c. first packet to reach the destination : $3 \times 0.005 = 0.015$

time for last packet to arrive : $(800-1) \times 0.05 = 3.995$

$3.995 + 0.015 = 4.01$ sec

d. for efficient error handling

for better network resource management.

e. Since packets may arrive out of order, the destination must sort and reassemble them correctly.

Each packet includes a header, and segmenting a message into many packets means more total header bytes reducing useful data transmission efficiency.

P33. Consider sending a large file of F bits from Host A to Host B. There are three links (and two switches) between A and B, and the links are uncongested (that is, no queuing delays). Host A segments the file into segments of S bits each and adds 80 bits of header to each segment, forming packets of $L = 80 + S$ bits. Each link has a transmission rate of R bps. Find the value of S that minimizes the delay of moving the file from Host A to Host B. Disregard propagation delay.

Transmission time per link $= \frac{L}{R} = \frac{S+80}{R}$

file has F/s packets → total delay $\frac{F}{S} \times \frac{S+80}{R} \times 3 = \frac{3F(S+80)}{SR}$.

$\frac{F}{S} \times \frac{S+80}{R}$ at this time first packet arrived at destination
$\frac{F}{S}-1$th packet arrived at Second Router
Last packet arrived at first Router

last packet should go to first router → Second router → destination so
$\frac{S+80}{R} \times 2$

so whole file delay is $\frac{S+80}{R} \times \left(\frac{F}{S}+2\right)$

to calculate the value of S. which leads to the minimum delay,

$\frac{d}{dS}\left(\frac{S+80}{R} \times \left(\frac{F}{S}+2\right)\right) = 0$

$\frac{F}{R} \times \left(\frac{S+80}{S}\right)$

$\frac{F}{R} \times \left(0 - \frac{80}{S^2}\right) = -\frac{80F}{S^2R}$ $\qquad \frac{d}{dS}\left(\frac{2S}{R}\right) = \frac{2}{R}$

$-\frac{80F}{S^2R} + \frac{2}{R} = 0$ $\qquad -\frac{80F}{S^2} + 2 = 0$ $\qquad S^2 = 40F$ $\qquad S = \sqrt{40F}$

이거면 바로 [illegible]

좋~

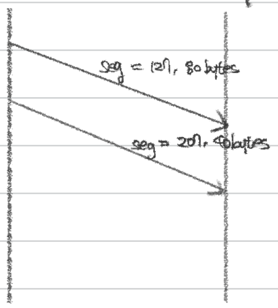
흥미진진~

22|02009 Jiwon Lee

#27

(a) second segment of Host A to B

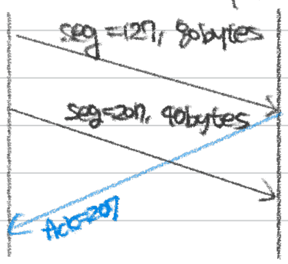
A(port=302) B(port=80)



the sequence number is 207
source port number is 302
destination port number is 80.

(b) If the first segment arrives before the second,
in the acknowledgement of the first arriving segment.

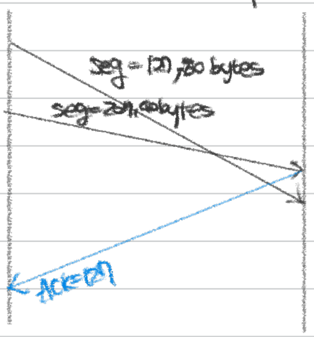
A(port=302) B(port=80)



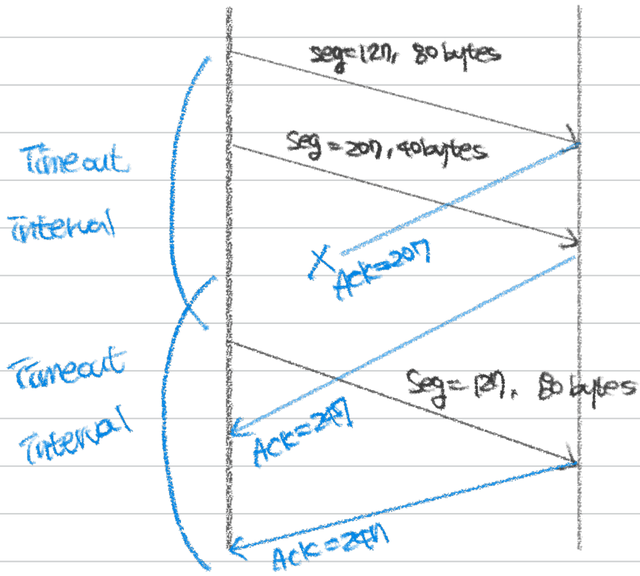
the acknowledgement number is 207
the source port number is 80
the destination port number is 302.

(c) indicating that it is still waiting for bytes 127 and onwards

A(port=302) B(port=80).



(d) A(port=302) B(port=80)



#P.28

Host A can send data at up to 100 Mbps, but Host B process data slower, causing the receive buffer to fill at around 60Mbps.
When the buffer is full, Host B sets Rcv Window = 0, telling A to stop sending

Host A waits until it sees Rcv Window > 0, then resumes sending.
This stop-and-start behavior continues, and as result, Host A's average sending rate is about 60 Mbps.

