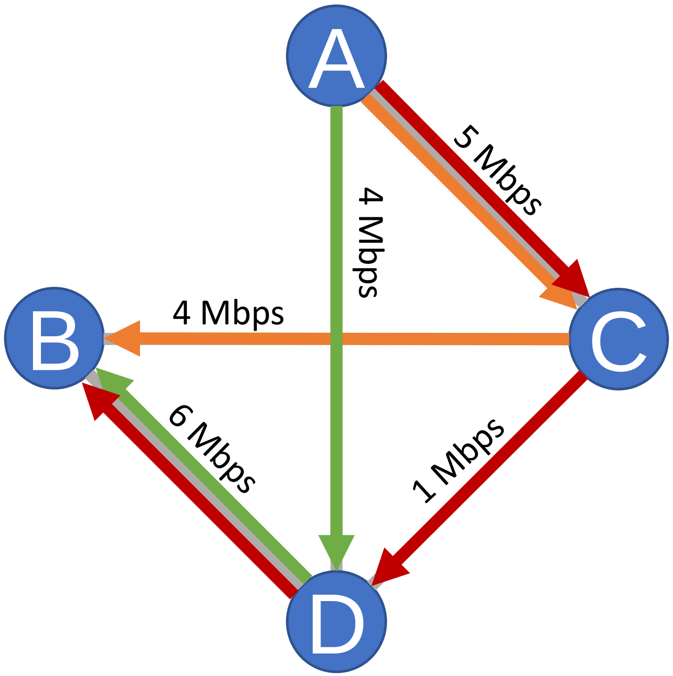
Problem Set 1 Question 1

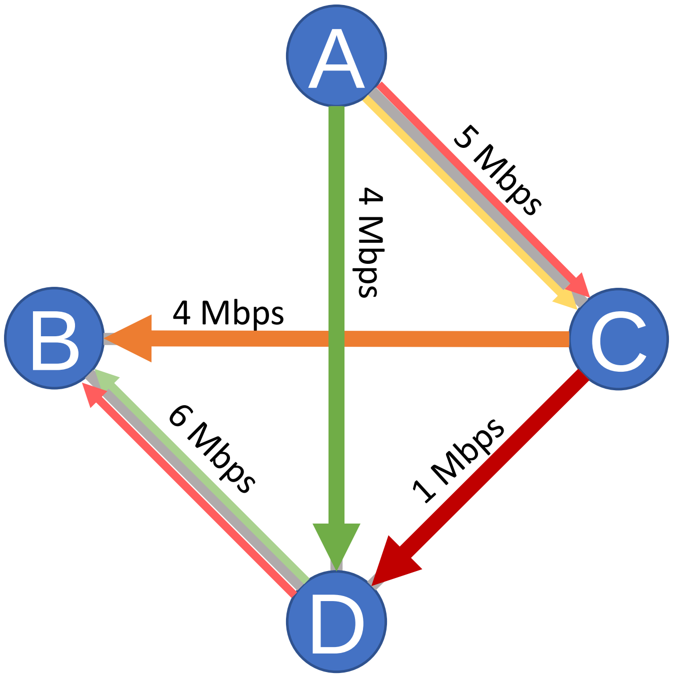
a) **How many 0.5 Mbps circuits can simultaneously be supported between A and B? Which links would they use?**



- Identify possible paths
  - **A – C – B**
  - **A – D – B**
  - **A – C – D – B**

Problem Set 1 Question 1

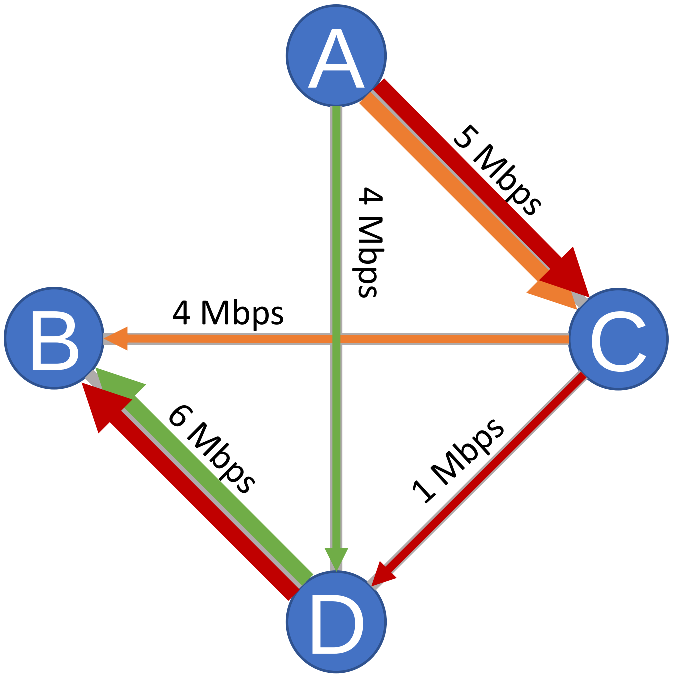
a) **How many 0.5 Mbps circuits can simultaneously be supported between A and B? Which links would they use?**



- Identify possible paths
  - **A – C – B**
  - **A – D – B**
  - **A – C – D – B**
- Identify bottleneck on each path
  - **A – C – B** **4 Mbps**
  - **A – D – B** **4 Mbps**
  - **A – C – D – B** **1 Mbps**

Problem Set 1 Question 1

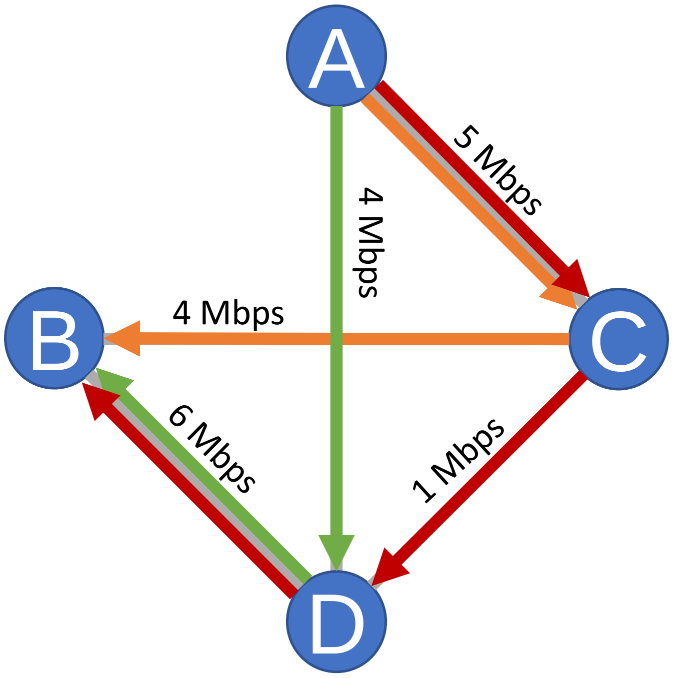
a) **How many 0.5 Mbps circuits can simultaneously be supported between A and B? Which links would they use?**



- Identify possible paths
  - **A – C – B**
  - **A – D – B**
  - **A – C – D – B**
- Identify bottleneck on each path
  - **A – C – B 4 Mbps**
  - **A – D – B 4 Mbps**
  - **A – C – D – B 1 Mbps**
- Check that shared links can support combined bandwidth
  - Here, **A – C** and **D – B** are shared. Both support combined 5 Mbps.

Problem Set 1 Question 1

a) How many 0.5 Mbps circuits can simultaneously be supported between A and B? Which links would they use?

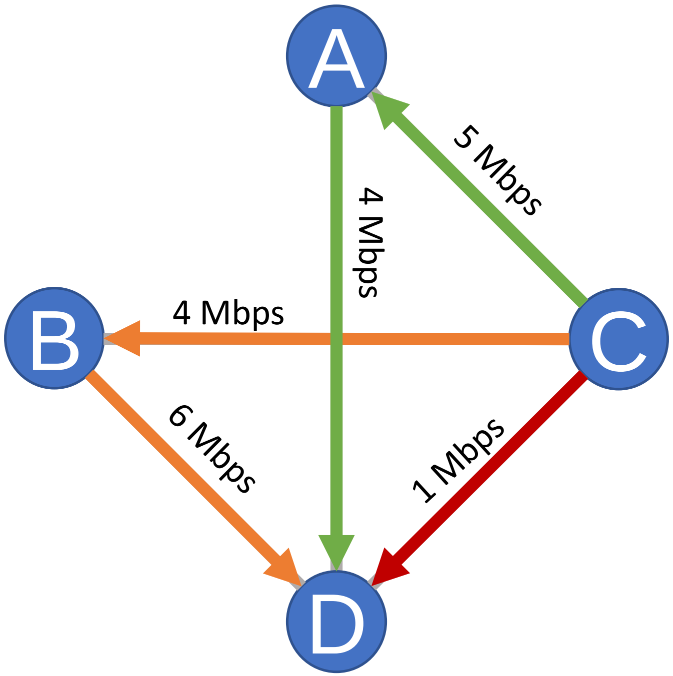


- Calculate total number of circuits
  - **A – C – B** **4 Mbps**
  - **A – D – B** **4 Mbps**
  - **A – C – D – B** **1 Mbps**

$$\frac{4 + 4 + 1\ Mbps}{0.5\ Mbps\ per\ circuit} = 18\ circuits$$

Problem Set 1 Question 1

b) How many 0.5 Mbps circuits can simultaneously be supported between C and D? Which links would they use?

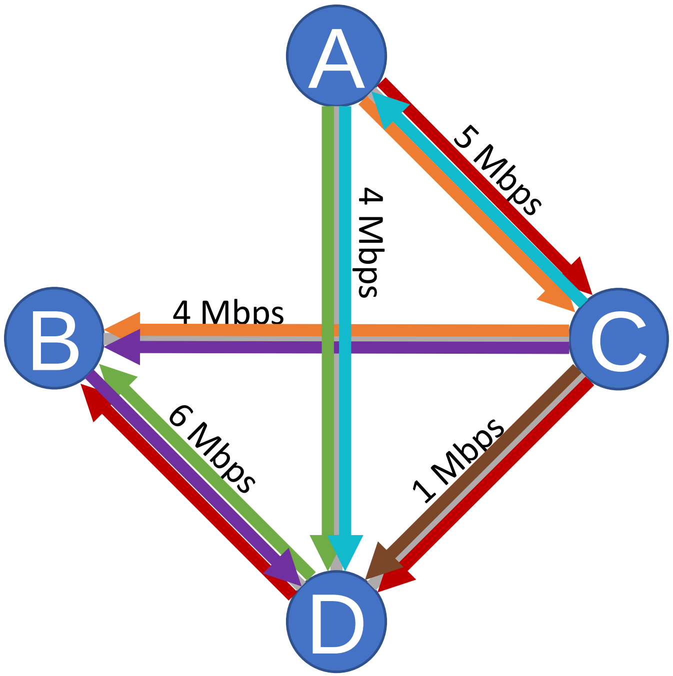


- Possible paths:
  - C – B – D 4 Mbps
  - C – A – D 4 Mbps
  - C – D 1 Mbps
- No shared links to check

$$\frac{4 + 4 + 1\ Mbps}{0.5\ Mbps\ per\ circuit} = 18\ circuits$$

Problem Set 1 Question 1

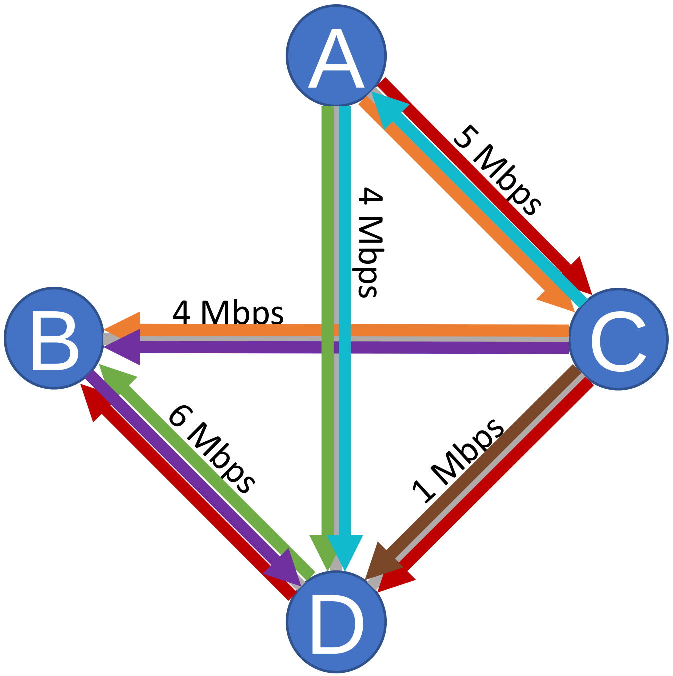
c) Suppose circuits between A – B and C – D are established simultaneously. What is the maximum number of circuits?



- Possible paths:
  - **A – C – B** 4 Mbps
  - **A – D – B** 4 Mbps
  - **A – C – D – B** 1 Mbps
  - **C – B – D** 4 Mbps
  - **C – A – D** 4 Mbps
  - **C – D** 1 Mbps
- If we assign each path bandwidth equal to its bottleneck, some links are overused.
  - Must assign bandwidth to each path such that shared links are fully utilized

Problem Set 1 Question 1

c) **Suppose circuits between A – B and C – D are established simultaneously. What is the maximum number of circuits?**



- One possible assignment:
  - **A – C – B** **2 Mbps**
  - **A – D – B** **2 Mbps**
  - **A – C – D – B** **0.5 Mbps**
  - **C – B – D** **2 Mbps**
  - **C – A – D** **2 Mbps**
  - **C – D** **0.5 Mbps**

- All links can support their total bandwidth under this assignment.

$$\frac{2+2+0.5+2+2+0.5\ Mbps}{0.5\ Mbps\ per\ circuit} = 18\ circuits$$

Problem Set 1 Question 2

a) **Calculate the total time to transfer a 1 KB packet over a link with propagation delay of 5 ms and bandwidth of 100 Kbps.**

$$TD = \frac{1\ KB}{100\ Kbps} = \frac{8\ Kb}{100\ Kbps} = 0.08\ s = 80\ ms$$

$$Total\ Time = TD + PD = 80\ ms + 5\ ms = \mathbf{85\ ms}$$

Problem Set 1 Question 2

b) **Calculate the total time to transfer a 1 KB packet over a link with propagation delay of 5 ms and bandwidth of 1 Mbps.**

$$TD = \frac{1\ KB}{\mathbf{1\ Mbps}} = \frac{8\ Kb}{1024\ Kbps} = 0.00781\ s = 7.81\ ms$$

$$Total\ Time = TD + PD = 7.81\ ms + 5\ ms = \mathbf{12.81\ ms}$$

Problem Set 1 Question 2

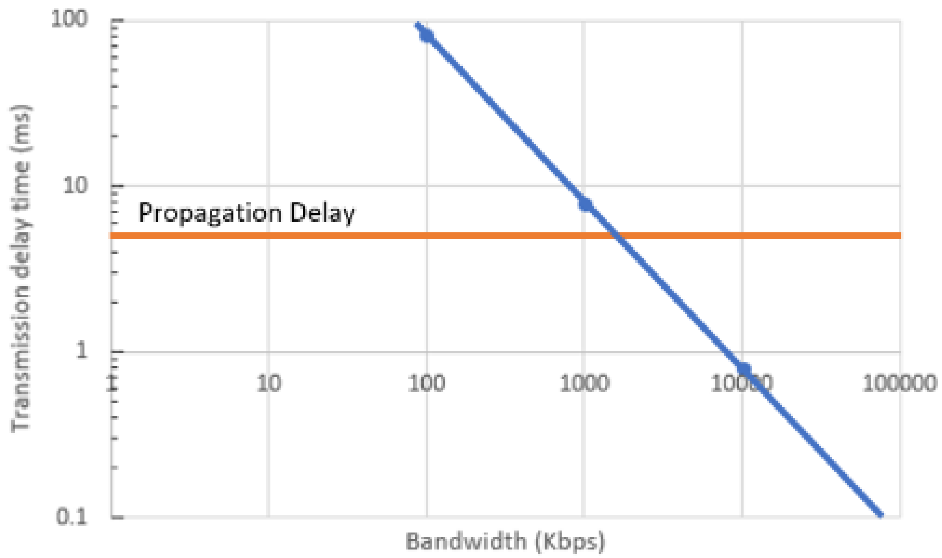
c) **Calculate the total time to transfer a 1 KB packet over a link with propagation delay of 5 ms and bandwidth of 10 Mbps.**

$$TD = \frac{1\ KB}{\mathbf{10\ \mathit{Mbps}}} = \frac{8\ Kb}{10240\ Kbps} = 0.000781\ s = 0.781\ ms$$

$$Total\ Time = TD + PD = 0.781\ ms + 5\ ms = \mathbf{5.781\ \mathit{ms}}$$

Problem Set 1 Question 2

d) **Plot the transmission and propagation delays for parts a – c. At what bandwidth will the propagation delay equal the transmission delay?**



$$TD = \frac{8\ Kb}{x} = 5\ ms \qquad x = \frac{8\ Kb}{0.005\ s} = 1600\ Kbps$$

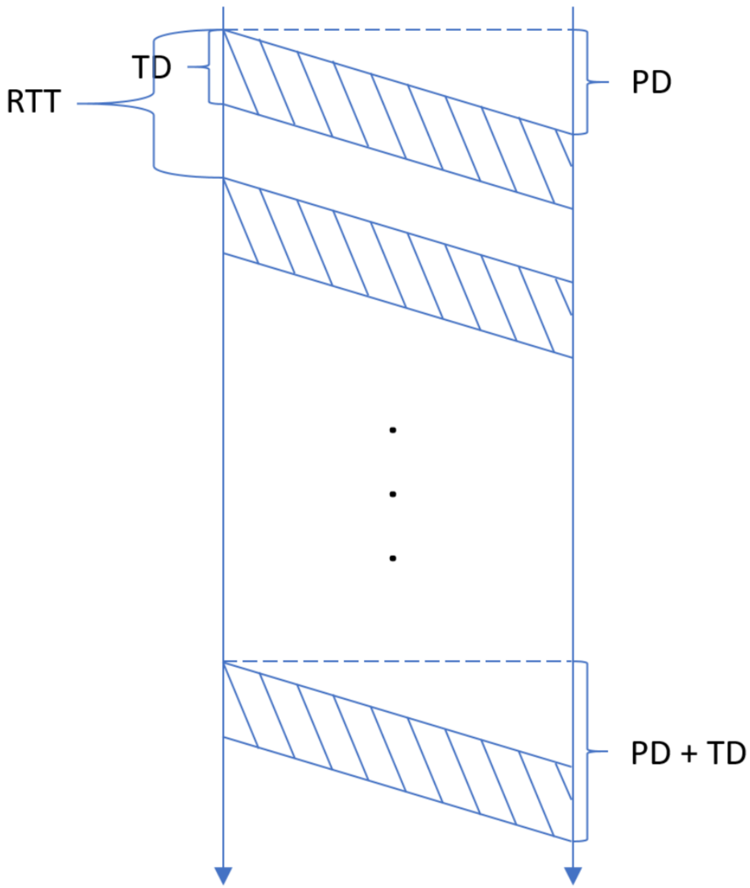
Problem Set 1 Question 2

Round-Trip Time (RTT):
In this problem, an acknowledgment bit is sent immediately once the first bit of a packet is received. There is no transmission delay to send this bit. The propagation delay is 5ms. How long is the RTT in this problem?

$$RTT = 2 * PD = 10ms$$

Problem Set 1 Question 2

e) Assume the bandwidth is 1 Mbps, but we must wait 1 RTT between sending the first bit of consecutive 1 KB packets. How long does it take to transmit a 2000 KB file?



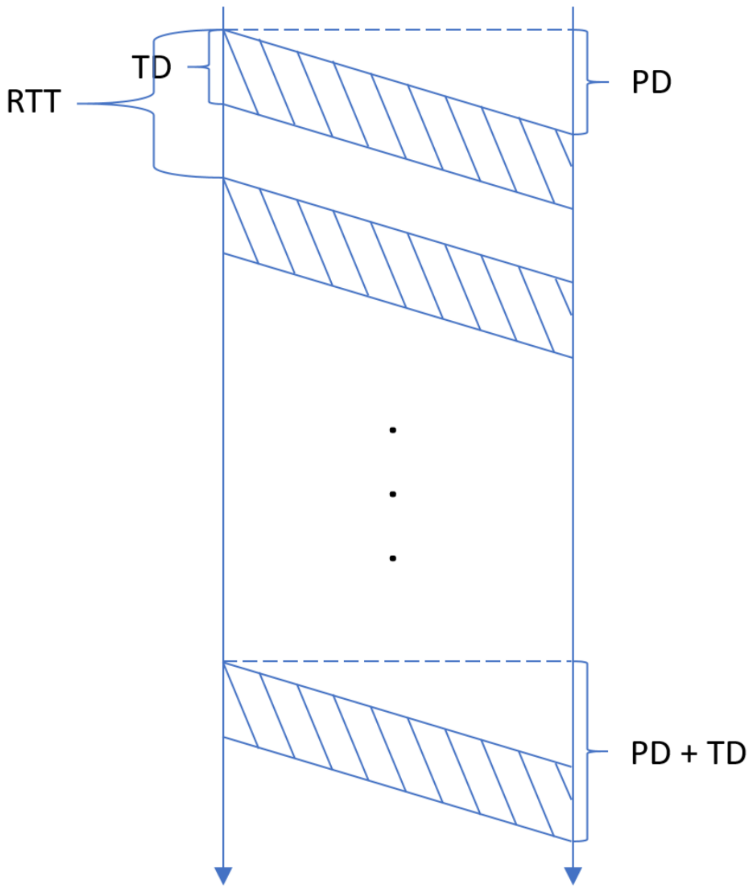
- We must wait a full RTT after sending the first 1999 packets
- Once the 2000th packet is done being transmitted and propagated, we are finished.

$$TD = \frac{1\ KB}{1\ Mbps} = \frac{8\ Kb}{1024\ Kbps} = 7.81\ ms$$

$$\begin{aligned} Total\ Time &= 1999 * RTT + TD + PD \\ &= 1999 * 10 + 7.81 + 5\ ms \\ &\approx 20\ s \end{aligned}$$

Problem Set 1 Question 2

f) Assume the bandwidth is infinite (no transmission delay) and 20 packets can be sent per RTT.