#32

a) $\text{Estimated RTT}(n) = (1-\alpha) \times \text{Estimated RTT}(n-1) + \alpha \cdot \text{Sample RTT}(n-1)$

$\text{Estimated RTT}_4 = \alpha \cdot \text{Sample RTT}_1 + (1-\alpha)\Big(\alpha \cdot \text{Sample RTT}_2 + (1-\alpha)\big(\alpha \cdot \text{Sample RTT}_3 + (1-\alpha)\,\text{Sample RTT}_4\big)\Big)$

$= \alpha \cdot \text{Sample RTT}_1 + (1-\alpha)\alpha\,\text{Sample RTT}_2 + (1-\alpha)^2\alpha\,\text{Sample RTT}_3 + (1-\alpha)^3\,\text{Sample RTT}_4$

$\alpha = 0.1 \rightarrow 0.1\,\text{Sample RTT}_1 + 0.9 \cdot 0.1\,\text{Sample RTT} + 0.9^2 \cdot 0.1\,\text{Sample RTT}_3 + 0.9^3\,\text{Sample RTT}_4$

(b) $\text{Estimated RTT}^{(n)} = \alpha \sum_{j=1}^{n-1} (1-\alpha)^{j-1}\,\text{Sample RTT}_j + (1-\alpha)^{n-1}\,\text{Sample RTT}_n$

(c) $\underbrace{\text{Estimated RTT}^{(\infty)}}_{E_n} = \frac{\alpha}{1-\alpha} \sum_{j=1}^{\infty} (1-\alpha)^j\,\text{Sample RTT}$

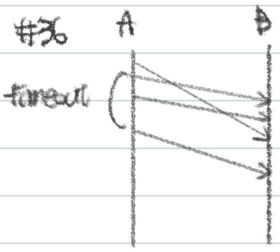
$\lim_{n\to\infty} E_n = \lim_{n\to\infty}\left(\alpha \sum_{j=1}^{n-1} (1-\alpha)^{j-1}\,\text{Sample RTT}_j + (1-\alpha)^{n-1}\,\text{Sample RTT}_n\right)$

$\frac{0.1}{0.9} \sum_{j=1}^{\infty} (0.9)^j\,\text{Sample RTT}_j$

$= \frac{1}{9} \sum_{j=1}^{\infty} (0.9)^j\,\text{Sample RTT}_j$

#34 If there is no packet loss, LastByte Rcvd is declined to sender via header
⇒ SendBase = LastByte Rcvd +1

But there is probability that ack packet could be loss
So SendBase ≤ LastByte Rcvd +1

#36


→ this situation could be happend

first segment arrived sucessfully but late.
If sender retransmit same thing, same data is delivered
To prevent this, we need to wait for more duplicate ACK.

#40
(a) during 1-6 and 23-26 slow start.
(b) during 6-16 and 17-22 avoidance is operating
(c) After transmission round, packet loss is recognized by a triple duplicate Ack. If there was a time out the cognestion window size would have dropped to 1
(d) This time decreased to 1 so timeout is occured
(e) Avoidance is started at 6th transmission round, and window size is 32, so first threshold is 32
(f) loss is occured at the 16th round so the threshold is set as 42÷2=21
So threshold at 18th is 21.
(g) same way it is 29÷2 = 14.5 but it is floored So 14
(h) 1st = 1 ↘+2
2nd = 3 ↘+4
3rd = 7 ↘+8
4th = 15 ↘+16
5th = 31 ↘+32
6th = 63 ↘+64
7th = 127

so 70th segment is delivered at 7th transmission round
(i) threshold = 8÷2 = 4 and window size 4+3=7
(j) threshold is 21 ← 42÷2 window size is 1

(k) $17^{th} = 1$
$18^{th} = 3$ $\downarrow +2$
$19^{th} = 7$ $\downarrow +4$
$20^{th} = 15$ $\downarrow +8$
$21^{th} = 31$ $\downarrow +16$
$\downarrow \cancel{+32}$ → but threshold = 21 so 21 segments would be transfered
$22^{th} = \underline{52}$
$31 + 21$

$\therefore 52$

computer networks homework #3 Jiwon Lee

P5. Consider a datagram network using 32-bit host addresses. Suppose a router has four links, numbered 0 through 3, and packets are to be forwarded to the link interfaces as follows:

Destination Address Range	Link Interface
11100000 00000000 00000000 00000000 through 11100000 00111111 11111111 11111111	0
11100000 01000000 00000000 00000000 through 11100000 01000000 11111111 11111111	1
11100000 01000001 00000000 00000000 through 11100001 01111111 11111111 11111111	2
otherwise	3

a. Provide a forwarding table that has five entries, uses longest prefix matching, and forwards packets to the correct link interfaces.

b. Describe how your forwarding table determines the appropriate link interface for datagrams with destination addresses:

> 11001000 10010001 01010001 01010101
> 11100001 01000000 11000011 00111100
> 11100001 10000000 00010001 01110111

a)

Prefix Match		Link Interface
11100000	00	0
11100000	01000000	1
1110000		2
11100001	1	3
otherwise		3

b)

> 11001000 10010001 01010001 01010101 → 3 otherwise
> 11100001 01000000 11000011 00111100 → 2
> 11100001 10000000 00010001 01110111 → 3

P6. Consider a datagram network using 8-bit host addresses. Suppose a router uses longest prefix matching and has the following forwarding table:

Prefix Match	Interface
00	0
010	1
011	2
10	2
11	3

For each of the four interfaces, give the associated range of destination host addresses and the number of addresses in the range.

Interface 0

0000 0000 ~ 0011 1111 $\quad 2^6 = 64 \quad$ 0 ~ 63

Interface 1

0100 0000 ~ 0101 1111 $\quad 2^5 = 32 \quad$ 64 ~ 95

Interface 2

0110 0000 ~ 0111 1111 $\quad 2^5 = 32 \quad$ 96 ~ 127

1000 0000 ~ 1011 1111 $\quad 2^6 = 64 \quad$ 128 ~ 191

Interface 3

1100 0000 ~ 1111 1111 $\quad 2^6 = 64 \quad$ 192 ~ 255

P12. Consider the topology shown in **Figure 4.20** . Denote the three subnets with hosts (starting clockwise at 12:00) as Networks A, B, and C. Denote the subnets without hosts as Networks D, E, and F.

a. Assign network addresses to each of these six subnets, with the following constraints: All addresses must be allocated from 214.97.254/23; Subnet A should have enough addresses to support 250 interfaces; Subnet B should have enough addresses to support 120 interfaces; and Subnet C should have enough addresses to support 120 interfaces. Of course, subnets D, E and F should each be able to support two interfaces. For each subnet, the assignment should take the form a.b.c.d/x or a.b.c.d/x – e.f.g.h/y.

b. Using your answer to part (a), provide the forwarding tables (using longest prefix matching) for each of the three routers.

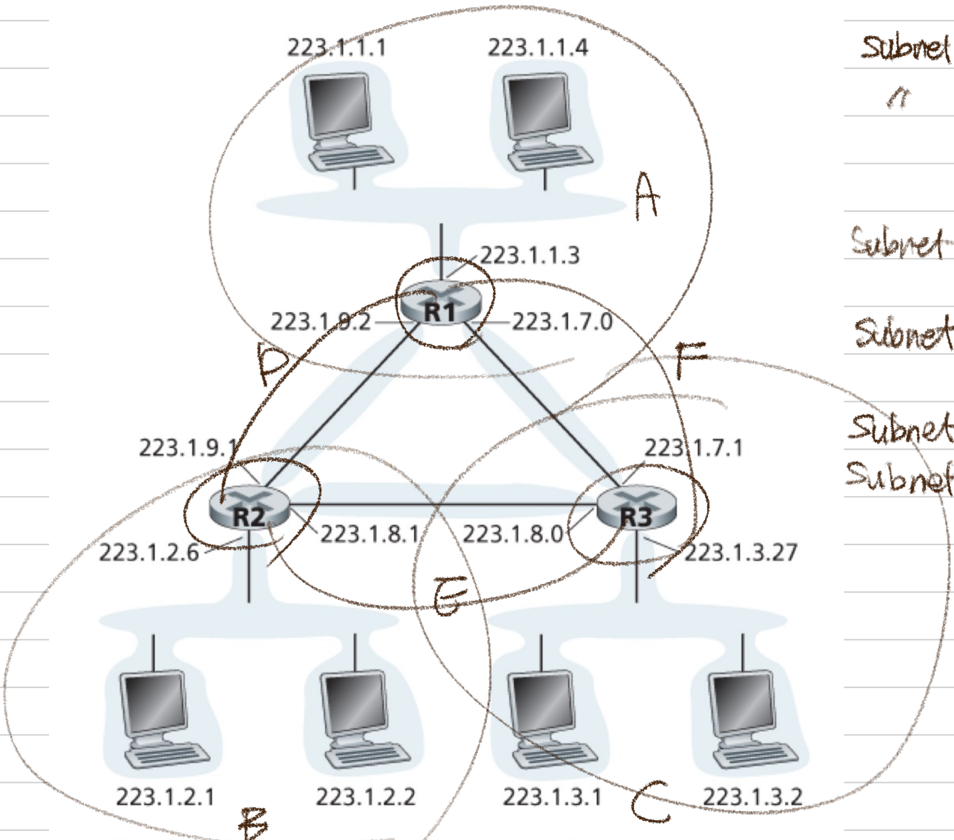


Figure 4.20 Three routers interconnecting six subnets

Subnet A: 214.97.255/24 (256 address)
" B: 214.97.254.0/25 128
~214.97.254.0/29
128 - 8 = 120 address
Subnet C: 214.97.254.128/25
128 address
Subnet D: 214.97.254.0/31
2 address
Subnet E: 214.97.254.2/31 2
Subnet F: 214.97.254.4/30 4

Router 1

A 11010110 01100001 11111111
D 11010110 01100001 11111110 0000000
F 11010110 01100001 11111110 000001

Router 2

D 11010110 01100001 11111111 0000000
B 11010110 01100001 11111110 0
E 11010110 01100001 11111110 0000001

Router 3

C 11010110 01100001 11111110 1
E 11010110 01100001 11111110 0000001
F 11010110 01100001 11111111 1

P17. Suppose you are interested in detecting the number of hosts behind a NAT. You observe that the IP layer stamps an identification number sequentially on each IP packet. The identification number of the first IP packet generated by a host is a random number, and the identification numbers of the subsequent IP packets are sequentially assigned. Assume all IP packets generated by hosts behind the NAT are sent to the outside world.

a. Based on this observation, and assuming you can sniff all packets sent by the NAT to the outside, can you outline a simple technique that detects the number of unique hosts behind a NAT? Justify your answer.
b. If the identification numbers are not sequentially assigned but randomly assigned, would

your technique work? Justify your answer.

(a)
Yes, it is possible. Since each host behind the NAT assigns sequential IP identification numbers starting from a random initial value, observing multiple independent sequences of ID values in outbound packets allows us to estimate the number of unique hosts behind the NAT.