- How many "batches" do we need?

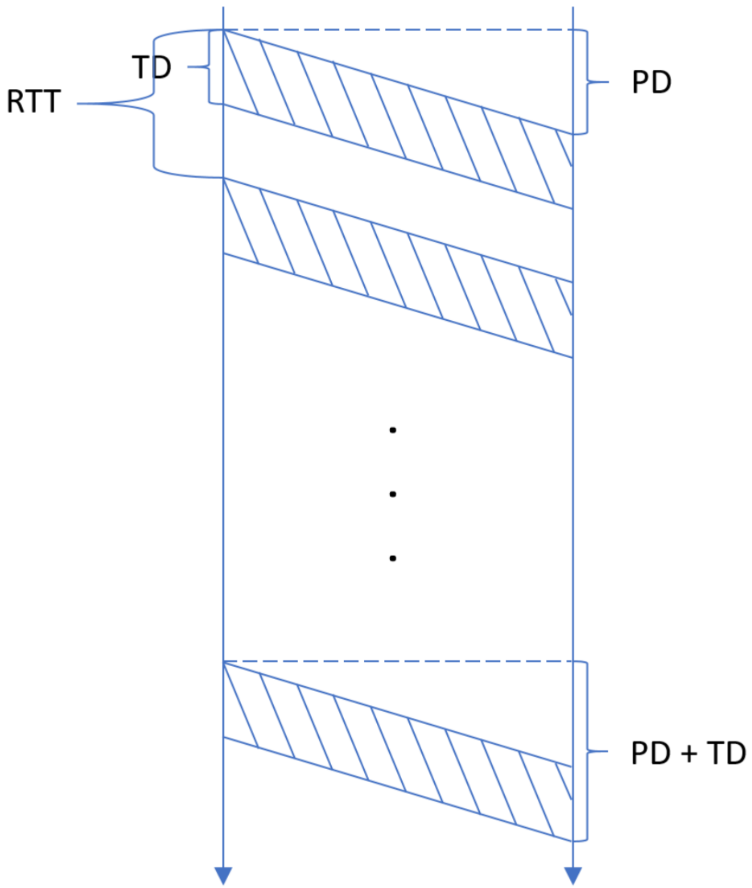
$$\frac{2000\ Packets}{20\ packets\ per\ batch} = 100\ batches$$

- We need to wait a full RTT for the first 99 batches, and then only the propagation delay for the last batch.

$$\begin{aligned} Total\ Time &= 99 * RTT + PD \\ &= 99 * 10 + 5\ ms \\ &= 995\ ms \end{aligned}$$

Problem Set 1 Question 2

g) Assume the bandwidth is infinite. During the nth RTT, we can send 2^{n-1} packets.

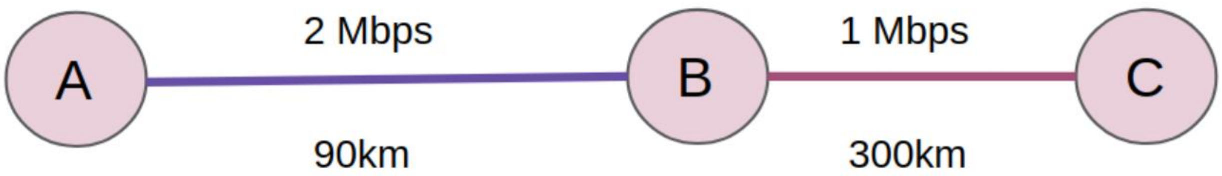


- How many "batches" do we need?
  - After the n^{th} RTT, we have sent $2^0 + 2^1 + \cdots + 2^{n-1} = \mathbf{2^n - 1}$ packets.
  - After 10 RTTs, we have sent 1023 packets. The 11^{th} RTT is the last one.

$$\begin{aligned} Total\ Time &= 10 * RTT + PD \\ &= 10 * 10 + 5\ ms \\ &= 105\ ms \end{aligned}$$

Problem Set 1 Question 3

a) **How long does it take to send a 1KB packet from node A to C and back? Packets propagate at 3*10^8 m/s.**



$$TD_{AB} = \frac{Packet\ Size}{Bandwidth} = \frac{1\ KB}{2\ Mbps} = \frac{8\ Kb}{2048\ Kbps} = 3.91\ ms$$

$$PD_{AB} = \frac{Distance}{Speed} = \frac{90\ km}{3 * 10^8\ m/s} = \frac{90 * 10^3\ m}{3 * 10^8\ m/s} = 0.30\ ms$$

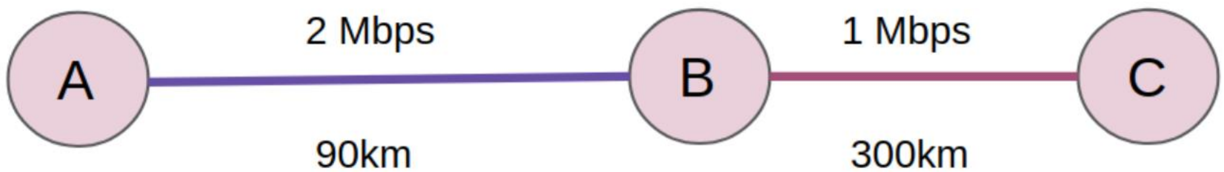
$$TD_{BC} = 7.81\ ms \qquad PD_{BC} = 1.00\ ms$$

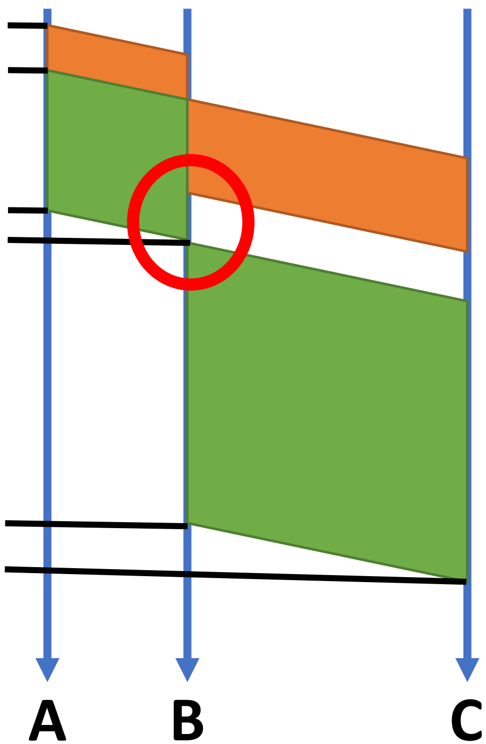
$$Total\ Time = 2 * (TD_{AB} + PD_{AB} + TD_{BC} + PD_{BC})$$

$$Total\ Time = 2 * (3.91 + 0.30 + 7.81 + 1.00) = \mathbf{26.04\ ms}$$

Problem Set 1 Question 3

b) **Assume a 1 KB packet is sent from A to C. Immediately after, a 3 KB packet is sent from A to C as well. How long would it take for C to receive the second packet?**



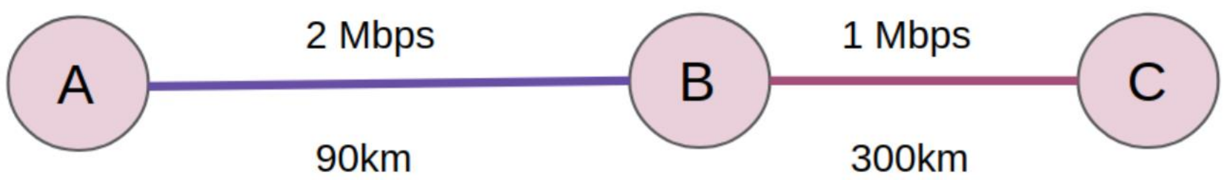


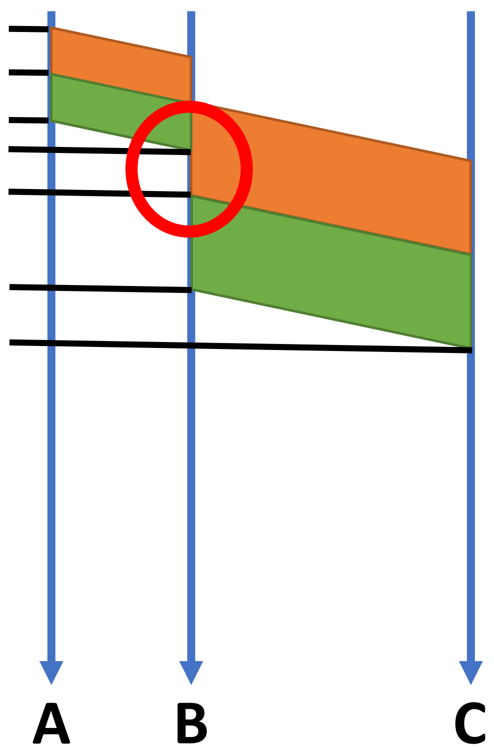
- Draw a parallelogram diagram!
  - Since $TD_{BC}(1\ KB) < TD_{AB}(3\ KB)$ there is no queuing delay.
- Total delay:

$$TD_{AB}(1KB) + TD_{AB}(3KB) + PD_{AB} + TD_{BC}(3KB) + PD_{BC}$$

Problem Set 1 Question 3

c) **Assume two 1 KB packets are sent from A to C back to back. How long would it take for C to receive the second packet?**





- Draw a parallelogram diagram!
  - Since $TD_{BC}(1\ KB) > TD_{AB}(1\ KB)$ there is queuing delay.

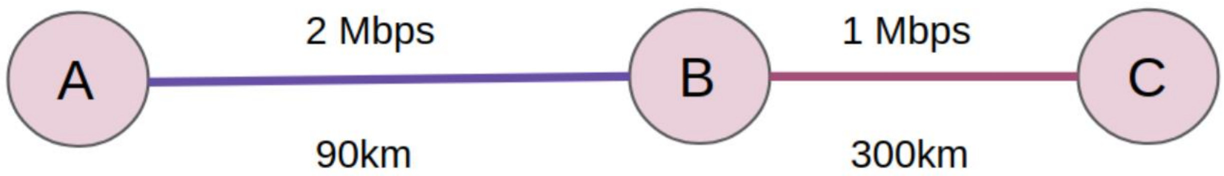
$$QD = TD_{BC}(1\ KB) - TD_{AB}(1\ KB)$$

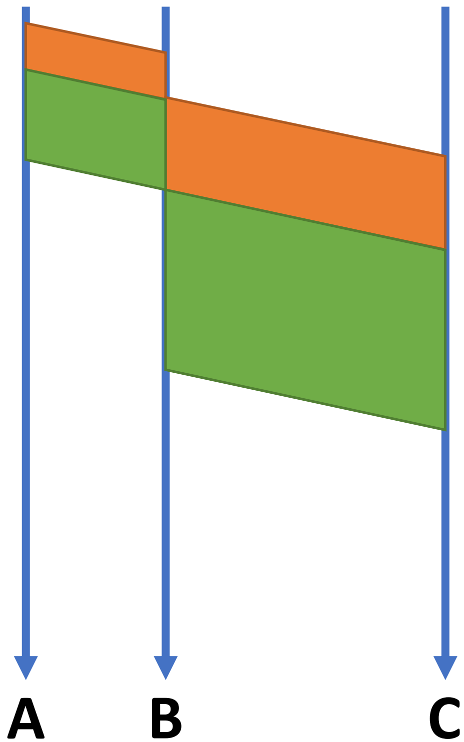
- Total delay:

$$TD_{AB}(1KB) + TD_{AB}(1KB) + PD_{AB} + QD + TD_{BC}(1KB) + PD_{BC}$$

Problem Set 1 Question 3

d) **Suppose a packet of B bytes is sent from A to C. A second packet is sent immediately after. What is the minimum size of the second packet such that there is no queuing delay?**





$$QD = TD_{BC}(Packet\ 1) - TD_{AB}(Packet\ 2) \leq 0$$

$$TD_{AB}(Packet\ 2) \geq TD_{BC}(Packet\ 1)$$

$$\frac{x}{2\ Mbps} \geq \frac{B}{1\ Mbps} \quad \rightarrow \quad x \geq 2B$$

Problem Set 2 Question 1

- **Nodes A and B are using CSMA/CD to share an Ethernet link.**

- **After frames A_1 and B_1 collide, A wins the back off race and successfully transmits A_1.**

- **Frame A_2 then collides with B_1's first retransmission attempt.**

Problem Set 2 Question 1

a) If frame A_2 is on its first retransmission attempt, and frame B_1 is on its second attempt, what is the probability that A_2 wins this back off race?

- A_2 can select from time slots 0 and 1.
- B_1 can select from time slots 0, 1, 2, and 3.

- There are 8 total combinations. A_2 wins in the following combinations:

  (0,1) (0,2) (0,3) (1,2) (1,3)

- A_2 wins in 5/8 combinations, so it has a 5/8 chance of winning.

Problem Set 2 Question 1

b) If frame A_3 is on its first retransmission attempt, and frame B_1 is on its third attempt, what is the probability that A_3 wins this back off race?

- A_3 can select from time slots 0 and 1.
- B_1 can select from time slots 0 – 7.

- There are 16 total combinations. There are only three in which A_3 does not win:

  (0,0) (1,0) (1,1)

- A_3 wins in 13/16 combinations, so it has a 13/16 chance of winning.

Problem Set 2 Question 1

c) **Given that A wins the first three back off races, what is a lower bound for the probability that A wins all of the remaining back off races?**

$$P(A\ wins\ race\ 2) = \frac{5}{8} \geq \frac{1}{2}$$

$$P(A\ wins\ race\ 3) = \frac{13}{16} \geq \frac{3}{4}$$

$$P(A\ wins\ race\ n) = 1 - \frac{3}{2^{n+1}} \geq 1 - \frac{1}{2^{n-1}}$$

$$P(A\ wins\ remaining\ races) = \prod_{i=4}^{\infty}\left(1 - \frac{1}{2^{n-1}}\right)$$

Problem Set 2 Question 1

d) If B continues to lose back off races indefinitely, what happens to frame B_1?

Eventually, B gives up on sending B_1 and moves on to B_2.

Problem Set 2 Question 2

a) A and B are both trying to transmit a single packet over Ethernet and collide. What is the probability of either A or B succeeding on the (k+1)th exponential back off attempt?

- A or B will succeed as long as they don't both select the same slot.

- In the (k+1)th attempt, there are 2^k time slots to pick from. The probability of failure is therefore $\frac{1}{2^k}$.

- The probability of success is $P_k = 1 - \frac{1}{2^k}$

Problem Set 2 Question 2

b) Let S_k be the probability of success after at most k+1 attempts. Write S_k in terms of k.

$$P_k = 1 - \frac{1}{2^k}$$

$$S_k = 1 - \prod_{i=1}^{k}(1 - P_i) = 1 - \prod_{i=1}^{k}\frac{1}{2^i}$$

$$= 1 - \frac{1}{2} * \frac{1}{4} * \frac{1}{8} * \cdots * \frac{1}{2^k} = 1 - \frac{1}{2^{\frac{k(k+1)}{2}}}$$

Problem Set 2 Question 2

c) **Let S be the probability of success eventually, after an arbitrary number of collisions. Calculate S.**

$$S_k = 1 - \frac{1}{2^{\frac{k(k+1)}{2}}}$$

$$S = \lim_{k \to \infty} S_k = \lim_{k \to \infty} 1 - \frac{1}{2^{\frac{k(k+1)}{2}}} = 1$$

Eventually, either A or B will win.

Problem Set 2 Question 2

Parts d) – f) use a non-uniform probability for selecting a slot.

Later slots are more likely to be selected.

$$\boldsymbol{P = \left\{p, 2p, 3p, 4p, \ldots, 2^k p\right\}}$$

$$\boldsymbol{p + 2p + 3p + 4p + \cdots + 2^k p = 1}$$

Problem Set 2 Question 2

d) Calculate the probability of success in the second attempt.

$$p + 2p = 1 \rightarrow p = \frac{1}{3}$$

$$\overline{P_1} = p * p + 2p * 2p = 5p^2 = \frac{5}{9}$$

$$P_1 = 1 - \overline{P_1} = 1 - \frac{5}{9} = \frac{4}{9}$$

Problem Set 2 Question 2

e) **Calculate the probability of success in the third attempt, as well as the probability of success in either the second or third attempt.**

$$p + 2p + 3p + 4p = 1 \rightarrow p = \frac{1}{10} = 0.1$$

$$\overline{P_2} = p^2 + 4p^2 + 9p^2 + 16p^2 = 30p^2 = 30 * 0.01 = 0.3$$

$$P_2 = 1 - \overline{P_2} = 1 - 0.3 = 0.7$$

$$S_2 = 1 - \overline{P_1} * \overline{P_2} = 1 - \frac{5}{9} * \frac{3}{10} = 1 - \frac{1}{6} = \frac{5}{6}$$

Problem Set 2 Question 2

f) Write P_k and S_k in terms of k

$$p + 2p + \cdots + 2^k p = 1 \rightarrow \frac{2^k(2^k+1)}{2} p = 1 \rightarrow p = \frac{1}{2^{k-1}(2^k+1)}$$

$$\overline{P_k} = p^2\left(1^2 + 2^2 + 3^2 + \cdots + 2^{2k}\right) = p^2 * \frac{2^k(2^k+1)(2^{k+1}+1)}{6}$$

$$\overline{P_k} = \frac{2^{k-1}(2^k+1)(2^{k+1}+1)}{3 * (2^{k-1}(2^k+1))^2} = \frac{2^{k+1}+1}{3 * 2^{k-1}(2^k+1)}$$

$$P_k = 1 - \overline{P_k}$$

Problem Set 2 Question 2

f) Write P_k and S_k in terms of k

$$\overline{P_k} = \frac{2^{k+1}+1}{3*2^{k-1}(2^k+1)}$$

$$S_k = 1 - \prod_{i=1}^{k} \overline{P_k}$$

$$S_k = 1 - \frac{\cancel{2^2+1}}{3*2^0(2^1+1)} * \frac{\cancel{2^3+1}}{3*2^1\cancel{(2^2+1)}} * \cdots * \frac{2^{k+1}+1}{3*2^{k-1}\cancel{(2^k+1)}}$$

$$S_k = 1 - \frac{2^{k+1}+1}{3^k * 2^{0+1+2+\cdots+k-1}(2^1+1)} = 1 - \frac{2^{k+1}+1}{3^{k+1} * 2^{\frac{(k-1)k}{2}}}$$

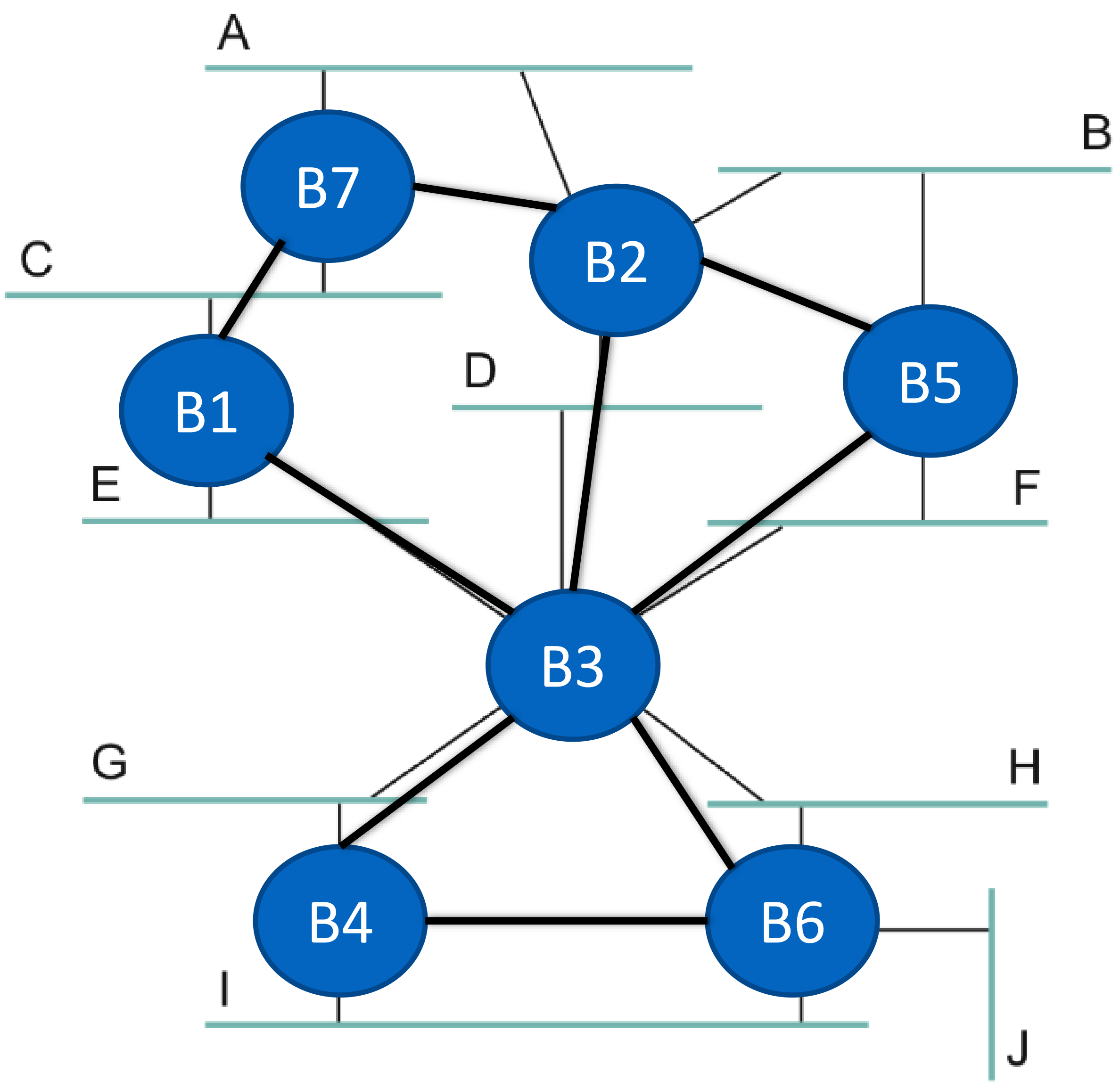
Problem Set 2 Question 2

g) If there are three stations sharing an Ethernet link (using uniform probabilities during the back-off race), can we use the same method used in parts a-c to calculate P_k and S_k?