(b)
No, it would not work. If identification numbers are randomly assigned, there would be no observable sequential pattern, making it impossible to disti

computer networks homework #4

22102009 Jiwon Lee #4

P5. Consider a datagram network using 32-bit host addresses. Suppose a router has four links, numbered 0 through 3, and packets are to be forwarded to the link interfaces as follows:

Destination Address Range	Link Interface
11100000 00000000 00000000 00000000 through 11100000 00111111 11111111 11111111	0
11100000 01000000 00000000 00000000 through 11100000 01000000 11111111 11111111	1
11100000 01000001 00000000 00000000 through 11100001 01111111 11111111 11111111	2
otherwise	3

a. Provide a forwarding table that has five entries, uses longest prefix matching, and forwards packets to the correct link interfaces.
b. Describe how your forwarding table determines the appropriate link interface for datagrams with destination addresses:

> 11001000 10010001 01010001 01010101
> 11100001 01000000 11000011 00111100
> 11100001 10000000 00010001 01110111

a)

Prefix match	Link Interface
11100000 00	0
11100000 01000000	1
1110000	2
11100001 1	3
otherwise	3

b)

> 11001000 10010001 01010001 01010101 → 3 otherwise
> 11100001 01000000 11000011 00111100 → 2
> 11100001 10000000 00010001 01110111 → 3

P12. Consider the topology shown in **Figure 4.20** . Denote the three subnets with hosts (starting clockwise at 12:00) as Networks A, B, and C. Denote the subnets without hosts as Networks D, E, and F.

256 + 256

a. Assign network addresses to each of these six subnets, with the following constraints: All addresses must be allocated from 214.97.254/23; Subnet A should have enough addresses to support 250 interfaces; Subnet B should have enough addresses to support 120 interfaces; and Subnet C should have enough addresses to support 120 interfaces. Of course, subnets D, E and F should each be able to support two interfaces. For each subnet, the assignment should take the form a.b.c.d/x or a.b.c.d/x – e.f.g.h/y.

b. Using your answer to part (a), provide the forwarding tables (using longest prefix matching) for each of the three routers.

A = 250   B = 120   C = 120   D = 2   E = 2   F = 2

Subnet A : 214.97.255/24   (256)

Subnet B : 214.97.254.0/25 – 214.97.254.0/29   (120)

128   –   8

Subnet C : 214.97.254.128/25   (128) 2^7

Subnet D : 214.97.254.0/31   (2)

Subnet E : 214.97.254.2/31   (2)

Subnet F : 214.97.254.4/30   (4)

b. Using your answer to part (a), provide the forwarding tables (using longest prefix matching) for each of the three routers.

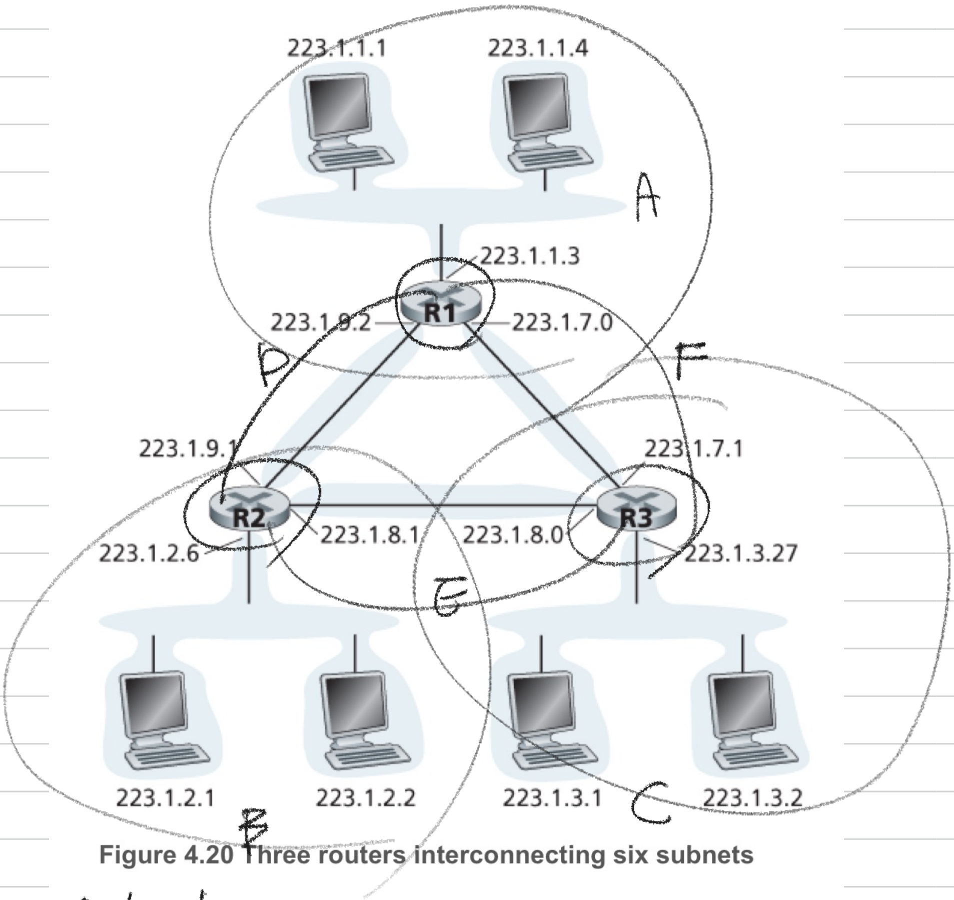


Figure 4.20 Three routers interconnecting six subnets

Router 1

A	11010110	01100001	11111111	
D	11010110	01100001	11111110	0000000
F	11010110	01100001	11111110	000001

Router 2

D	11010110	01100001	11111111	0000000
B	11010110	01100001	11111110	0
E	11010110	01100001	11111110	0000001

Router 3

C	11010110	01100001	11111110	1
E	11010110	01100001	11111110	0000001
F	11010110	01100001	11111111	1

P17. Suppose you are interested in detecting the number of hosts behind a NAT. You observe that the IP layer stamps an identification number sequentially on each IP packet. The identification number of the first IP packet generated by a host is a random number, and the identification numbers of the subsequent IP packets are sequentially assigned. Assume all IP packets generated by hosts behind the NAT are sent to the outside world.

a. Based on this observation, and assuming you can sniff all packets sent by the NAT to the outside, can you outline a simple technique that detects the number of unique hosts behind a NAT? Justify your answer.
b. If the identification numbers are not sequentially assigned but randomly assigned, would your technique work? Justify your answer.