- Because there are three nodes, there is new complexity.
- Assume that in one back-off race, A and B collide, while C picks a later slot.
- A and B now move on to the next race, but either one could still collide with C (which is still in the previous race).
- We can no longer calculate a discrete P_k for each race.

Problem Set 2 Question 3

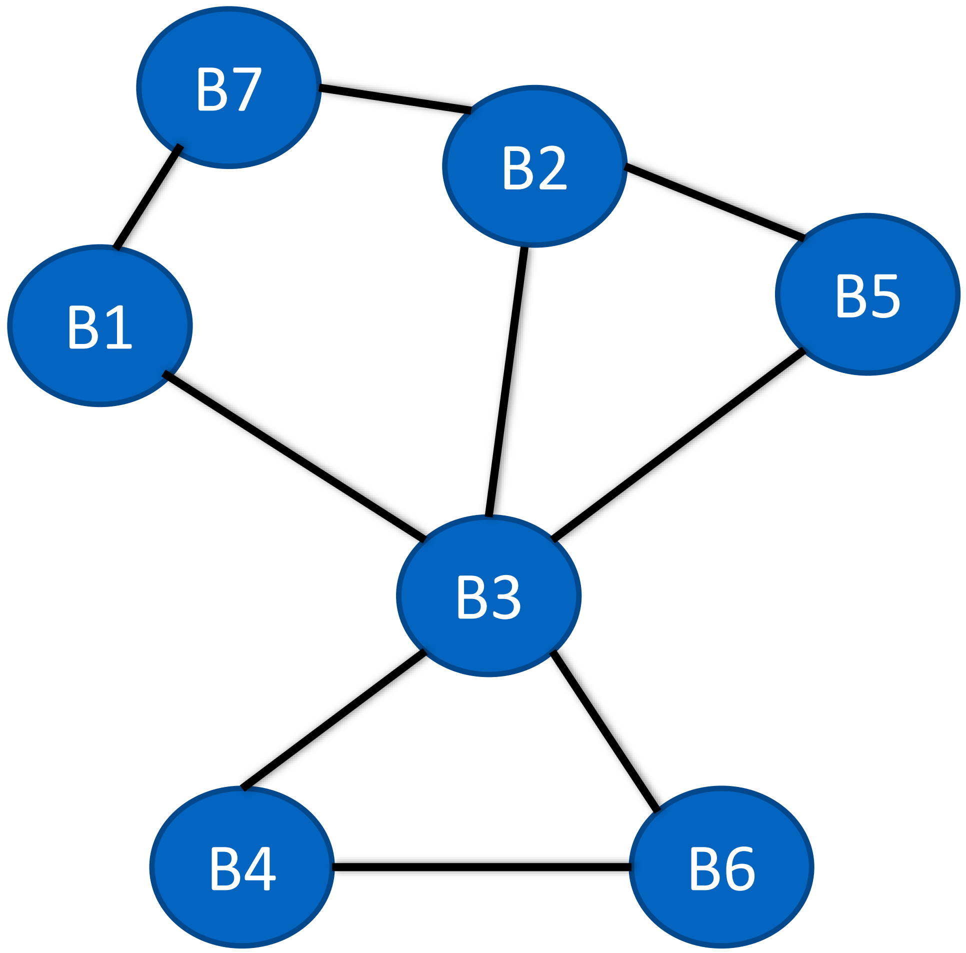
a) **Which ports are selected by the spanning tree algorithm?**



Problem Set 2 Question 3

a) **Which ports are selected by the spanning tree algorithm?**

Round 1

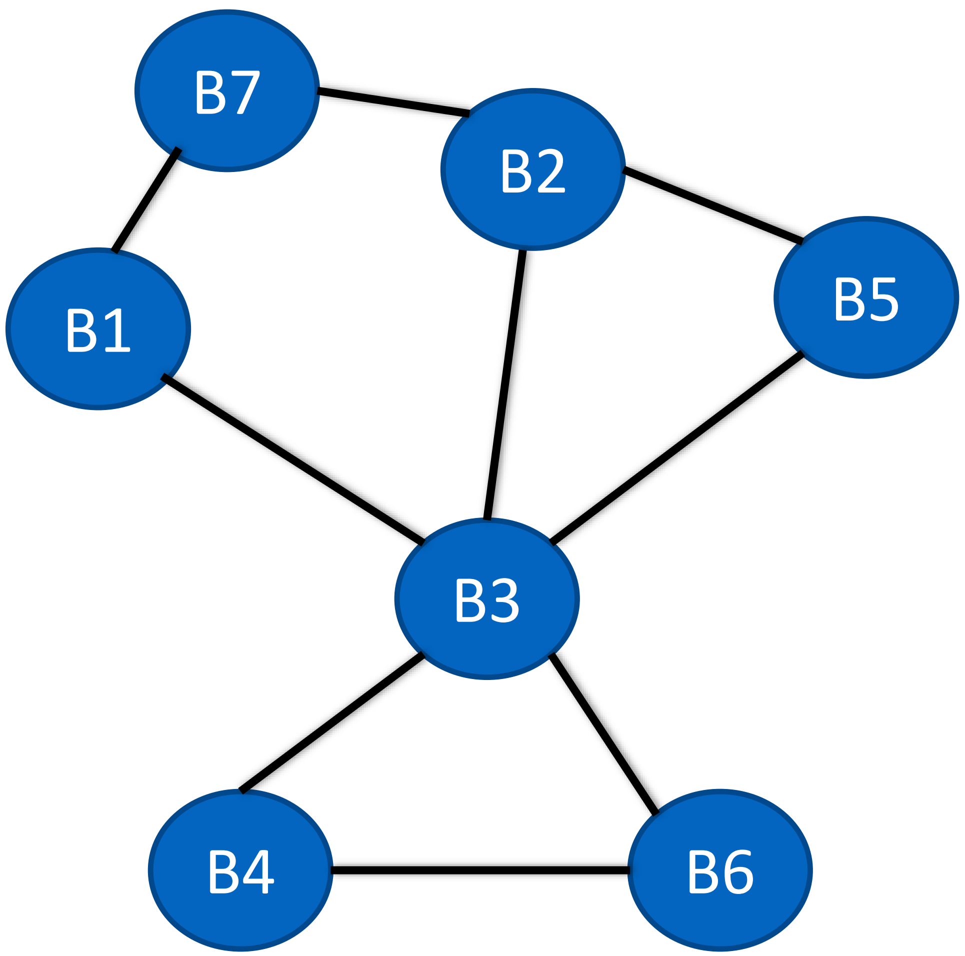


	Receive	Send	Next-hop
1		(1, 0, 1)	1
2		(2, 0, 2)	2
3		(3, 0, 3)	3
4		(4, 0, 4)	4
5		(5, 0, 5)	5
6		(6, 0, 6)	6
7		(7, 0, 7)	7

Problem Set 2 Question 3

a) **Which ports are selected by the spanning tree algorithm?**

Round 2

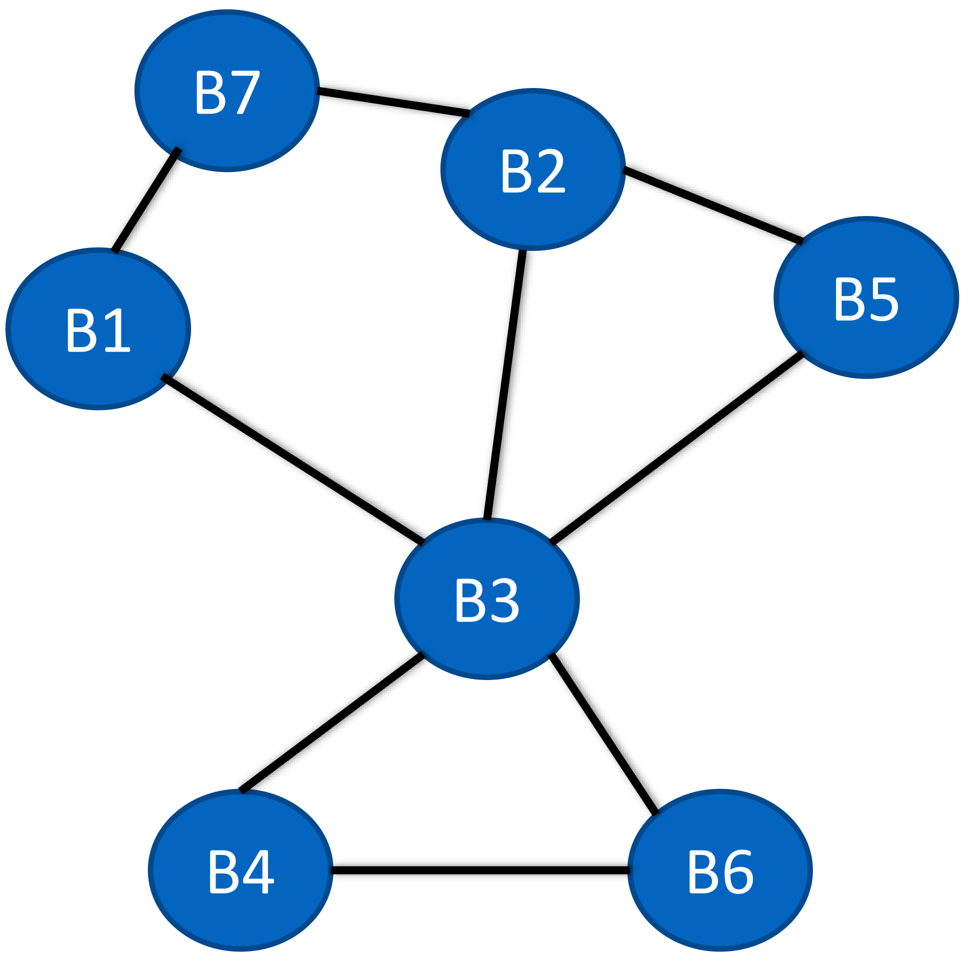


	Receive	Send	Next-hop
1	(3, 0, 3) (7, 0, 7)		1
2	(3, 0, 3) (5, 0, 5) (7, 0, 7)		2
3	(1, 0, 1) (2, 0, 2) (4, 0, 4) (5, 0, 5) (6, 0, 6)	(1, 1, 3)	1
4	(3, 0, 3) (6, 0, 6)	(3, 1, 4)	3
5	(2, 0, 2) (3, 0, 3)	(2, 1, 5)	2
6	(3, 0, 3) (4, 0, 4)	(3, 1, 6)	3
7	(1, 0, 1) (2, 0, 2)	(1, 1, 7)	1

Problem Set 2 Question 3

a) Which ports are selected by the spanning tree algorithm?

Round 3

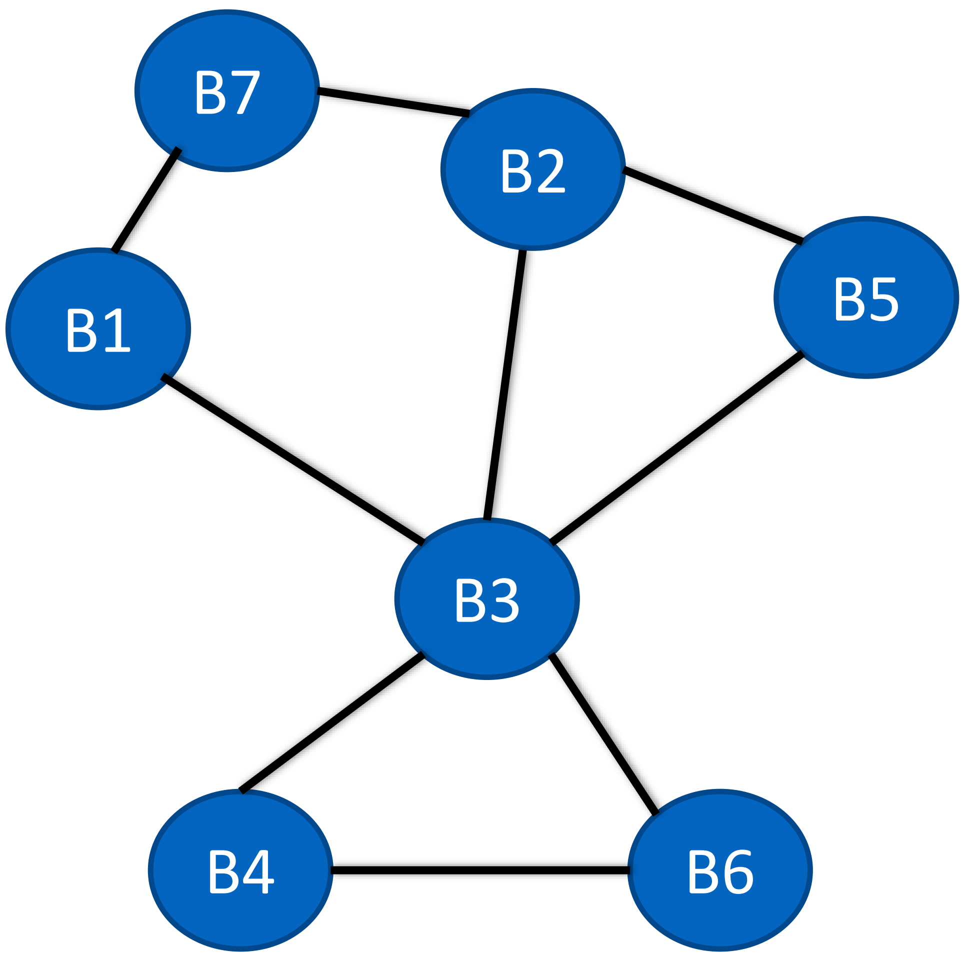


	Receive	Send	Next-hop
1	(1, 1, 3) (1, 1, 7)		1
2	(1, 1, 3) (2, 1, 5) (1, 1, 7)	(1, 2, 2)	3
3	(3, 1, 4) (2, 1, 5) (3, 1, 6)		1
4	(1, 1, 3) (3, 1, 6)	(1, 2, 4)	3
5	(1, 1, 3)	(1, 2, 5)	3
6	(1, 1, 3) (3, 1, 4)	(1, 2, 6)	3
7			1

Problem Set 2 Question 3

a) Which ports are selected by the spanning tree algorithm?

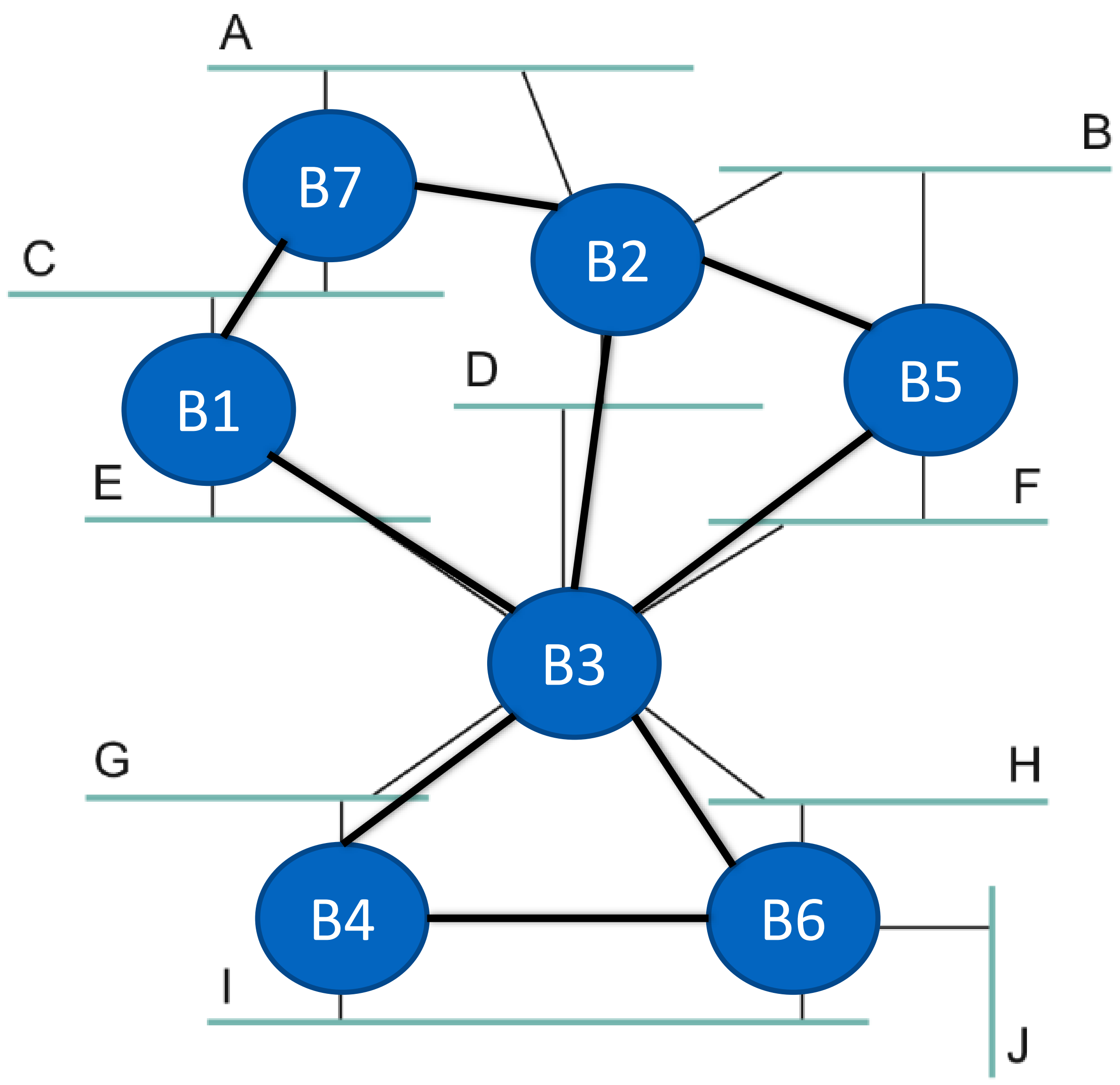
Round 4



	Receive	Send	Next-hop
1			1
2	(1, 2, 5)		3
3	(1, 2, 2) (1, 2, 4) (1, 2, 5) (1, 2, 6)		1
4	(1, 2, 6)		3
5	(1, 2, 2)		3
6	(1, 2, 4)		3
7	(1, 2, 2)		1

Problem Set 2 Question 3

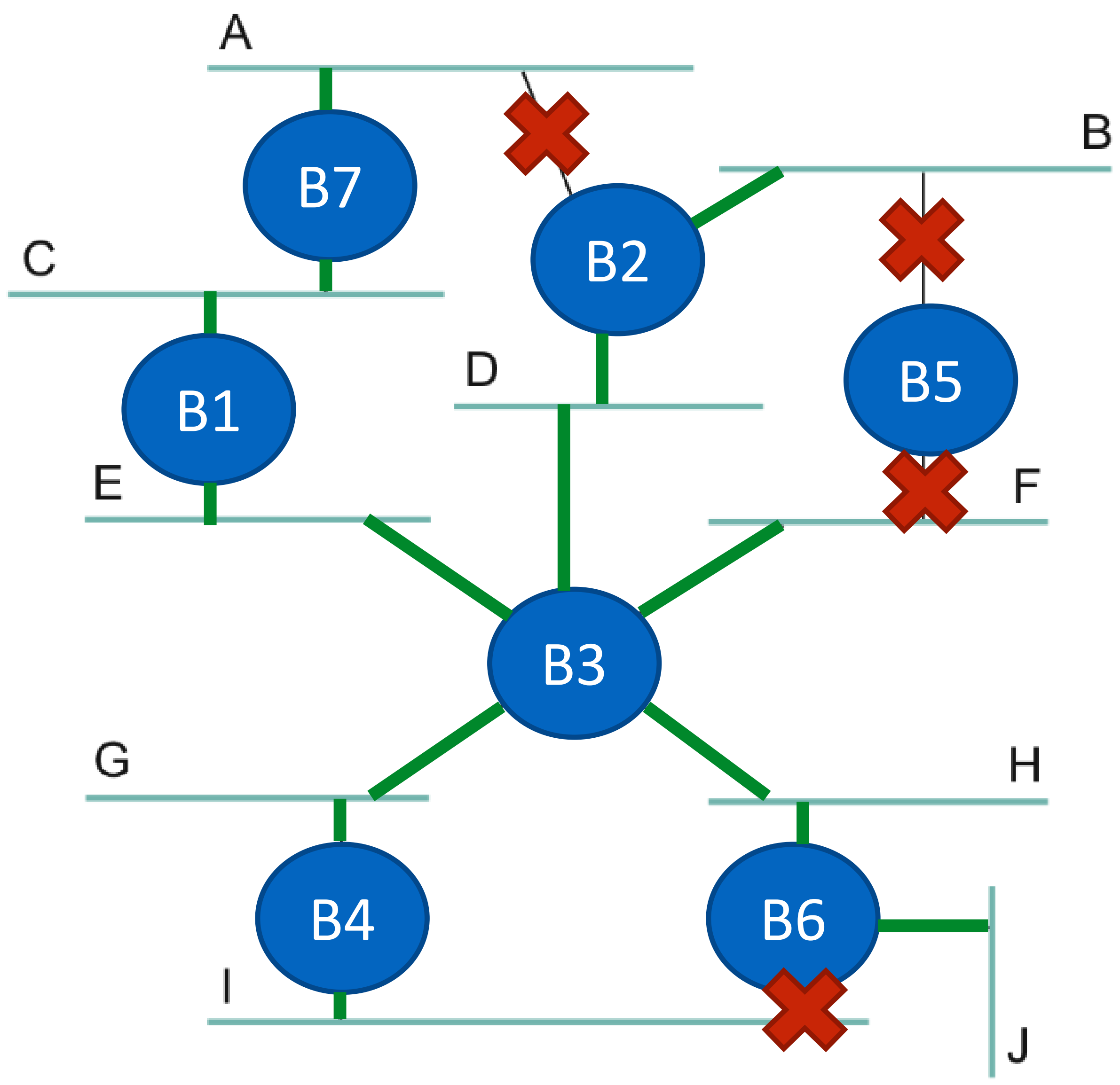
a) Which ports are selected by the spanning tree algorithm?