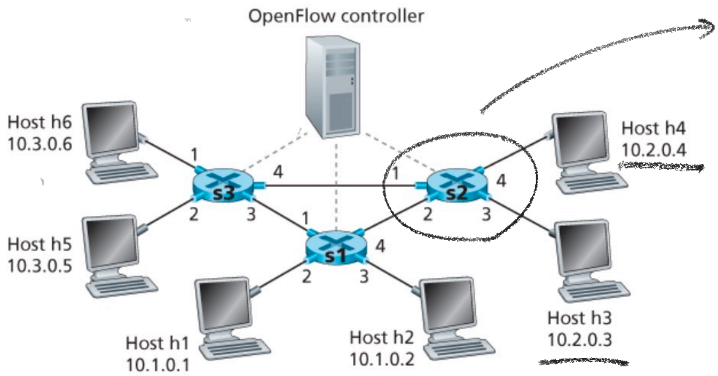
(a)
Yes, it is possible. Since each host behind the NAT assigns sequential IP identification numbers starting from a random initial value, observing multiple independent sequences of ID values in outbound packets allows us to estimate the number of unique hosts behind the NAT.

(b)
No, it would not work. If identification numbers are randomly assigned, there would be no observable sequential pattern, making it impossible to disti

P19. Consider the SDN OpenFlow network shown in **Figure 4.30** . Suppose that the desired forwarding behavior for datagrams arriving at s2 is as follows:

- any datagrams arriving on input port 1 from hosts h5 or h6 that are destined to hosts h1 or h2 should be forwarded over output port 2; Ingress port1 IP src 10.3.*.* Dst 10.1.*.* 2
- any datagrams arriving on input port 2 from hosts h1 or h2 that are destined to hosts h5 or h6 should be forwarded over output port 1; ingress port2 IP src 10.1.*.* Dst 10.3.*.* 2
- any arriving datagrams on input ports 1 or 2 and destined to hosts h3 or h4 should be delivered to the host specified;
  3 4
- hosts h3 and h4 should be able to send datagrams to each other.
  4 3 3 4

Specify the flow table entries in s2 that implement this forwarding behavior.



1 → S3 h5(10.3.0.5) h6(10.3.0.6)
2 → S1 h1(10.1.0.1) h2(10.1.0.2)
3 → host h3 10.2.0.3
4 → host h4 10.2.0.4

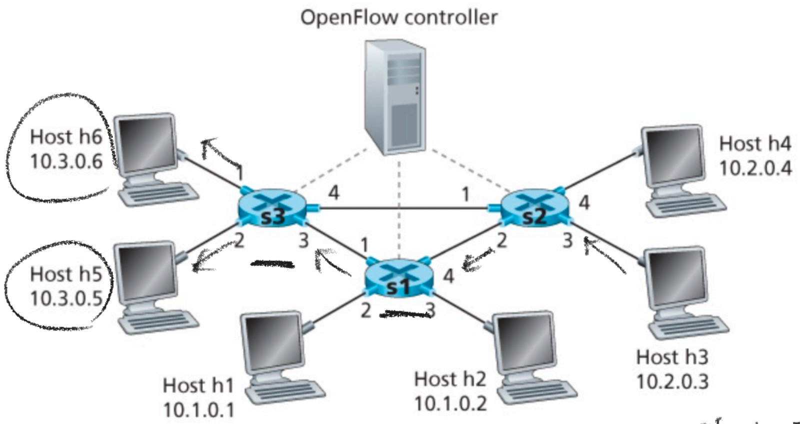
S2 flow table

Match	Action
Ingress port = 1 ; IP Src = 10.3.*.* ; IP Dst = 10.1.*.*	Forward (2)
Ingress port = 2 ; IP Src = 10.1.*.* ; IP Dst = 10.3.*.*	Forward (1)
Ingress port = 1 ; IP Dst = 10.2.0.3	Forward (3)
Ingress port = 2 ; IP Dst = 10.2.0.3	Forward (3)
Ingress port = 1 ; IP Dst = 10.2.0.4	Forward (4)
Ingress port = 2 ; IP Dst = 10.2.0.4	Forward (4)
Ingress port = 4	Forward (3)
Ingress port = 3	Forward (4)

P20. Consider again the SDN OpenFlow network shown in **Figure 4.30** . Suppose that the desired forwarding behavior for datagrams arriving from hosts h3 or h4 at s2 is as follows:

- any datagrams arriving from host h3 and destined for h1, h2, h5 or h6 should be forwarded in a clockwise direction in the network;
- any datagrams arriving from host h4 and destined for h1, h2, h5 or h6 should be forwarded in a counter-clockwise direction in the network.

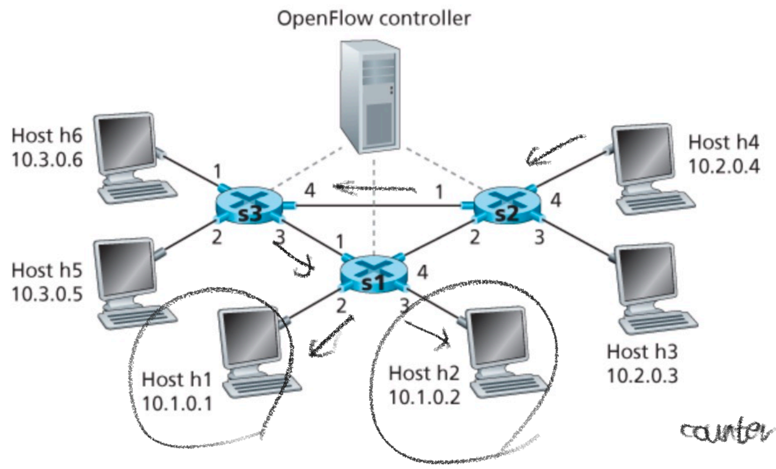
Specify the flow table entries in s2 that implement this forwarding behavior.