	Distance	Next-hop
1	0	1
2	2	3
3	1	1
4	2	3
5	2	3
6	2	3
7	1	1

Problem Set 2 Question 3

a) **Which ports are selected by the spanning tree algorithm?**



	Distance	Next-hop
1	0	1
2	2	3
3	1	1
4	2	3
5	2	3
6	2	3
7	1	1

Problem Set 3 Question 1

Suppose we have a network in which all links cost 1. Give the smallest network consistent with these two forwarding tables:

A

Node	Cost	Nexthop
B	1	B
C	1	C
D	2	B
[redacted]		
F	2	C

F

Node	Cost	Nexthop
A	2	C
B	3	C
C	1	C
D	2	C
E	1	E

Problem Set 3 Question 1

Suppose we have a network in which all links cost 1. Give the smallest network consistent with these two forwarding tables:

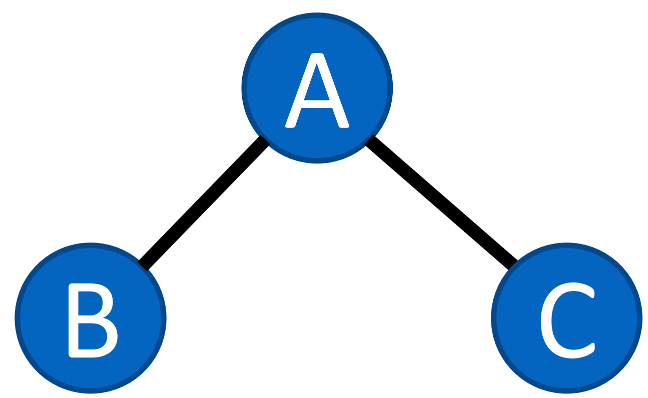
A

Node	Cost	Nexthop
B	1	B
C	1	C
D	2	B
[redacted]		
F	2	C

F

Node	Cost	Nexthop
A	2	C
B	3	C
C	1	C
D	2	C
E	1	E

- A must be directly connected to B and C (both have cost 1).



Problem Set 3 Question 1

Suppose we have a network in which all links cost 1. Give the smallest network consistent with these two forwarding tables:

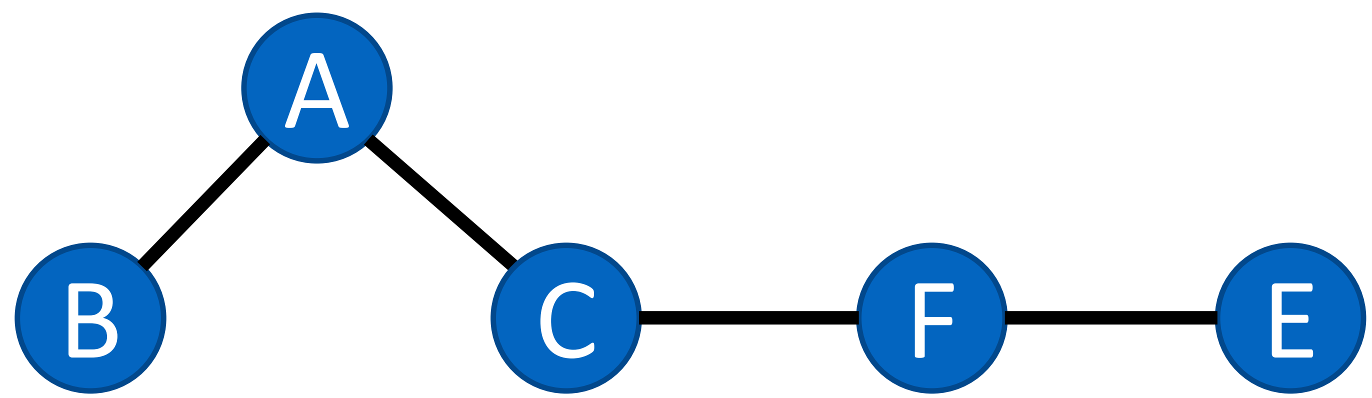
A

Node	Cost	Nexthop
B	1	B
C	1	C
D	2	B
[redacted]		
F	2	C

F

Node	Cost	Nexthop
A	2	C
B	3	C
C	1	C
D	2	C
E	1	E

- A must be directly connected to B and C (both have cost 1).
- F is directly connected to C and E



Problem Set 3 Question 1

Suppose we have a network in which all links cost 1. Give the smallest network consistent with these two forwarding tables:

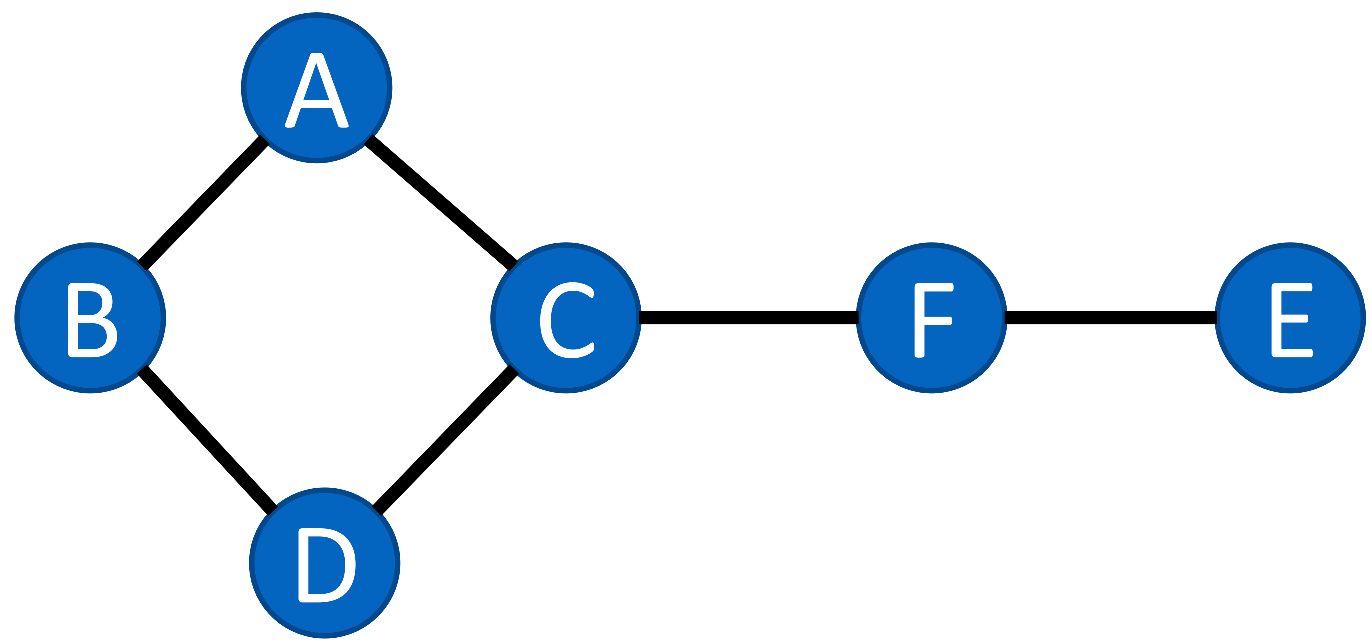
A

Node	Cost	Nexthop
B	1	B
C	1	C
D	2	B
[redacted]		
F	2	C

F

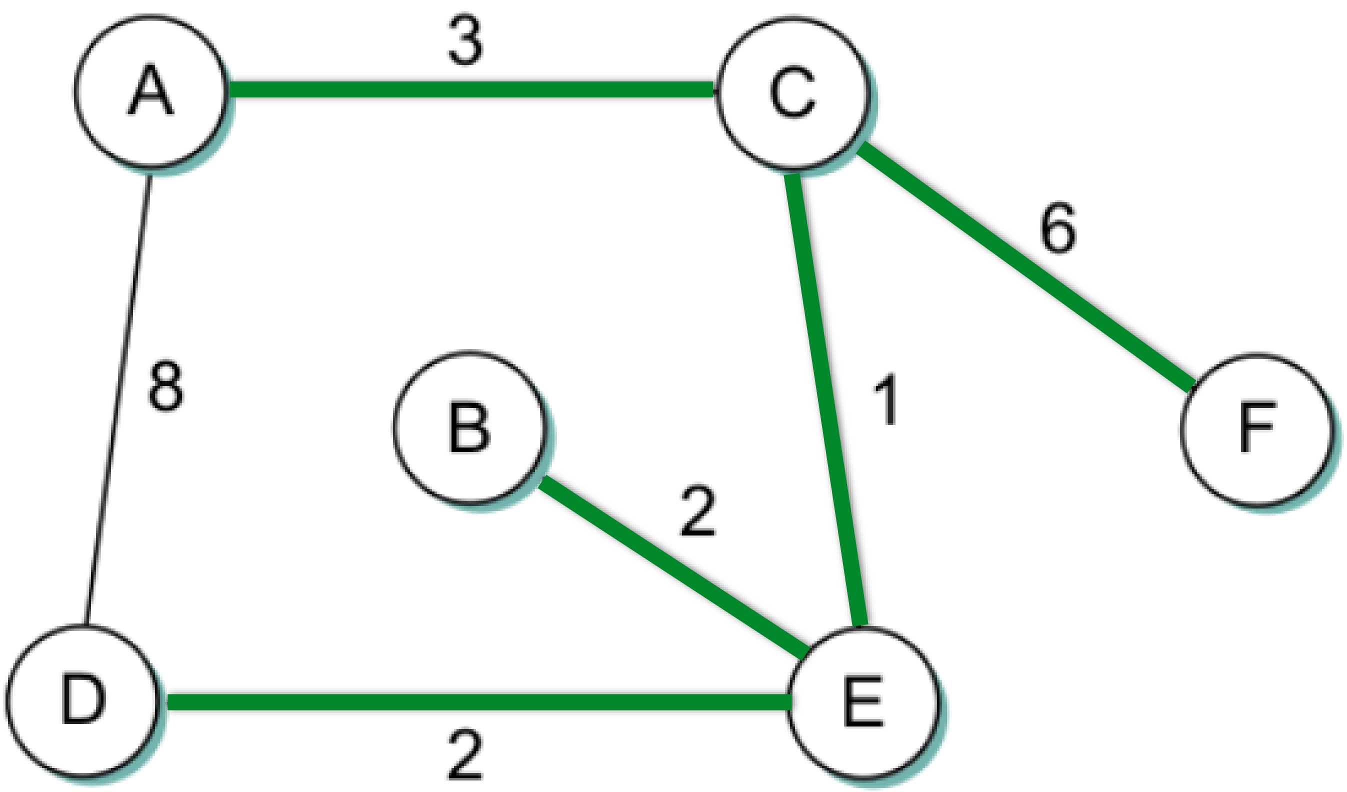
Node	Cost	Nexthop
A	2	C
B	3	C
C	1	C
D	2	C
E	1	E

- A must be directly connected to B and C (both have cost 1).
- F is directly connected to C and E
- D must connect to both B and C



Problem Set 3 Question 2

a) **Give the routing tables for this network such that each packet is forwarded via the lowest-cost path.**



Example: C's routing table

Dest.	Cost	Next Hop
A	3	A
B	3	E
D	5	E
E	1	E
F	6	F

Problem Set 3 Question 2

b) Assume link C—E fails. Give the forwarding tables after C and E report the news.

A

Dest.	Cost	Next Hop
B	6	C
C	3	C
D	6	C
E	4	C
F	9	C

B

Dest.	Cost	Next Hop
A	6	E
C	3	E
D	4	E
E	2	E
F	6	E

C

Dest.	Cost	Next Hop
A	3	A
B	~~3~~	~~E~~
D	~~5~~	~~E~~
E	~~1~~	~~E~~
F	6	F

D

Dest.	Cost	Next Hop
A	6	E
B	4	E
C	3	E
E	2	E
F	9	E

E

Dest.	Cost	Next Hop
A	~~4~~	~~C~~
B	2	B
C	~~1~~	~~C~~
D	2	D
F	~~7~~	~~C~~

F

Dest.	Cost	Next Hop
A	9	C
B	9	C
C	6	C
D	9	C
E	7	C

Problem Set 3 Question 2

b) **Assume link C—E fails. Give the forwarding tables after C and E report the news.**

A

Dest.	Cost	Next Hop
B	6	C
C	3	C
D	6	C
E	4	C
F	9	C

B

Dest.	Cost	Next Hop
A	6	E
C	3	E
D	4	E
E	2	E
F	6	E

C

Dest.	Cost	Next Hop
A	3	A
B	∞	-
D	∞	-
E	∞	-
F	6	F

D

Dest.	Cost	Next Hop
A	6	E
B	4	E
C	3	E
E	2	E
F	9	E

E

Dest.	Cost	Next Hop
A	∞	-
B	2	B
C	∞	-
D	2	D
F	∞	-

F

Dest.	Cost	Next Hop
A	9	C
B	9	C
C	6	C
D	9	C
E	7	C

Problem Set 3 Question 2

b) Assume link C—E fails. Give the forwarding tables after C and E report the news.

A

Dest.	Cost	Next Hop
B	~~6~~	~~C~~
C	3	C
D	~~6~~	~~C~~
E	~~4~~	~~C~~
F	9	C

B

Dest.	Cost	Next Hop
A	~~6~~	~~E~~
C	~~3~~	~~E~~
D	4	E
E	2	E
F	~~6~~	~~E~~

C

Dest.	Cost	Next Hop
A	3	A
B	∞	-
D	∞	-
E	∞	-
F	6	F

D

Dest.	Cost	Next Hop
A	~~6~~	~~E~~
B	4	E
C	~~3~~	~~E~~
E	2	E
F	~~9~~	~~E~~

E

Dest.	Cost	Next Hop
A	∞	-
B	2	B
C	∞	-
D	2	D
F	∞	-

F

Dest.	Cost	Next Hop
A	9	C
B	~~9~~	~~C~~
C	6	C
D	~~9~~	~~C~~
E	~~7~~	~~C~~

Problem Set 3 Question 2

b) **Assume link C—E fails. Give the forwarding tables after C and E report the news.**

A

Dest.	Cost	Next Hop
B	∞	-
C	3	C
D	∞	-
E	∞	-
F	9	C

B

Dest.	Cost	Next Hop
A	∞	-
C	∞	-
D	4	E
E	2	E
F	∞	-

C

Dest.	Cost	Next Hop
A	3	A
B	∞	-
D	∞	-
E	∞	-
F	6	F

D

Dest.	Cost	Next Hop
A	∞	-
B	4	E
C	∞	-
E	2	E
F	∞	-

E

Dest.	Cost	Next Hop
A	∞	-
B	2	B
C	∞	-
D	2	D
F	∞	-

F

Dest.	Cost	Next Hop
A	9	C
B	∞	-
C	6	C
D	∞	-
E	∞	-

Problem Set 3 Question 2

b) **Assume link C—E fails. Give the forwarding tables after C and E report the news.**

A

Dest.	Cost	Next Hop
B	∞	-
C	3	C
D	∞	-
E	∞	-
F	9	C

B

Dest.	Cost	Next Hop
A	∞	-
C	∞	-

C

Dest.	Cost	Next Hop
A	3	A
B	∞	-
	∞	-
	∞	-
	6	F

Nodes A and D do not immediately fail over to their shared link.

D

Dest.	Cost	Next Hop
A	∞	-
B	4	E
C	∞	-
E	2	E
F	∞	-

A	∞	-
B	2	B
C	∞	-
D	2	D
F	∞	-

F

	Cost	Next Hop
A	9	C
B	∞	-
C	6	C
D	∞	-
E	∞	-

Problem Set 3 Question 2

c) **Give the forwarding tables after A and D's next mutual exchange.**

A

Dest.	Cost	Next Hop
B	**12**	**D**
C	3	C
D	**8**	**D**
E	**10**	**D**
F	9	C

B

Dest.	Cost	Next Hop
A	∞	-
C	∞	-
D	4	E
E	2	E
F	∞	-

C

Dest.	Cost	Next Hop
A	3	A
B	∞	-
D	∞	-
E	∞	-
F	6	F

D

Dest.	Cost	Next Hop
A	**8**	**A**
B	4	E
C	**11**	**A**
E	2	E
F	**17**	**A**

E

Dest.	Cost	Next Hop
A	∞	-
B	2	B
C	∞	-
D	2	D
F	∞	-

F

Dest.	Cost	Next Hop
A	9	C
B	∞	-
C	6	C
D	∞	-
E	∞	-

Problem Set 3 Question 2

d) Give the forwarding tables after A exchanges with C.

A

Dest.	Cost	Next Hop
B	12	D
C	3	C
D	8	D
E	10	D
F	9	C

B

Dest.	Cost	Next Hop
A	∞	-
C	∞	-
D	4	E
E	2	E
F	∞	-

C

Dest.	Cost	Next Hop
A	3	A
B	**15**	**A**
D	**11**	**A**
E	**13**	**A**
F	6	F

D

Dest.	Cost	Next Hop
A	8	A
B	4	E
C	11	A
E	2	E
F	17	A

E

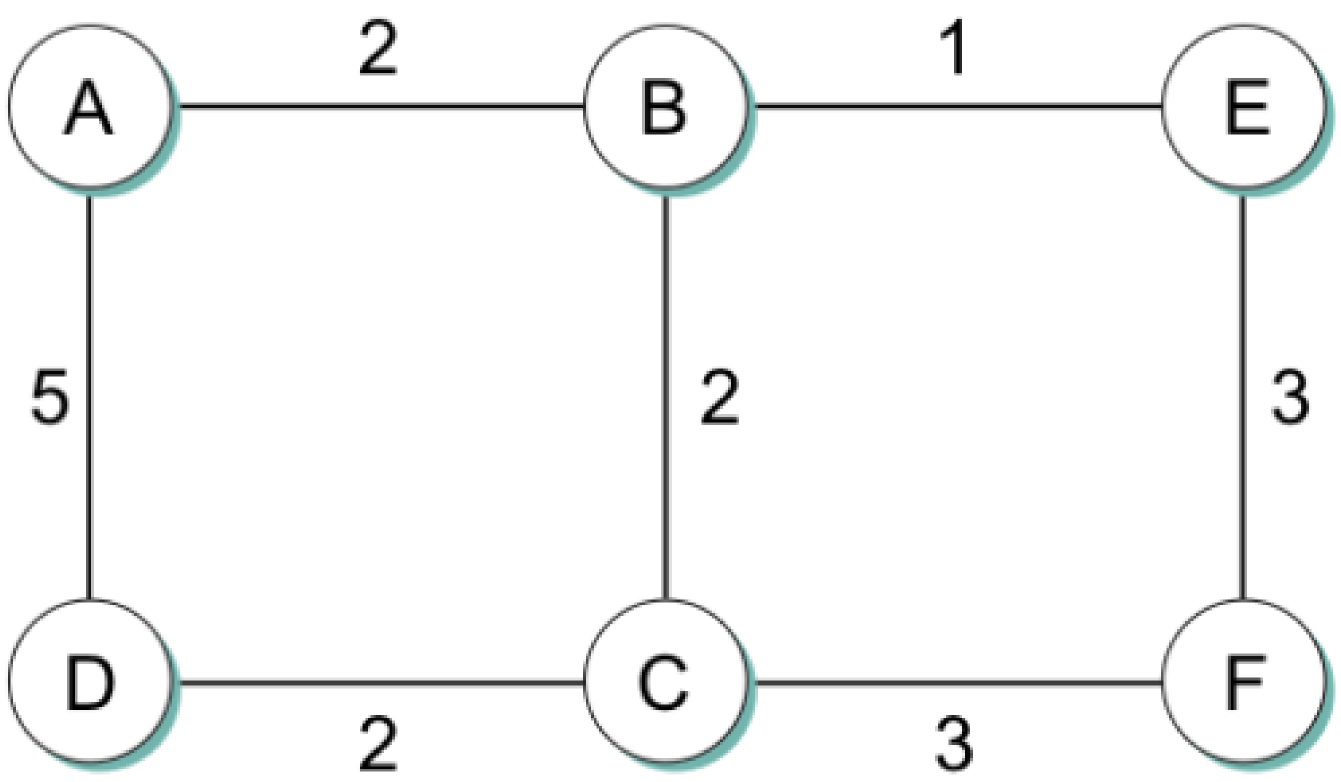
Dest.	Cost	Next Hop
A	∞	-
B	2	B
C	∞	-
D	2	D
F	∞	-