S2

1 → S3 h5 (10.3.0.5) h6 (10.3.06)
2 → S1 h1 (10.1.0.1) h2 (10.1.0.2)
3 → host h3 10.2.0.3
4 → host h4 10.2.0.4

Clockwise

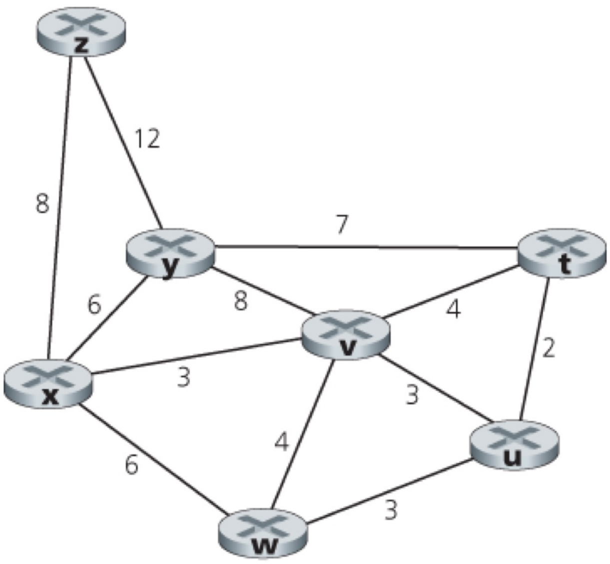


counter clockwise

S2 flow table

Match	Action
Ingress Port = 3 ; IP Dst = 10.1.*.*	Forward (2)
Ingress Port = 3 ; IP Dst = 10.3.*.*	Forward (2)
Ingress Port = 4 ; IP Dst = 10.1.*.*	Forward (1)
Ingress Port = 4 ; IP Dst = 10.3.*.*	Forward (1)

P3. Consider the following network. With the indicated link costs, use Dijkstra's shortest-path algorithm to compute the shortest path from *x* to all network nodes. Show how the algorithm works by computing a table similar to **Table 5.1** .



D(v) = 3, via x
D(w) = 6, via x
D(y) = 6, via x
D(z) = 8, via x
D(u) = ∞
D(t) = ∞

N' = {x}
add v N' = {x, v} D=3
v→u D=3+3=6 update u
v→t D=3+4=7 update t

add u N' = {x, v, u} D=6
u→t D=6+2=8 no update

add w N' = {x, v, u, w} D=6

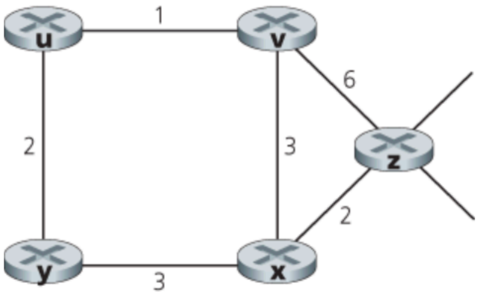
add y N' = {x, v, u, w, y} D=6

add t N' = {x, v, u, w, y, t} D=7

add z N = {x, v, u, w, y, t, z} D=8

step	N'	D(t) p(t)	D(u) p(u)	D(v) p(v)	D(w), p(w)	D(y) p(y)	D(z) p(z)
0	x	∞	∞	3, x	6, x	6, x	8, x
1	xv	7, v	6, v	3, x	6, x	6, x	8, x
2	xvu	7, v	6, v	3, x	6, x	6, x	8, x
3	xvuw	7, v	6, v	3, x	6, x	6, x	8, x
4	xvuwy	7, v	6, v	3, x	6, x	6, x	8, x
5	xvuwyt	7, v	6, v	3, x	6, x	6, x	8, x
6	xvuwytz	7, v	6, v	3, x	6, x	6, x	8, x

P5. Consider the network shown below, and assume that each node initially knows the costs to each of its neighbors. Consider the distance-vector algorithm and show the distance table entries at node z.



z → v 6
z → x 2

destination	via v	via x	next hop
u	∞	∞	∞
v	6	∞	6 (v)
x	∞	2	2 (x)
y	∞	∞	∞
z	0	0	-

v → u 1   z → v → u = 7 (via v)
v → x 3   z → v → x = 9   ~~x~~
v → z 6

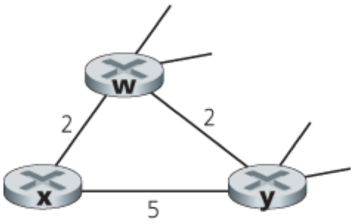
x → y 3   z → x → y = 5 (via x)
x → v 3   z → x → v = 5   z → v update
x → z 2

z → v → u = 6

Cost to

		u	v	x	y	z
	v	1	6	3	3	5
From	x	4	3	0	3	2
	z	6	5	2	5	0

P7. Consider the network fragment shown below. *x* has only two attached neighbors, *w* and *y*. *w* has a minimum-cost path to destination *u* (not shown) of 5, and *y* has a minimum-cost path to *u* of 6. The complete paths from *w* and *y* to *u* (and between *w* and *y*) are not shown. All link costs in the network have strictly positive integer values.