F

Dest.	Cost	Next Hop
A	9	C
B	∞	-
C	6	C
D	∞	-
E	∞	-

Problem Set 3 Question 3

a) **Give the routing tables for this network when each node only knows the distances to its immediate neighbors.**

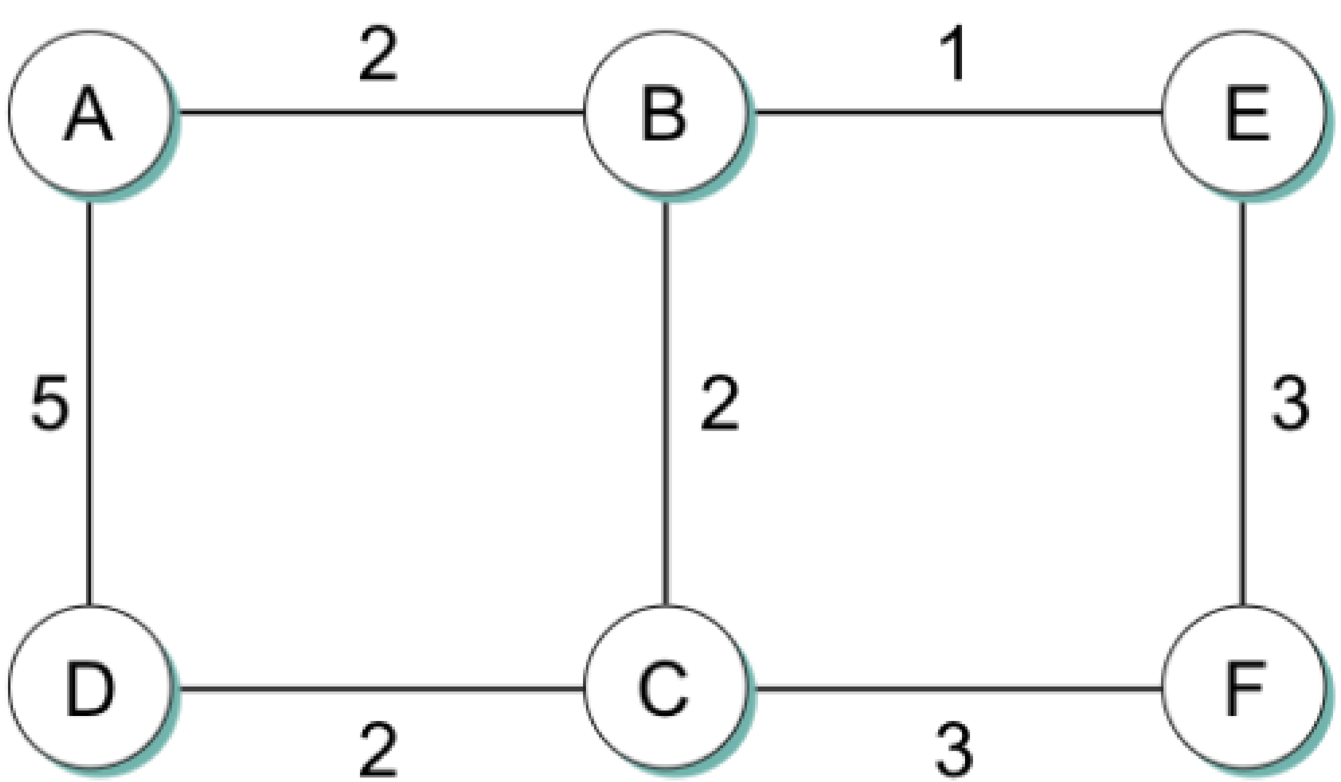


Example: A's routing table

Dest.	Cost	Next Hop
B	2	B
C	∞	-
D	5	D
E	∞	-
F	∞	-

Problem Set 3 Question 3

b) Give the routing tables for this network after each node reports the information from the previous step to its neighbors



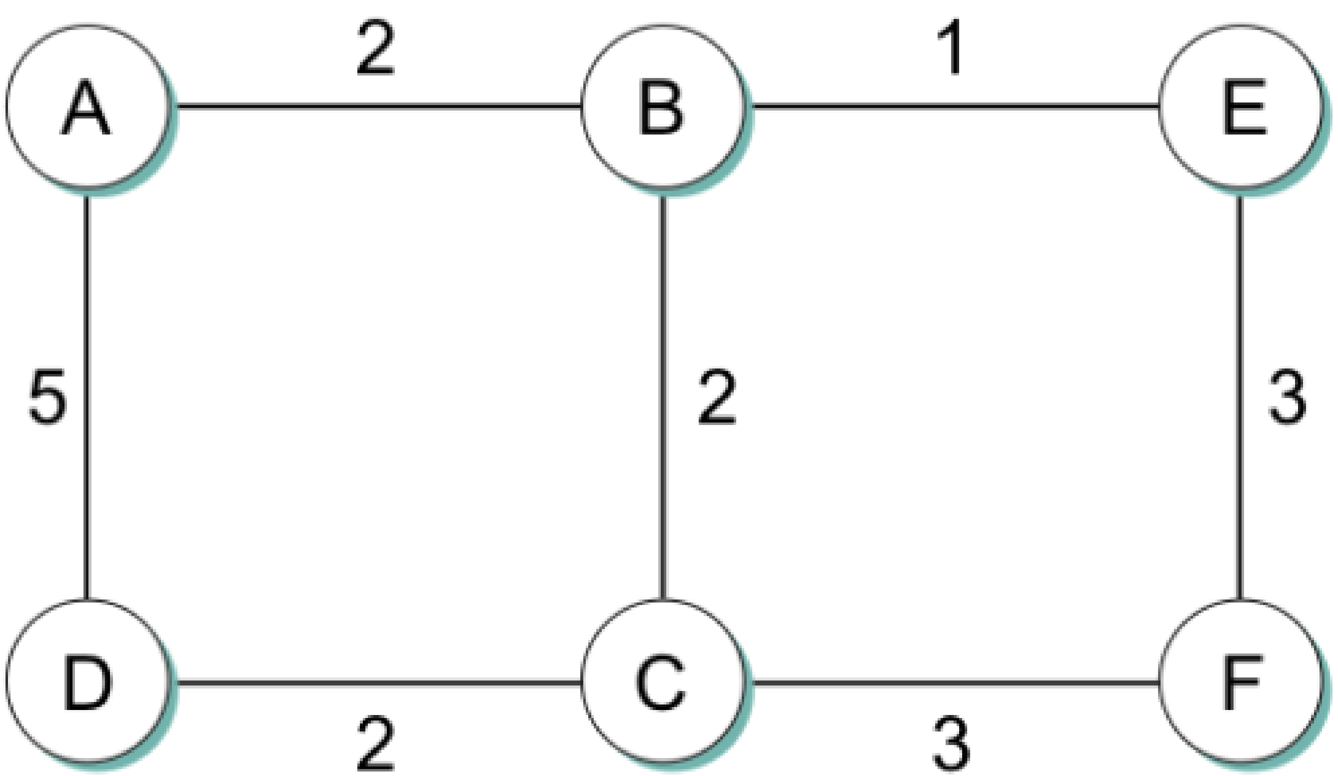
Example: A's routing table

Dest.	Cost	Next Hop
B	2	B
C	4	B
D	5	D
E	3	B
F	∞	-

Now, each node knows about paths with up to two hops.

Problem Set 3 Question 3

c) Give the routing tables for this network after step b happens a second time.



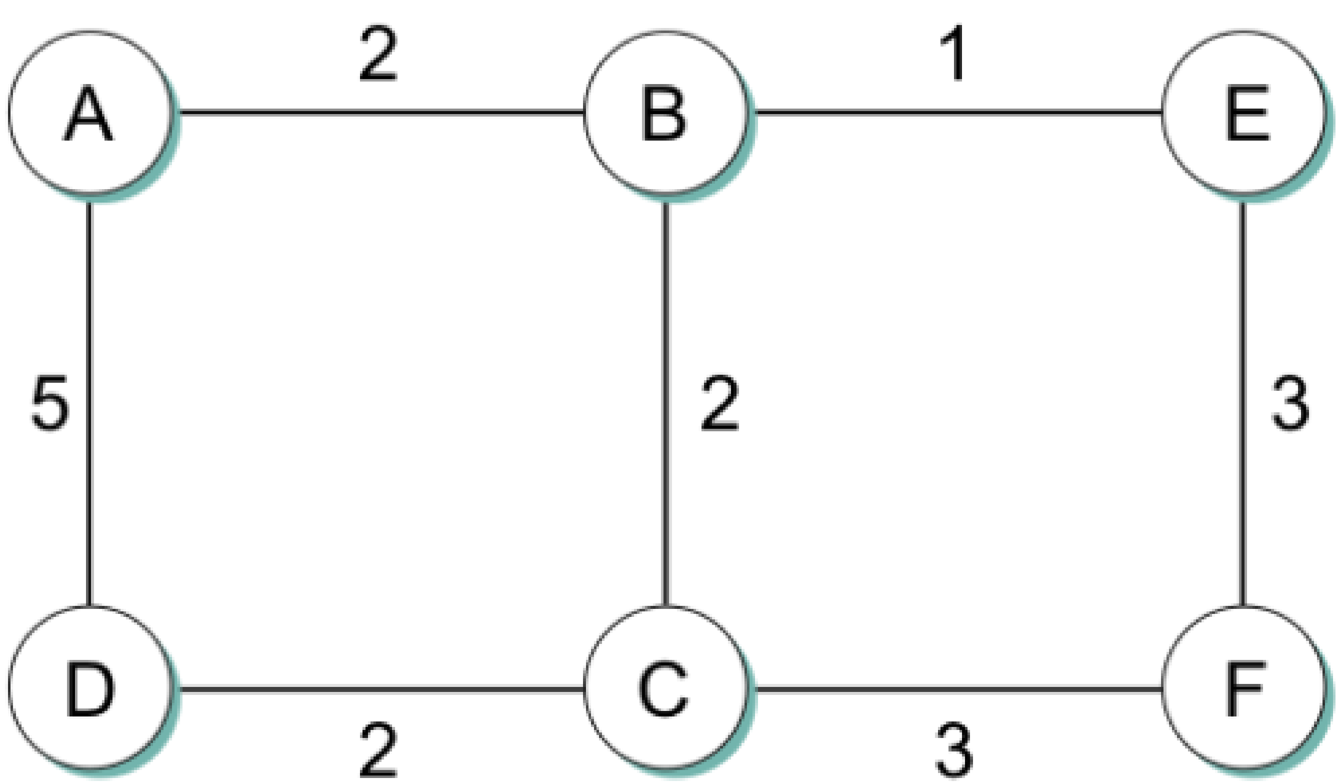
Example: A's routing table

Dest.	Cost	Next Hop
B	2	B
C	4	B
D	5	D
E	3	B
F	6	B

Now, each node knows about paths with up to three hops.

Problem Set 3 Question 3

d) Give the routing tables for this network after step b happens a third time.



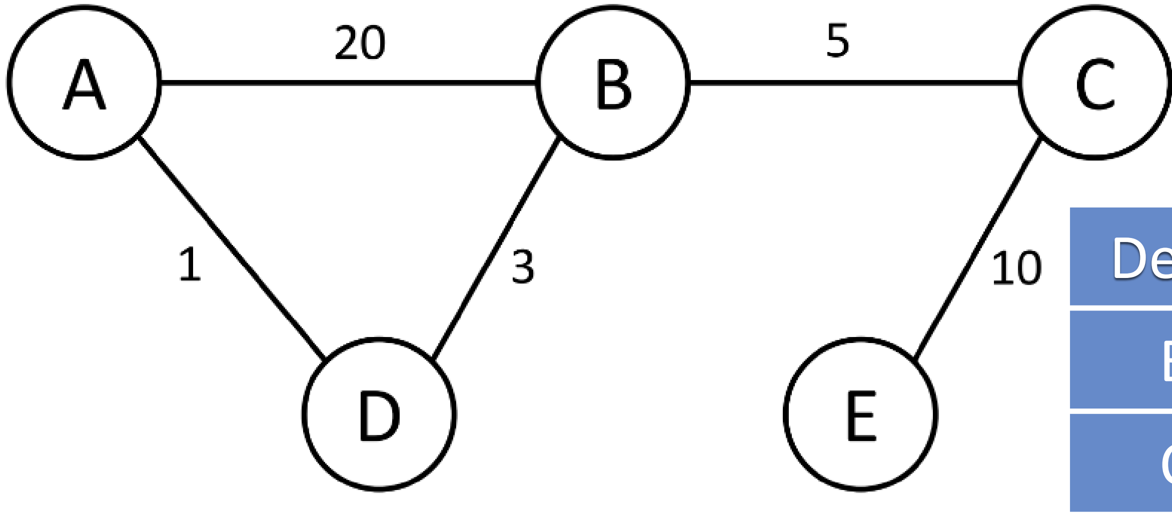
Example: A's routing table

Dest.	Cost	Next Hop
B	2	B
C	4	B
D	5	D
E	3	B
F	6	B

All of the optimal paths in this network are three hops or fewer, so the routing tables do not change in this step.

Problem Set 3 Question 4

a) Give the routing tables of the following network



A

Dest.	Cost	Next Hop
B	4	D
C	9	D
D	1	D
E	19	D

B

Dest.	Cost	Next Hop
A	4	D
C	5	C
D	3	D
E	15	C

C

Dest.	Cost	Next Hop
A	9	B
B	5	B
D	8	B
E	10	E

D

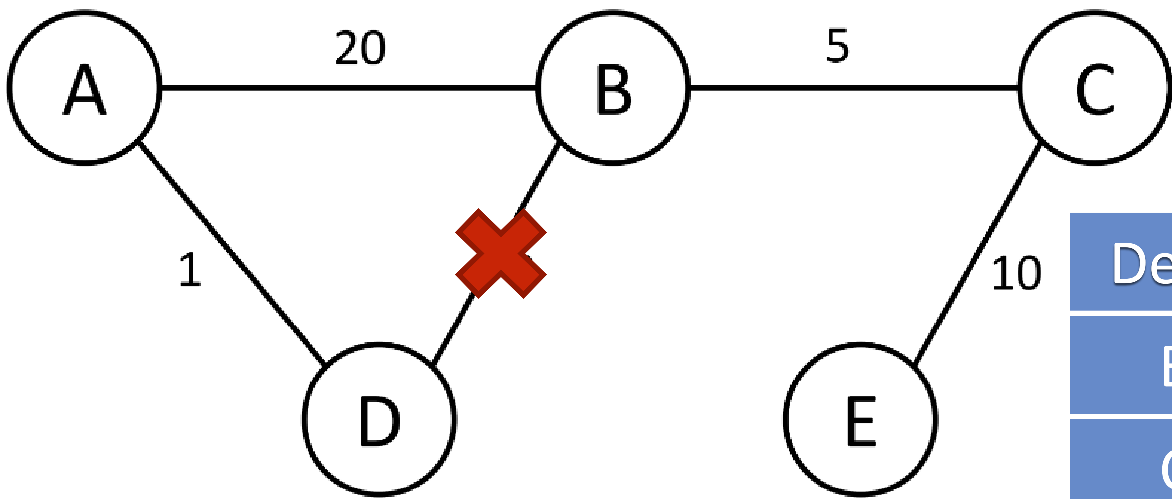
Dest.	Cost	Next Hop
A	1	A
B	3	B
C	8	B
E	18	B

E

Dest.	Cost	Next Hop
A	19	C
B	15	C
C	10	C
D	18	C

Problem Set 3 Question 4

b) What will happen if the link between B and D fails?
(simplified to only examine messages between A and D)



A

Dest.	Cost	Next Hop
B	4	D
C	9	D
D	1	D
E	19	D

B

Dest.	Cost	Next Hop
A	~~4~~	~~D~~
C	5	C
D	~~3~~	~~D~~
E	15	C

C

Dest.	Cost	Next Hop
A	9	B
B	5	B
D	8	B
E	10	E

D

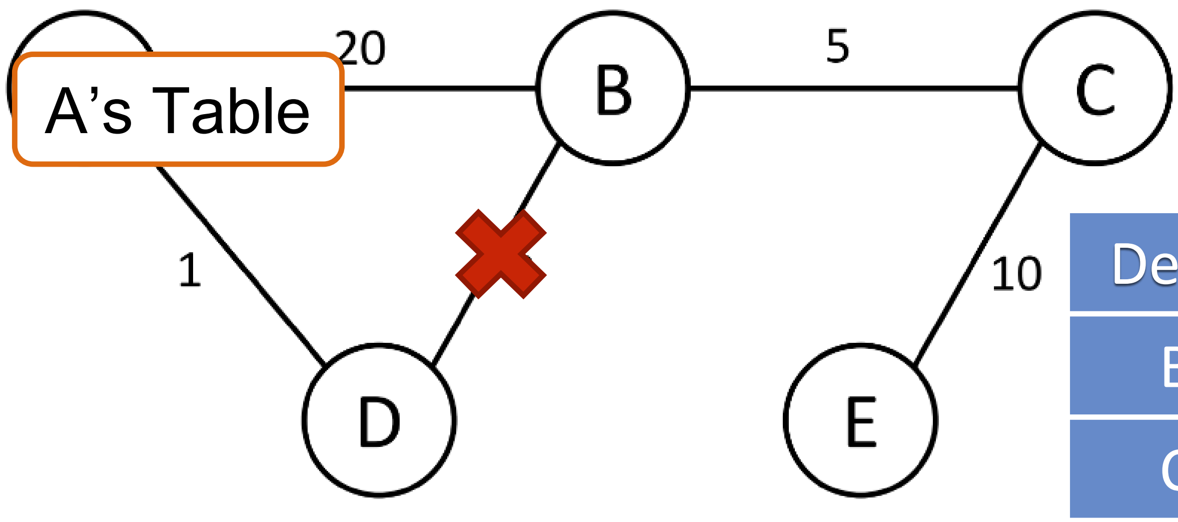
Dest.	Cost	Next Hop
A	1	A
B	~~3~~	~~B~~
C	~~8~~	~~B~~
E	~~18~~	~~B~~

E

Dest.	Cost	Next Hop
A	19	C
B	15	C
C	10	C
D	18	C

Problem Set 3 Question 4

b) What will happen if the link between B and D fails?
(simplified to only examine messages between A and D)



A

Dest.	Cost	Next Hop
B	4	D
C	9	D
D	1	D
E	19	D

B

Dest.	Cost	Next Hop
A	∞	-
C	5	C
D	∞	-
E	15	C

C

Dest.	Cost	Next Hop
A	9	B
B	5	B
D	8	B
E	10	E

D

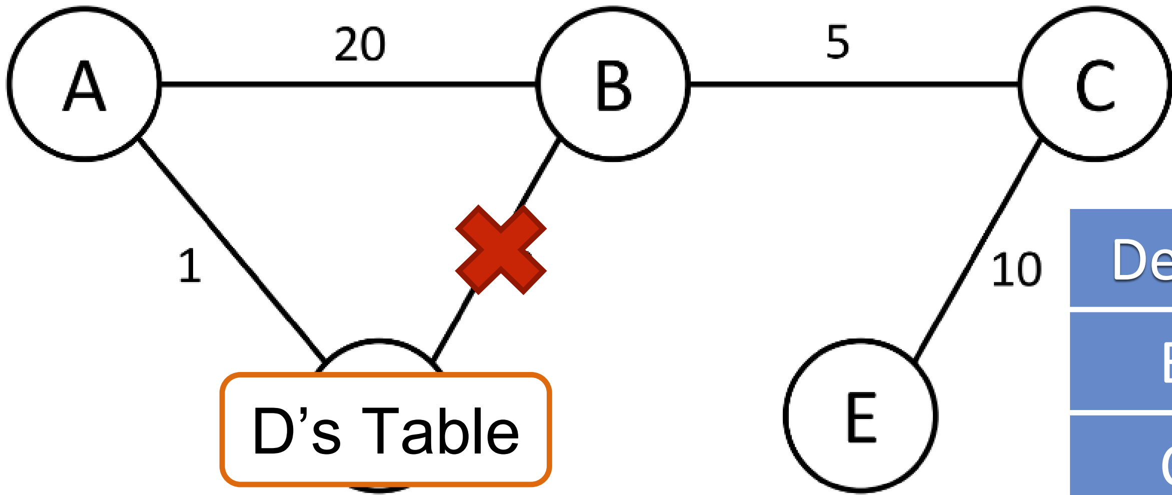
Dest.	Cost	Next Hop
A	1	A
B	∞	-
C	∞	-
E	∞	-

E

Dest.	Cost	Next Hop
A	19	C
B	15	C
C	10	C
D	18	C

Problem Set 3 Question 4

b) What will happen if the link between B and D fails?
(simplified to only examine messages between A and D)



A

Dest.	Cost	Next Hop
B	4	D
C	9	D
D	1	D
E	19	D

B

Dest.	Cost	Next Hop
A	∞	-
C	5	C
D	∞	-
E	15	C

C

Dest.	Cost	Next Hop
A	9	B
B	5	B
D	8	B
E	10	E

D

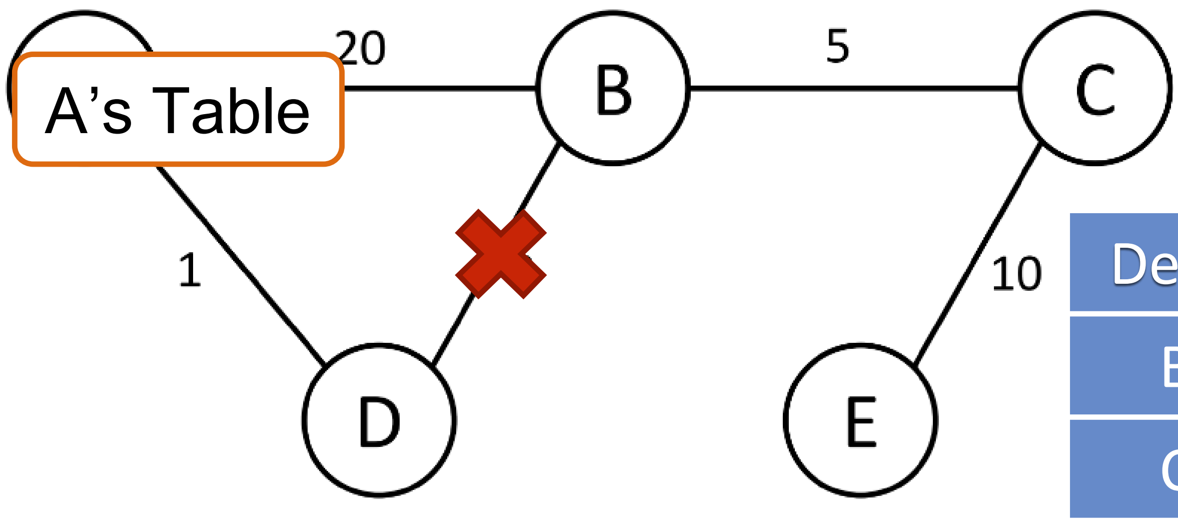
Dest.	Cost	Next Hop
A	1	A
B	**5**	**A**
C	**10**	**A**
E	**20**	**A**

E

Dest.	Cost	Next Hop
A	19	C
B	15	C
C	10	C
D	18	C

Problem Set 3 Question 4

b) What will happen if the link between B and D fails?
(simplified to only examine messages between A and D)



A

Dest.	Cost	Next Hop
B	**6**	**D**
C	**11**	**D**
D	1	D
E	**21**	**D**

B

Dest.	Cost	Next Hop
A	∞	-
C	5	C
D	∞	-
E	15	C

C

Dest.	Cost	Next Hop
A	9	B
B	5	B
D	8	B
E	10	E

D

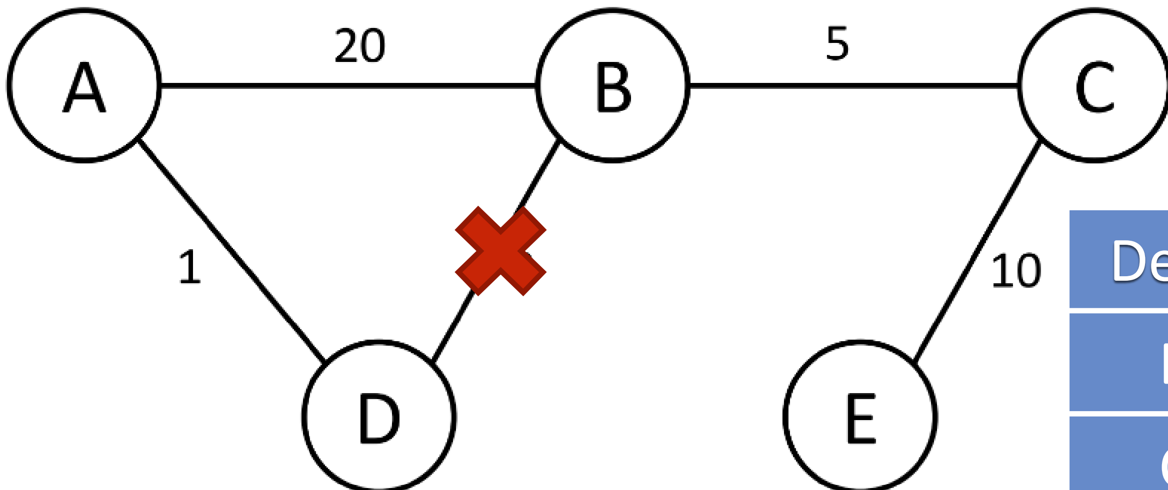
Dest.	Cost	Next Hop
A	1	A
B	**5**	**A**
C	**10**	**A**
E	**20**	**A**

E

Dest.	Cost	Next Hop
A	19	C
B	15	C
C	10	C
D	18	C

Problem Set 3 Question 4

b) What will happen if the link between B and D fails?
(simplified to only examine messages between A and D)



A

Dest.	Cost	Next Hop
B	**6**	**D**
C	**11**	**D**
D	1	D
E	**21**	**D**

B

Dest.	Cost	Next Hop
A	∞	-
C	5	C
D	∞	-
E	15	C

C

Dest.	Cost	Next Hop
A	9	B
B	5	B
D	8	B
E	10	E

D

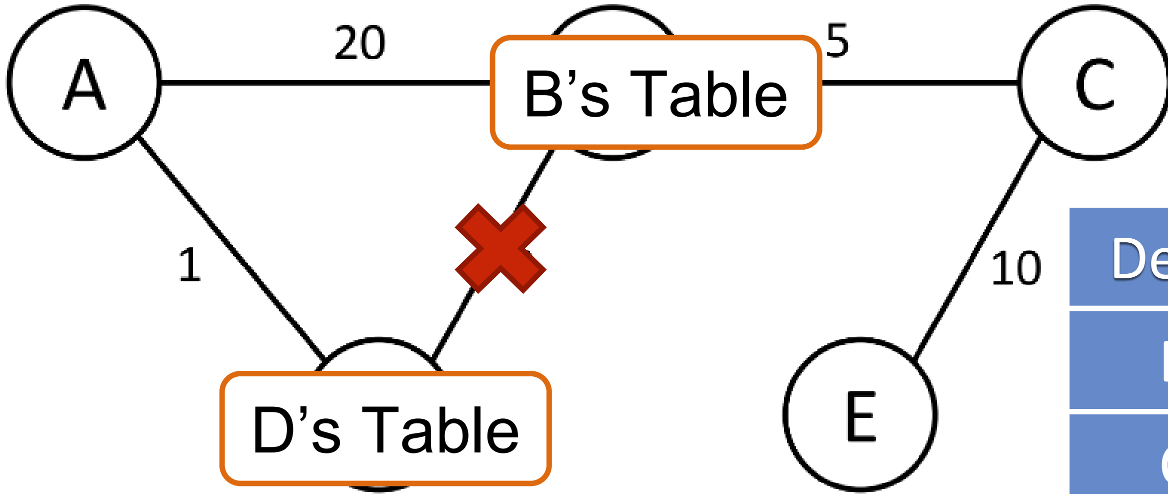
Dest.	Cost	Next Hop
A	1	A
B	**7**	**A**
C	**12**	**A**
E	**22**	**A**

E

Dest.	Cost	Next Hop
A	19	C
B	15	C
C	10	C
D	18	C

Problem Set 3 Question 4

c) If each node broadcasts its routing table every t seconds, how long does it take for routing tables to become stable?



A

Dest.	Cost	Next Hop
B	18	D
C	23	D
D	1	D
E	33	D

B

Dest.	Cost	Next Hop
A	∞	-
C	5	C
D	∞	-
E	15	C

C

Dest.	Cost	Next Hop
A	9	B
B	5	B
D	8	B
E	10	E

D

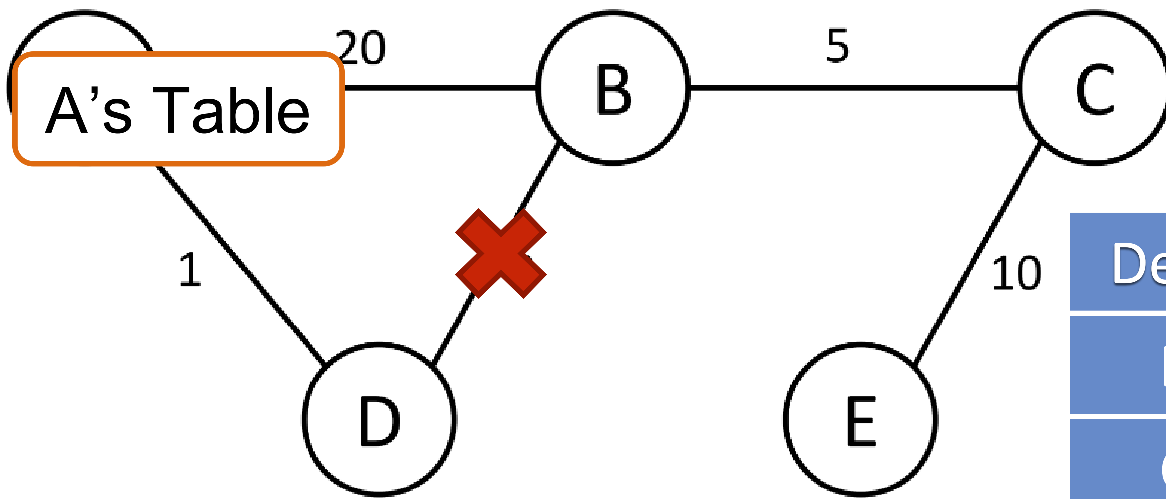
Dest.	Cost	Next Hop
A	1	A
B	19	A
C	24	A
E	34	A

E

Dest.	Cost	Next Hop
A	19	C
B	15	C
C	10	C
D	18	C

Problem Set 3 Question 4

c) **If each node broadcasts its routing table every t seconds, how long does it take for routing tables to become stable?**



A

Dest.	Cost	Next Hop
B	**20**	**B**
C	**25**	**B**
D	1	D
E	**35**	**B**

B

Dest.	Cost	Next Hop
A	∞	-
C	5	C
D	∞	-
E	15	C

C

Dest.	Cost	Next Hop
A	9	B
B	5	B
D	8	B
E	10	E

D

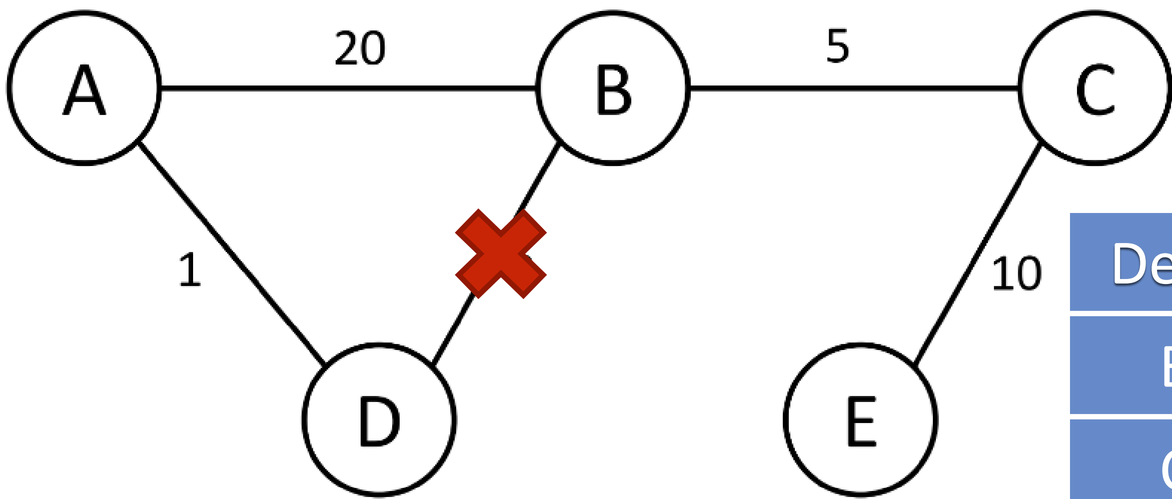
Dest.	Cost	Next Hop
A	1	A
B	**19**	**A**
C	**24**	**A**
E	**34**	**A**

E

Dest.	Cost	Next Hop
A	19	C
B	15	C
C	10	C
D	18	C

Problem Set 3 Question 4

c) If each node broadcasts its routing table every t seconds, how long does it take for routing tables to become stable?



A

Dest.	Cost	Next Hop
B	**20**	**B**
C	**25**	**B**
D	1	D

B

Dest.	Cost	Next Hop
A	∞	-
C	5	C
D	∞	-
	15	C

It takes 16 rounds to get to this point, so the total time is 16t. Different tiebreaking could add additional rounds.

C

Dest.	Cost	Next
A	9	B
B	5	B
D	8	B
E	10	E

D

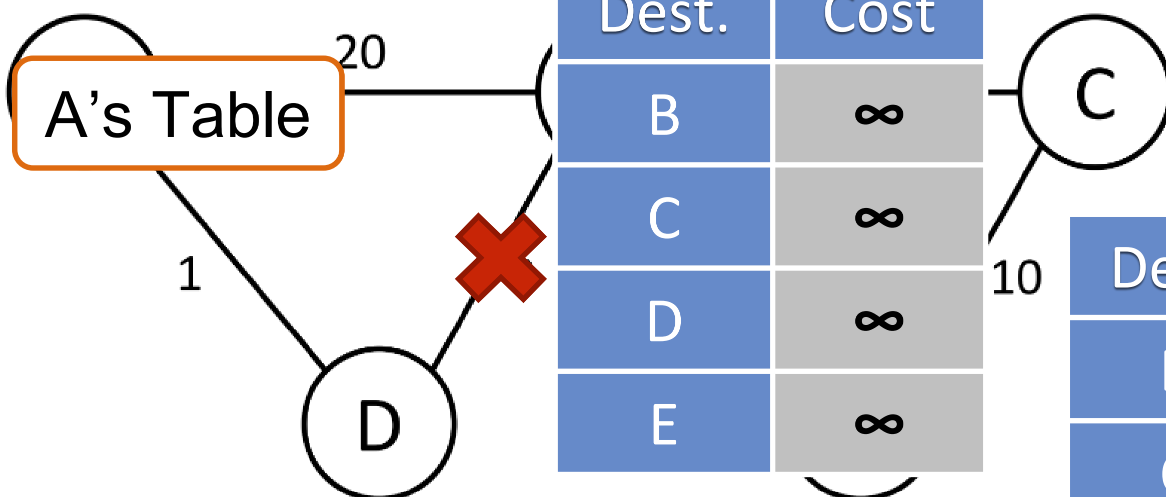
Dest.	Cost	Next Hop
A	1	A
B	**21**	**A**
C	**26**	**A**
E	**36**	**A**

E

	Cost	Next Hop
A	19	C
B	15	C
C	10	C
D	18	C

Problem Set 3 Question 4

d) How does poisoned reverse fix this problem?



A (version sent to D)

Dest.	Cost
B	∞
C	∞
D	∞
E	∞

A

Dest.	Cost	Next Hop
B	4	D
C	9	D
D	1	D
E	19	D

B

Dest.	Cost	Next Hop
A	∞	-
C	5	C
D	∞	-
E	15	C

C

Dest.	Cost	Next Hop
A	9	B
B	5	B
D	8	B
E	10	E

D

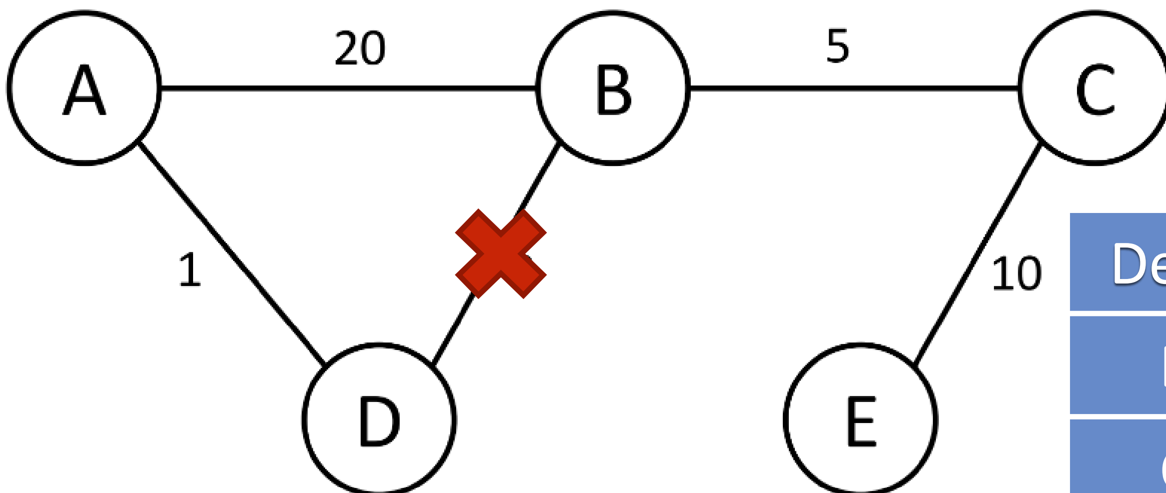
Dest.	Cost	Next Hop
A	1	A
B	∞	-
C	∞	-
E	∞	-

E

Dest.	Cost	Next Hop
A	19	C
B	15	C
C	10	C
D	18	C

Problem Set 3 Question 4

d) How does poisoned reverse fix this problem?



A

Dest.	Cost	Next Hop
B	4	D
C	9	D
D	1	D
[illegible]	[illegible]	[illegible]

B

Dest.	Cost	Next Hop
A	∞	-
C	5	C
D	∞	-
[illegible]	15	C

C

Dest.	Cost	Next [illegible]
A	9	B
B	5	B
D	8	B
E	10	E

[illegible]	[illegible]	[illegible]
A	1	A
B	∞	-
C	∞	-
E	∞	-

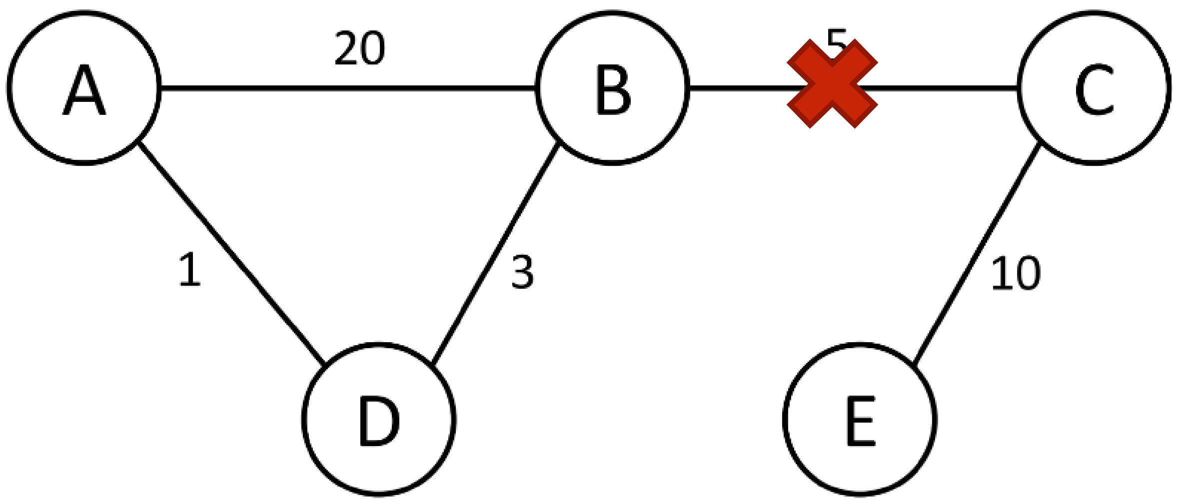
E

[illegible]	Cost	Next Hop
A	19	C
B	15	C
C	10	C
D	18	C

When A sends its table to D, it will replace the cost of its routes that pass through D with infinity. This prevents a circular route from forming in this case.

Problem Set 3 Question 4

e) Identify a scenario where poisoned reverse fails.



A

Dest.	Cost	Next Hop
B	4	D
C	9	D
D	1	D
E	19	D

B

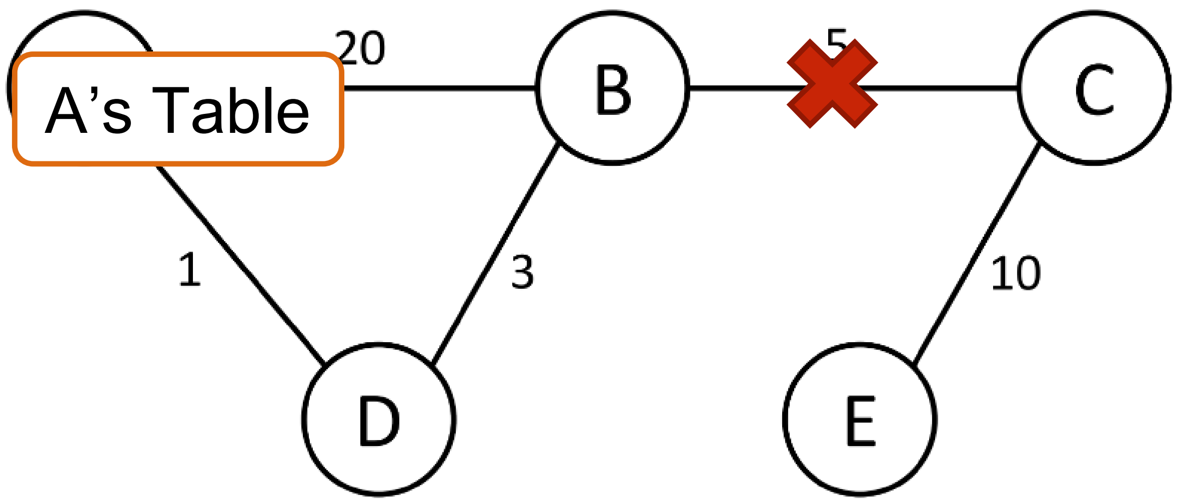
Dest.	Cost	Next Hop
A	4	D
C	~~5~~	~~C~~
D	3	D
E	~~15~~	~~C~~

D

Dest.	Cost	Next Hop
A	1	A
B	3	B
C	8	B
E	18	B

Problem Set 3 Question 4

e) Identify a scenario where poisoned reverse fails.