x→w 2
x→y 5
y→w 2

w→u 5
y→u 6

x→w→u 7
Dx(u)=7

a. Give *x*'s distance vector for destinations *w, y,* and *u*. Dx(w)=2 Dx(y)=4

b. Give a link-cost change for either *c*(*x, w*) or *c*(*x, y*) such that *x* will inform its neighbors of a new minimum-cost path to *u* as a result of executing the distance-vector algorithm.

c. Give a link-cost change for either *c*(*x, w*) or *c*(*x, y*) such that *x* will *not* inform its neighbors of a new minimum-cost path to *u* as a result of executing the distance-vector algorithm.

b) If c(x,w) decline to 1
x→w→u = 6 better path → inform neighbors
If c(x,w) increase to 7.
x→w→u = 12 <u>x→y→u = 11</u> is better path
x inform neighbors
∴ If c(x,w) becomes too small or too large x will inform to its neighbors

c) If c(x,y) is 1 x→y→u = 7
it is same as x→w→u = 7 ∴ no change
if c(x,y) ≥ 1 x's least-cost path doesn't change, no update, no inform

P11. Consider Figure 5.7. Suppose there is another router w, connected to router y and z. The costs of all links are given as follows: c(x,y)=4, c(x,z)=50, c(y,w)=1, c(z,w)=1, c(y,z)=3. Suppose that poisoned reverse is used in the distance-vector routing algorithm.

a. When the distance vector routing is stabilized, router w, y, and z inform their distances to x to each other. What distance values do they tell each other?

b. Now suppose that the link cost between x and y increases to 60. Will there be a count-to-infinity problem even if poisoned reverse is used? Why or why not? If there is a count-to-infinity problem, then how many iterations are needed for the distance-vector routing to reach a stable state again? Justify your answer.

c. How do you modify *c(y, z)* such that there is no count-to-infinity problem at all if *c(y,x)* changes from 4 to 60?

a)

router z	Informs w	$D_z(x) = \infty$
	Informs y	$D_z(x) = 6$
router w	Informs y	$D_w(x) = \infty$
	Informs z	$D_w(x) = 5$
router y	Informs w	$D_y(x) = 4$
	Informs z	$D_y(x) = 4$

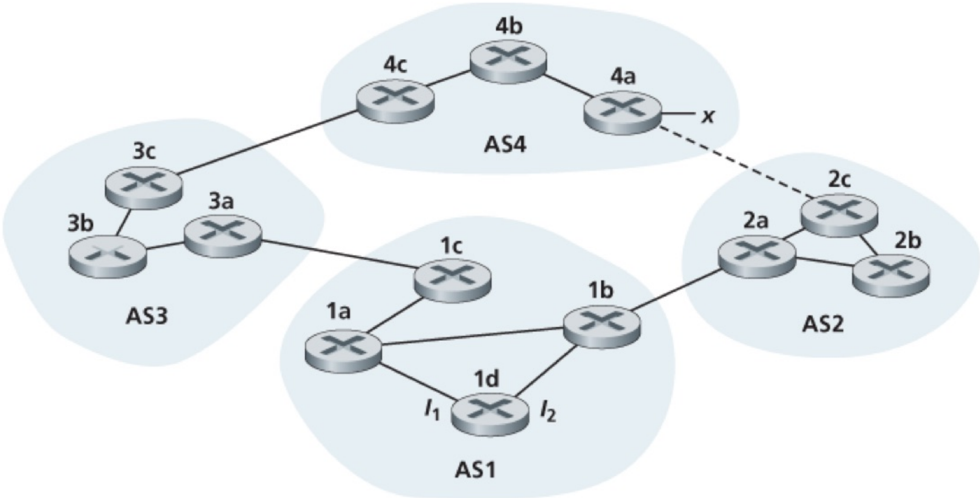
(z→w→y→x
w→z→y→x) this make loop

b) Yes, there will be a count-to-infinity problem.
Even though poisoned reverse is used, routers w, y, and z form a loop and keep increasing the cost to reach x, forwarding incorrect information to each other.
As shown in the iteration table, the distance vectors keep increasing until router z finally realizes it can reach x directly with a cost of 50.
The routing stabilizes at time t31, so the network takes 31 iterations to converge.

c) cut the link between y and z

P14. Consider the network shown below. Suppose AS3 and AS2 are running OSPF for their intra-AS routing protocol. Suppose AS1 and AS4 are running RIP for their intra-AS routing protocol. Suppose eBGP and iBGP are used for the inter-AS routing protocol. Initially suppose there is *no* physical link between AS2 and AS4. AS4 → AS3 eBGP

a. Router 3c learns about prefix *x* from which routing protocol: OSPF, RIP, eBGP, or iBGP?
b. Router 3a learns about *x* from which routing protocol? Inside of AS3 IBGP
c. Router 1c learns about *x* from which routing protocol? eBGP
d. Router 1d learns about *x* from which routing protocol? IBGP



P15. Referring to the previous problem, once router 1d learns about *x* it will put an entry (*x*, *I*) in its forwarding table.

a. Will *I* be equal to I_1 or I_2 for this entry? Explain why in one sentence.
b. Now suppose that there is a physical link between AS2 and AS4, shown by the dotted line. Suppose router 1d learns that *x* is accessible via AS2 as well as via AS3. Will *I* be set to I_1 or I_2? Explain why in one sentence.
c. Now suppose there is another AS, called AS5, which lies on the path between AS2 and AS4 (not shown in diagram). Suppose router 1d learns that *x* is accessible via AS2 AS5 AS4 as well as via AS3 AS4. Will *I* be set to I_1 or I_2? Explain why in one sentence.

(a) Answer: I1

Because router 1d learns about prefix x through router 1c via iBGP, and interface I1 leads to 1c, the next-hop toward x.