A (version sent to B)

Dest.	Cost
B	4
C	9
D	1
E	19

A

Dest.	Cost	Next Hop
B	4	D
C	9	D
D	1	D
E	19	D

B

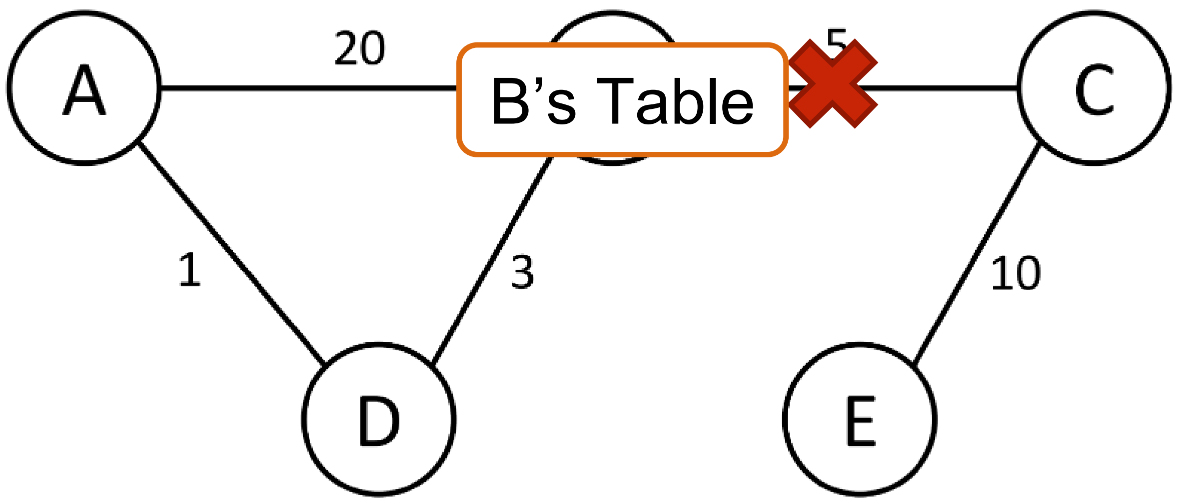
Dest.	Cost	Next Hop
A	4	D
C	**29**	**A**
D	3	D
E	**39**	**A**

D

Dest.	Cost	Next Hop
A	1	A
B	3	B
C	8	B
E	18	B

Problem Set 3 Question 4

e) Identify a scenario where poisoned reverse fails.



B (version sent to D)

Dest.	Cost
A	∞
C	**29**
D	∞
E	**39**

A

Dest.	Cost	Next Hop
B	4	D
C	9	D
D	1	D
E	19	D

B

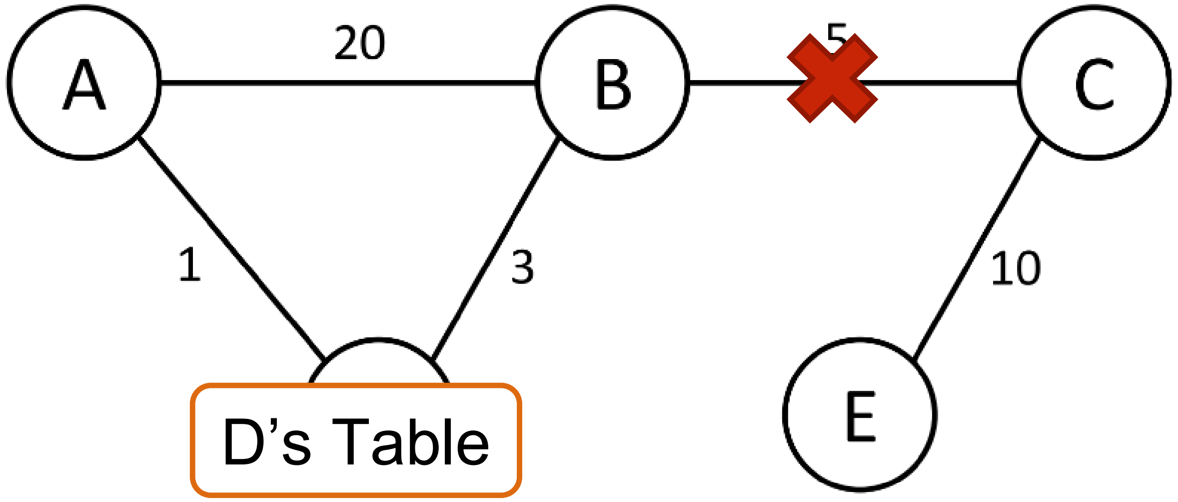
Dest.	Cost	Next Hop
A	4	D
C	**29**	**A**
D	3	D
E	**39**	**A**

D

Dest.	Cost	Next Hop
A	1	A
B	3	B
C	**32**	**B**
E	**42**	**B**

Problem Set 3 Question 4

e) Identify a scenario where poisoned reverse fails.



D (version sent to A)

Dest.	Cost
A	∞
B	3
C	**32**
E	**42**

A

Dest.	Cost	Next Hop
B	4	D
C	**33**	**D**
D	1	D
E	**43**	**D**

B

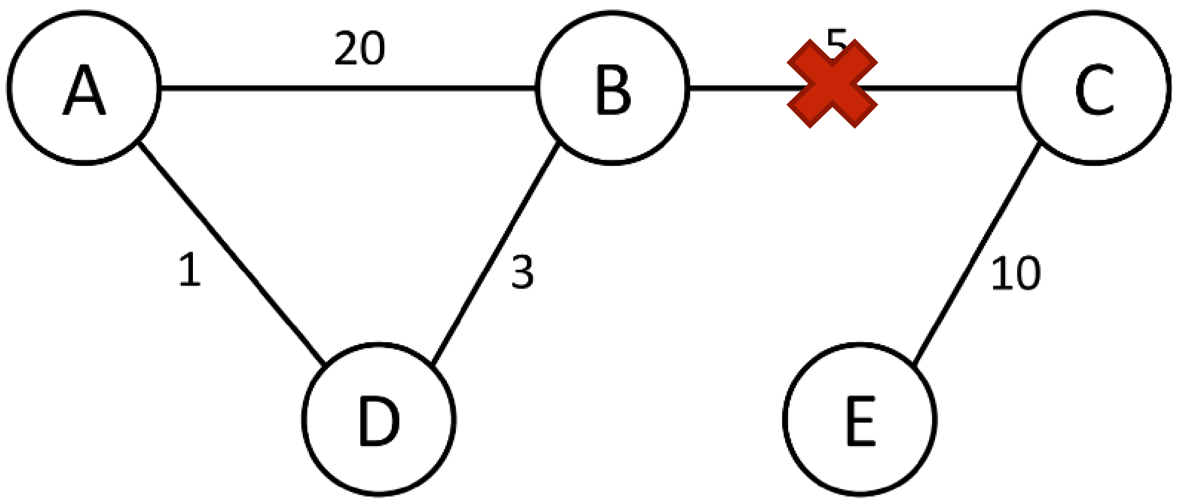
Dest.	Cost	Next Hop
A	4	D
C	**29**	**A**
D	3	D
E	**39**	**A**

D

Dest.	Cost	Next Hop
A	1	A
B	3	B
C	**32**	**B**
E	**42**	**B**

Problem Set 3 Question 4

e) Identify a scenario where poisoned reverse fails.



Because there is a loop, poisoned reverse is not enough to prevent counting to infinity.

A

Dest.	Cost	Next Hop
B	4	D
C	**33**	**D**
D	1	D
E	**43**	**D**

B

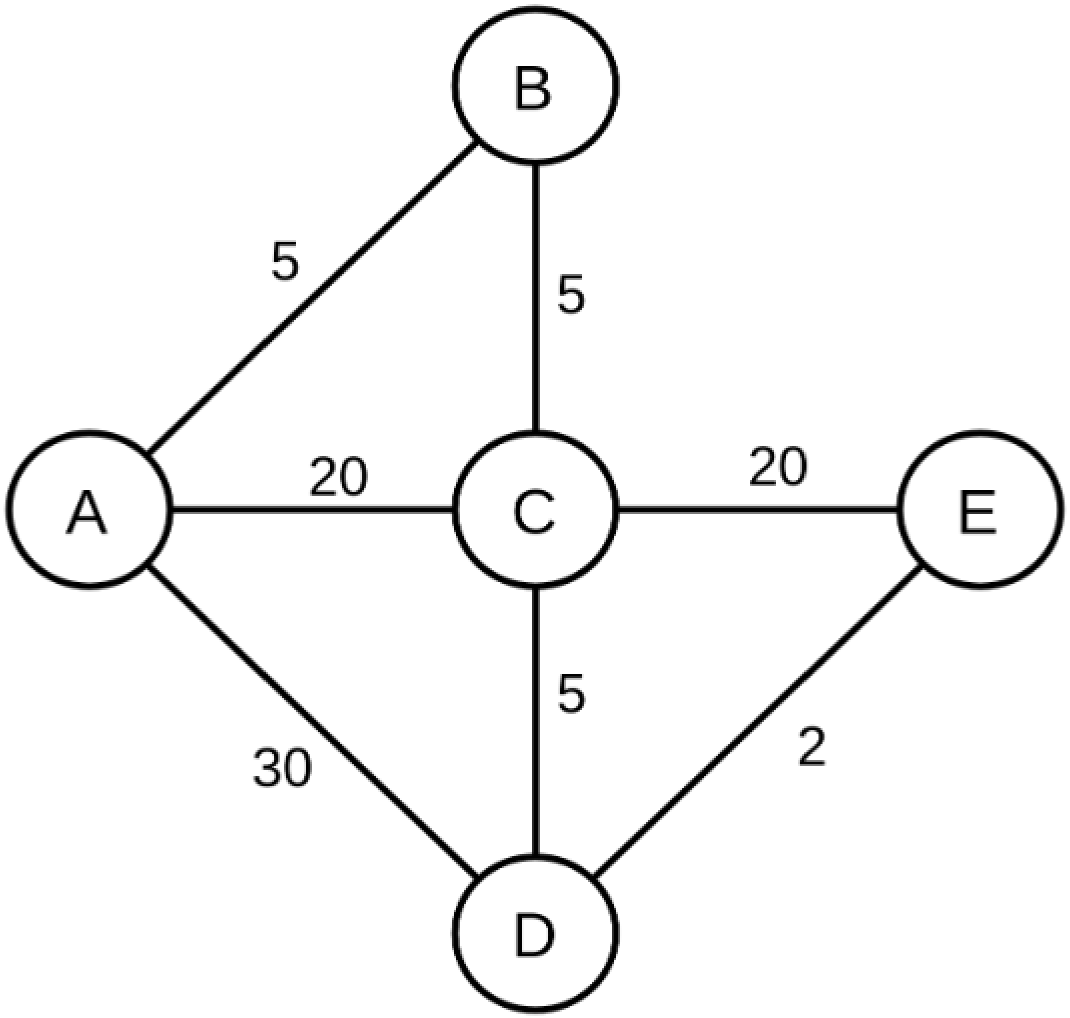
Dest.	Cost	Next Hop
A	4	D
C	**29**	**A**
D	3	D
E	**39**	**A**

D

Dest.	Cost	Next Hop
A	1	A
B	3	B
C	**32**	**B**
E	**42**	**B**

Problem Set 4 Question 1

a) If the cost of each link is its latency, each node knows its neighbors at t=0, and distance vectors are sent every 10 time units (starting at 0), what is node A's forwarding table at t=6?

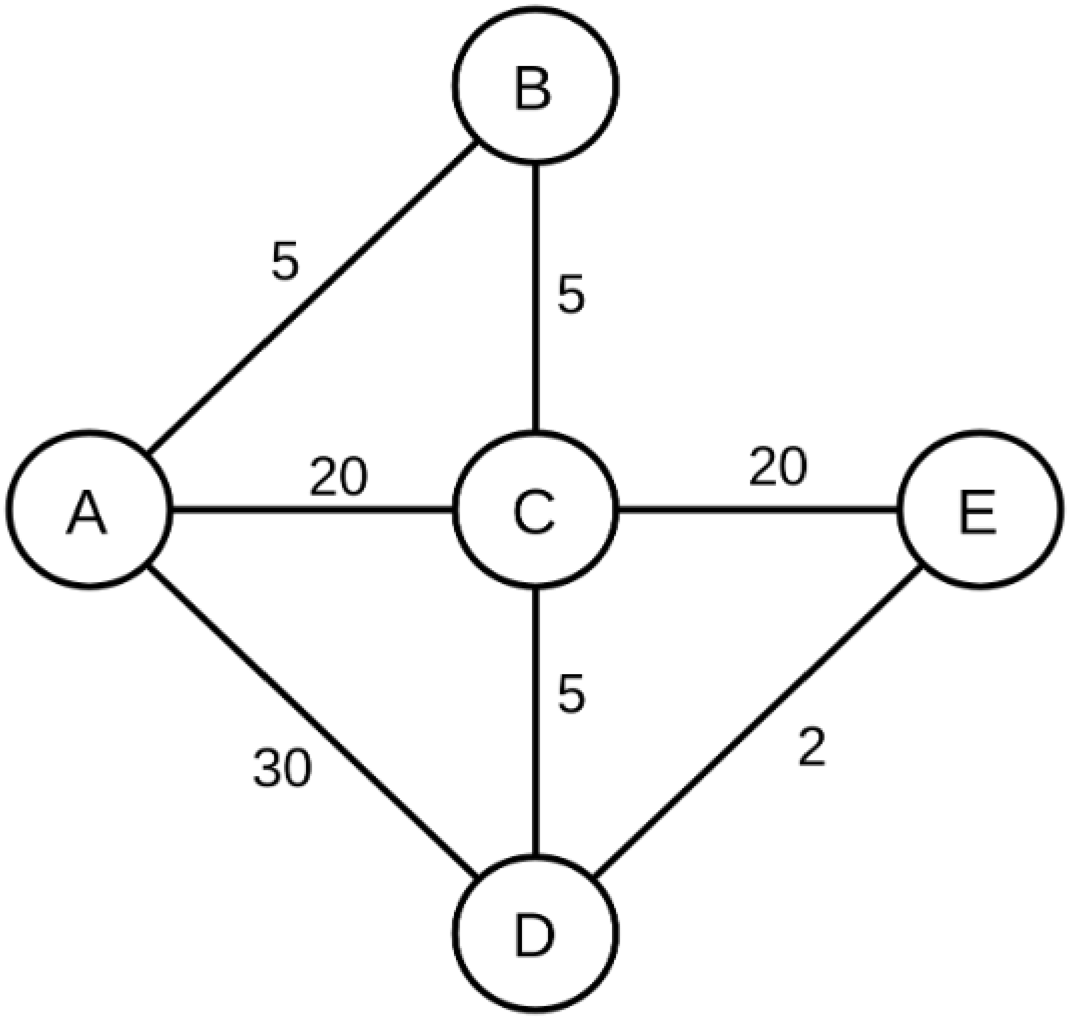


- By t=6, A knows about routes that pass through B.

Dest.	Cost	Next Hop
B	5	B
C	10	B
D	30	D
E	∞	-

Problem Set 4 Question 1

a) What is node A's forwarding table at t=16?

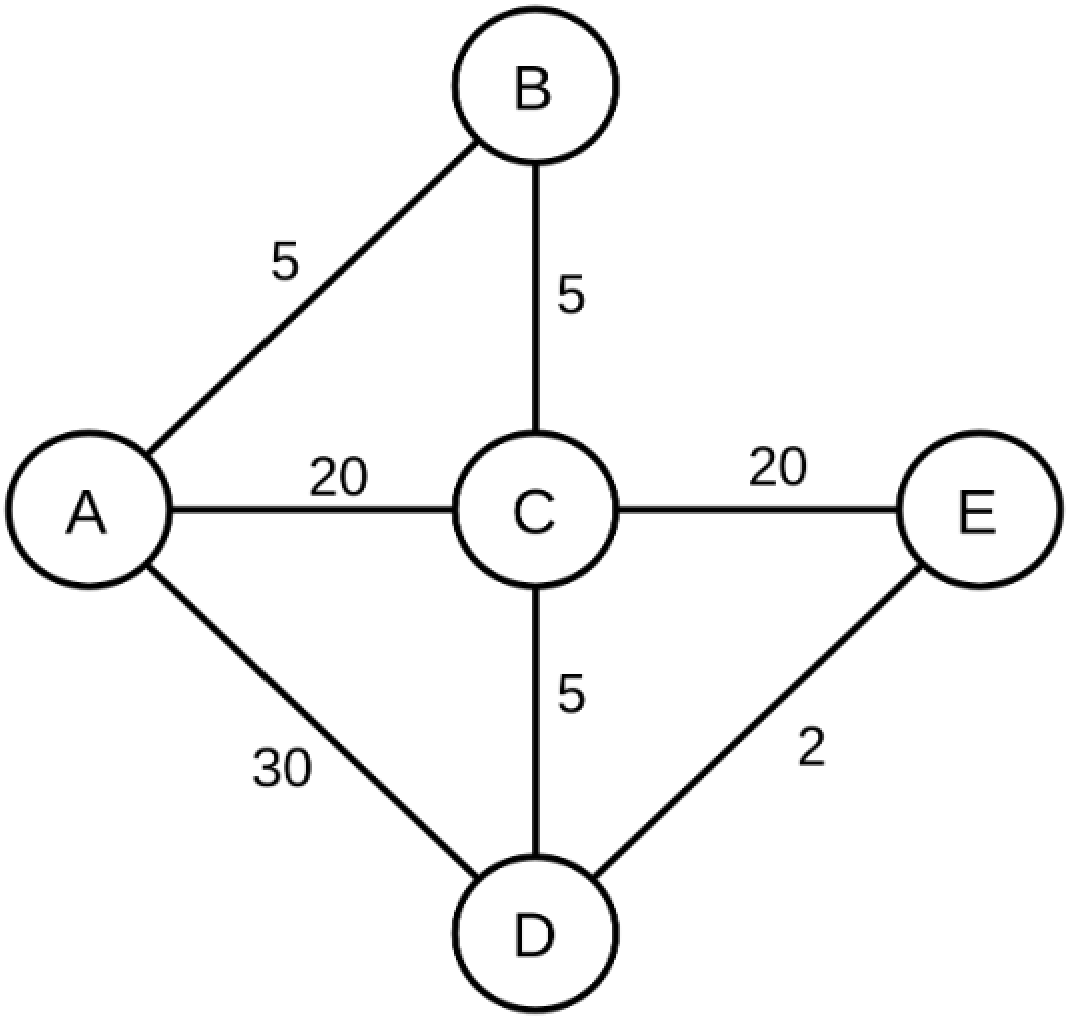


- At t=5, node B received C's table.
- At t=10, B sends its updated routing table to A.
- By t=16, A knows about routes that pass through B and C.

Dest.	Cost	Next Hop
B	5	B
C	10	B
D	15	B
E	30	B

Problem Set 4 Question 1

a) What is node A's forwarding table at t=26?



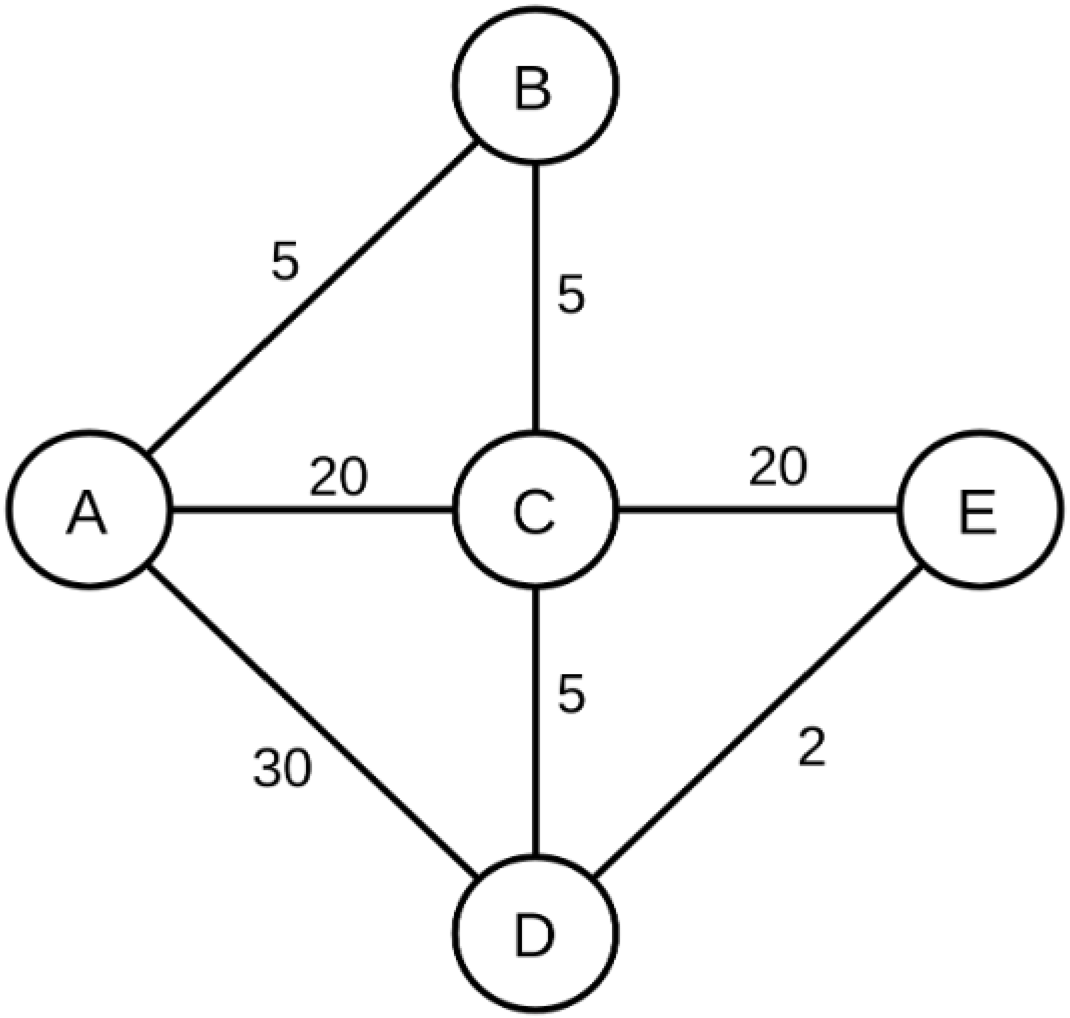
- By t=26, the faster path through D to reach E has had time to propagate to node A.