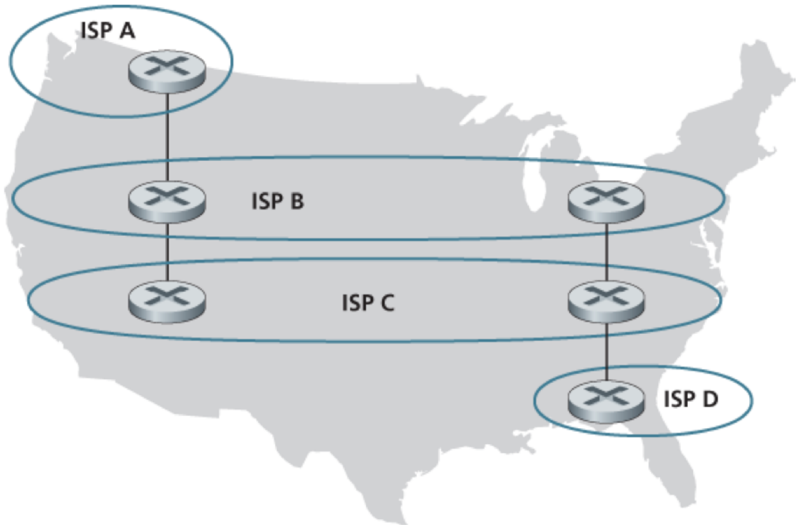
(b) Answer: I2

Even though both AS paths have the same length, router 1d chooses the route via AS2 since the next-hop is closer in terms of IGP cost, and I2 leads to that next-hop.

(c) Answer: I1

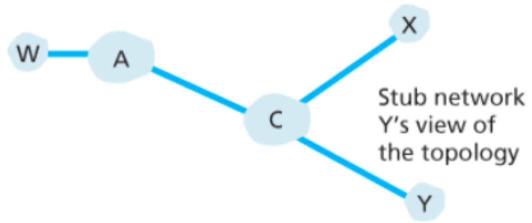
Router 1d selects the route through AS3 because it has a shorter AS path compared to the route via AS2–AS5–AS4, and I1 directs packets along that shorter path.

P16. Consider the following network. ISP B provides national backbone service to regional ISP A. ISP C provides national backbone service to regional ISP D. Each ISP consists of one AS. B and C peer with each other in two places using BGP. Consider traffic going from A to D. B would prefer to hand that traffic over to C on the West Coast (so that C would have to absorb the cost of carrying the traffic cross-country), while C would prefer to get the traffic via its East Coast peering point with B (so that B would have carried the traffic across the country). What BGP mechanism might C use, so that B would hand over A-to-D traffic at its East Coast peering point? To answer this question, you will need to dig into the BGP specification.



C can ensure that B hands over all traffic destined for D at the East Coast peering point by advertising the route to D only through that peering location.

P17. In Figure 5.13 , consider the path information that reaches stub networks W, X, and Y. Based on the information available at W and X, what are their respective views of the network topology? Justify your answer. The topology view at Y is shown below.



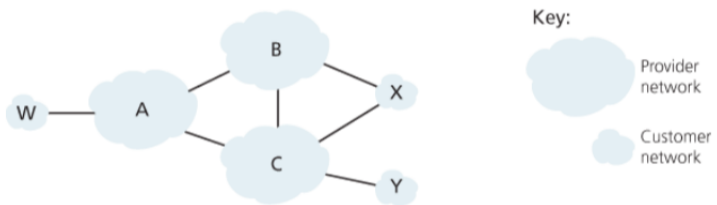
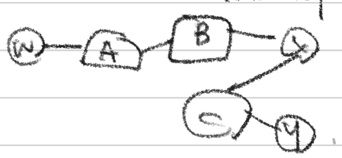
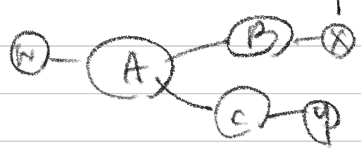


Figure 5.13 A simple BGP policy scenario

X's view of the topology



W's view of the top



X sees B and the path to W via A. It also sees Y via C.
However, X does not know about the direct link between A and C, because it never receives an AS-PATH advertisement that includes both AS A and AS C.

W receives advertisements from A that include paths to both B and C.
Thus, W knows about both sides of the network and has the most complete view among the three.

Each stub network (W, X, and Y) forms its view of the network topology based only on the BGP path advertisements it receives. Because BGP does not distribute full topology information, each stub's view may be incomplete or different.

P19. In Figure 5.13 , suppose that there is another stub network V that is a customer of ISP A. Suppose that B and C have a peering relationship, and A is a customer of both B and C. Suppose that A would like to have the traffic destined to W to come from B only, and the traffic destined to V from either B or C. How should A advertise its routes to B and C? What AS routes does C receive?

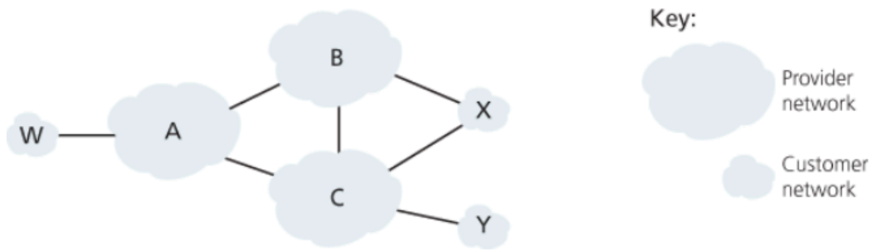


Figure 5.13 A simple BGP policy scenario

A advertises two routes to B: AS-paths [A W] and [A V].

A advertises only one route to C: AS-path [A V].

C receives only one AS path: [A V].

C does not receive any AS paths via B, since B and C are peers and do not provide transit for each other's routes.