Dest.	Cost	Next Hop
B	5	B
C	10	B
D	15	B
E	17	B

Problem Set 4 Question 1

b) Node A receives a packet destined to node E at t=6s. What path does it take? What is its end-to-end latency?

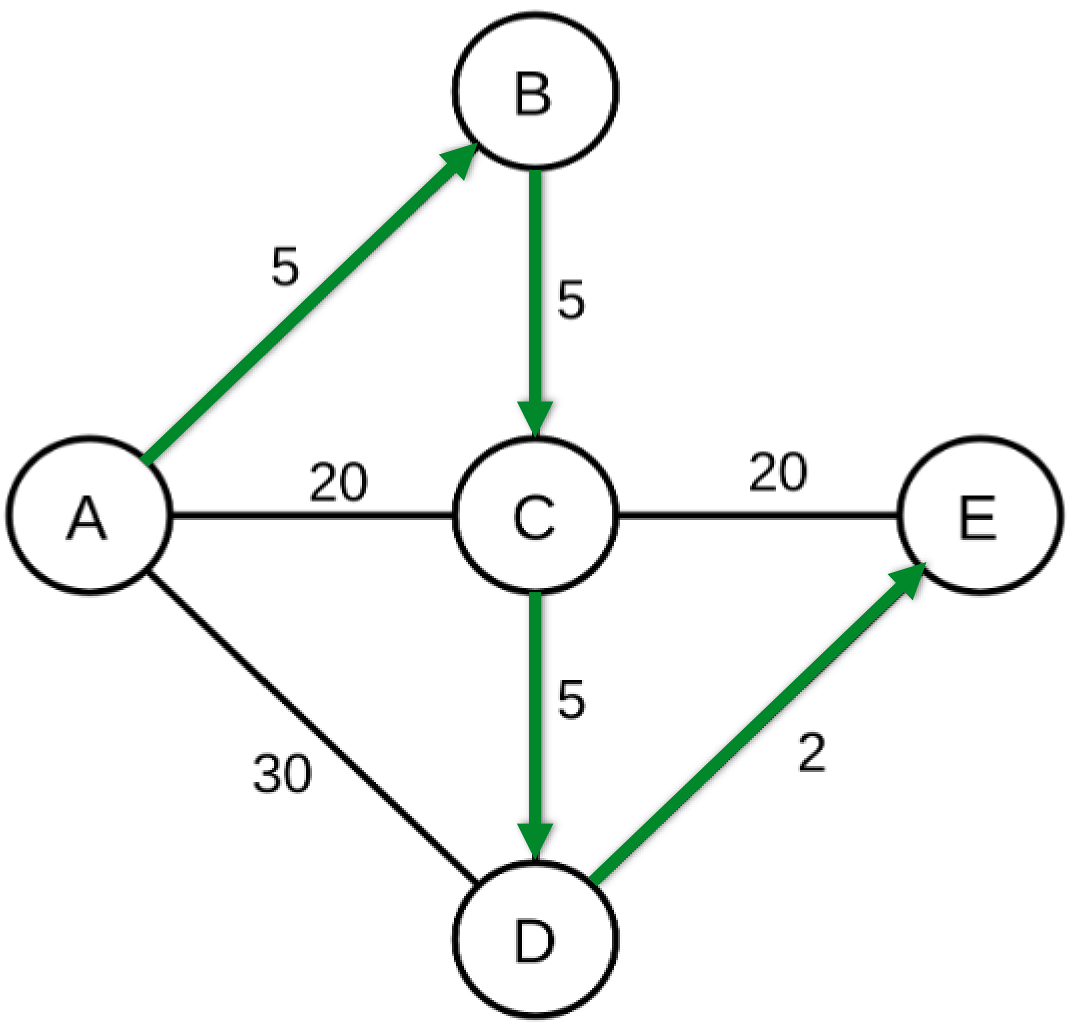
- At t=6, A has no route to E and drops the packet.



Dest.	Cost	Next Hop
B	5	B
C	10	B
D	30	D
E	∞	-

Problem Set 4 Question 1

b) Node A receives a packet destined to node E at t=16s. What path does it take? What is its end-to-end latency?

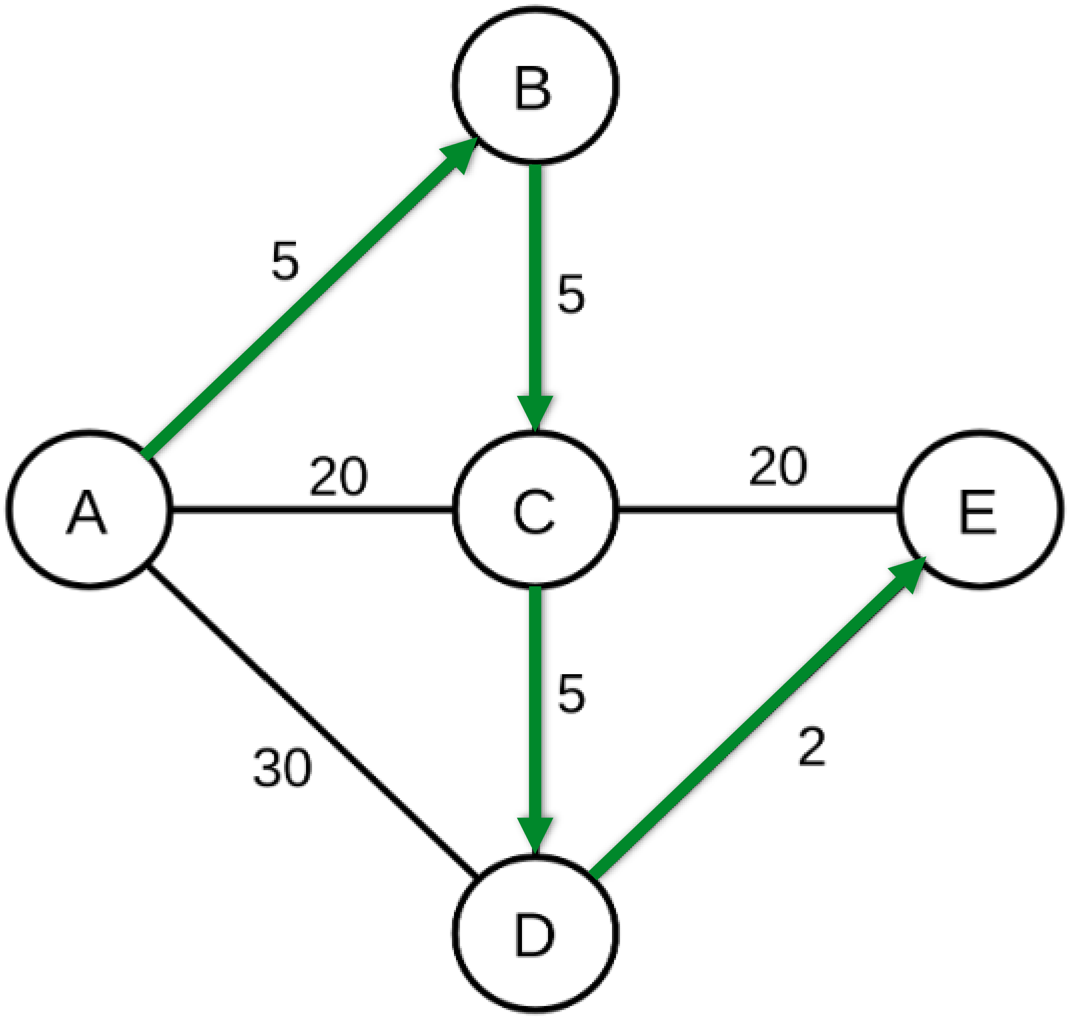


- At t=16, A sends the packet to node B expecting a cost of 30.
- Node C sends the packet via D, since it heard about this shorter route at t=5. The latency is 17.

Dest.	Cost	Next Hop
B	5	B
C	10	B
D	15	B
E	30	B

Problem Set 4 Question 1

b) Node A receives a packet destined to node E at t=26s. What path does it take? What is its end-to-end latency?



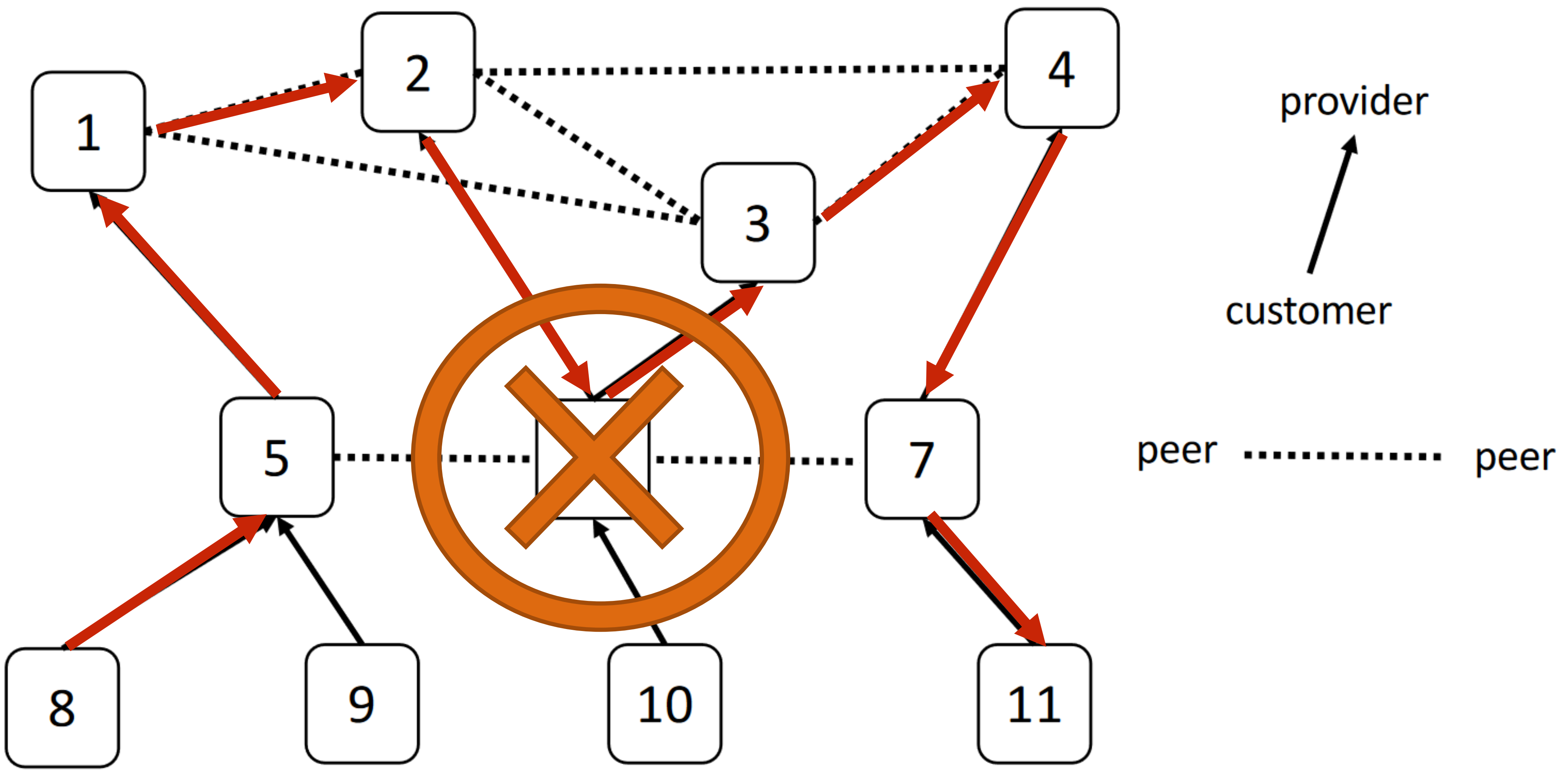
- At t=26, A sends the packet to node B expecting a cost of 17. This time the latency is indeed 17.

Dest.	Cost	Next Hop
B	5	B
C	10	B
D	15	B
E	17	B

Problem Set 4 Question 2

Valley-free paths:

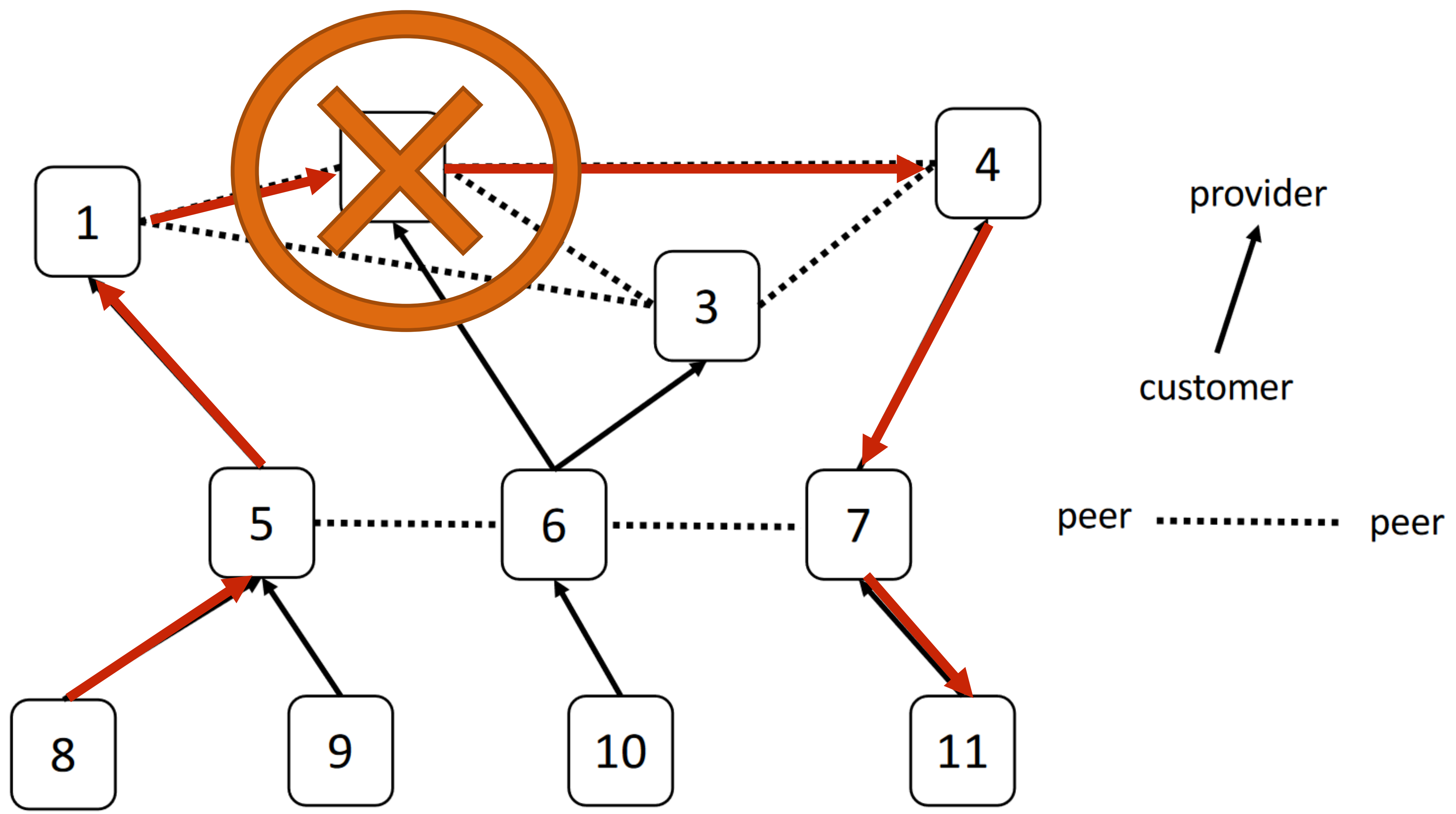
A path that uses zero or more provider links, followed by at most one peer link, followed by zero or more customer links.



Problem Set 4 Question 2

Valley-free paths:

A path that uses zero or more provider links, followed by at most one peer link, followed by zero or more customer links.



In a valley-free path, each intermediate AS will make money, since one of their customers will be part of the path.

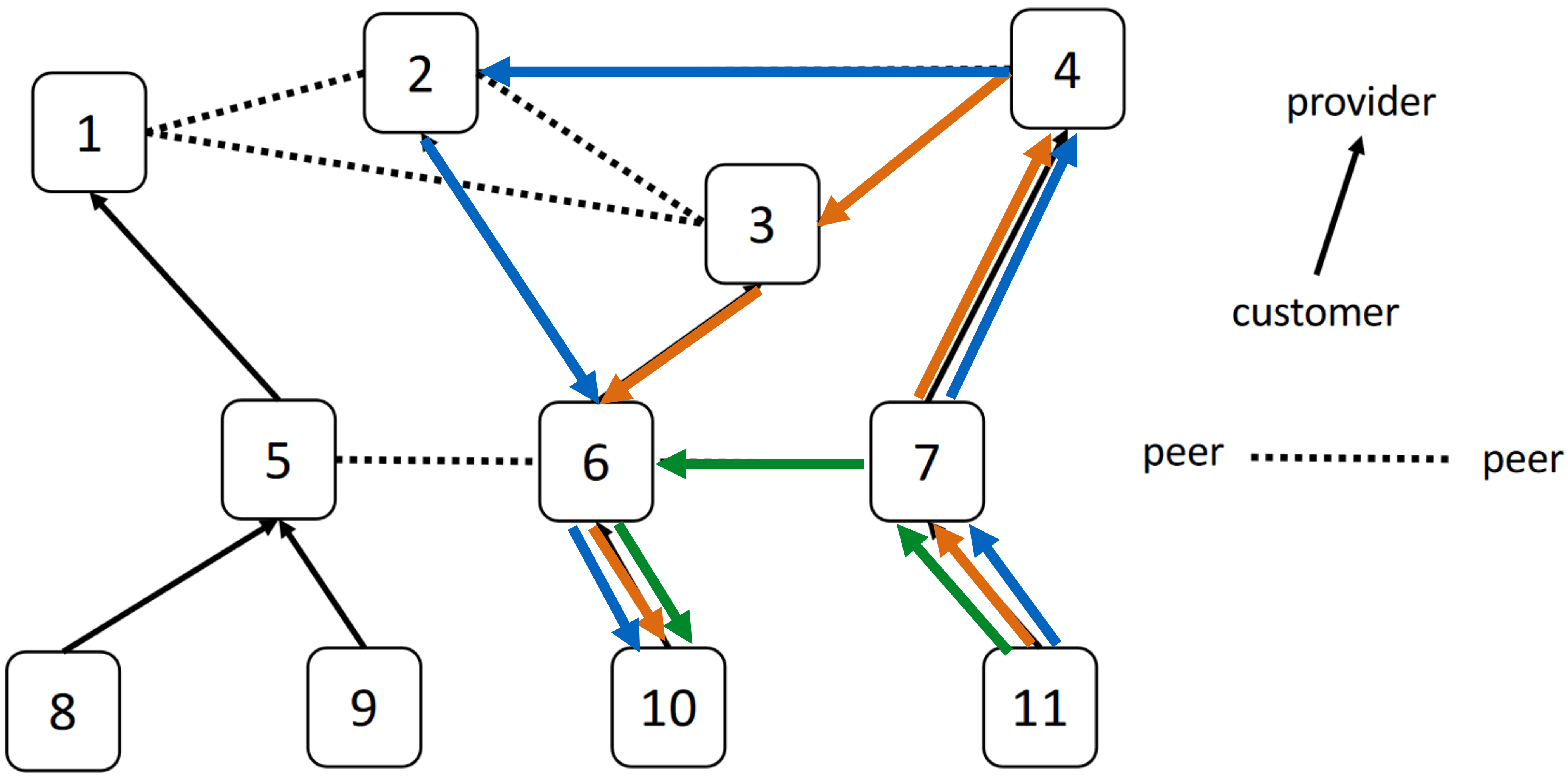
Problem Set 4 Question 2

a) **In order to enforce valley-free paths, fill in whether a route imported from a given neighbor type should be exported to another neighbor type.**

Route received from	Route sent to		
	Customer	Provider	Peer
Customer	Yes	Yes	Yes
Provider	Yes	No	No
Peer	Yes	No	No

Problem Set 4 Question 2

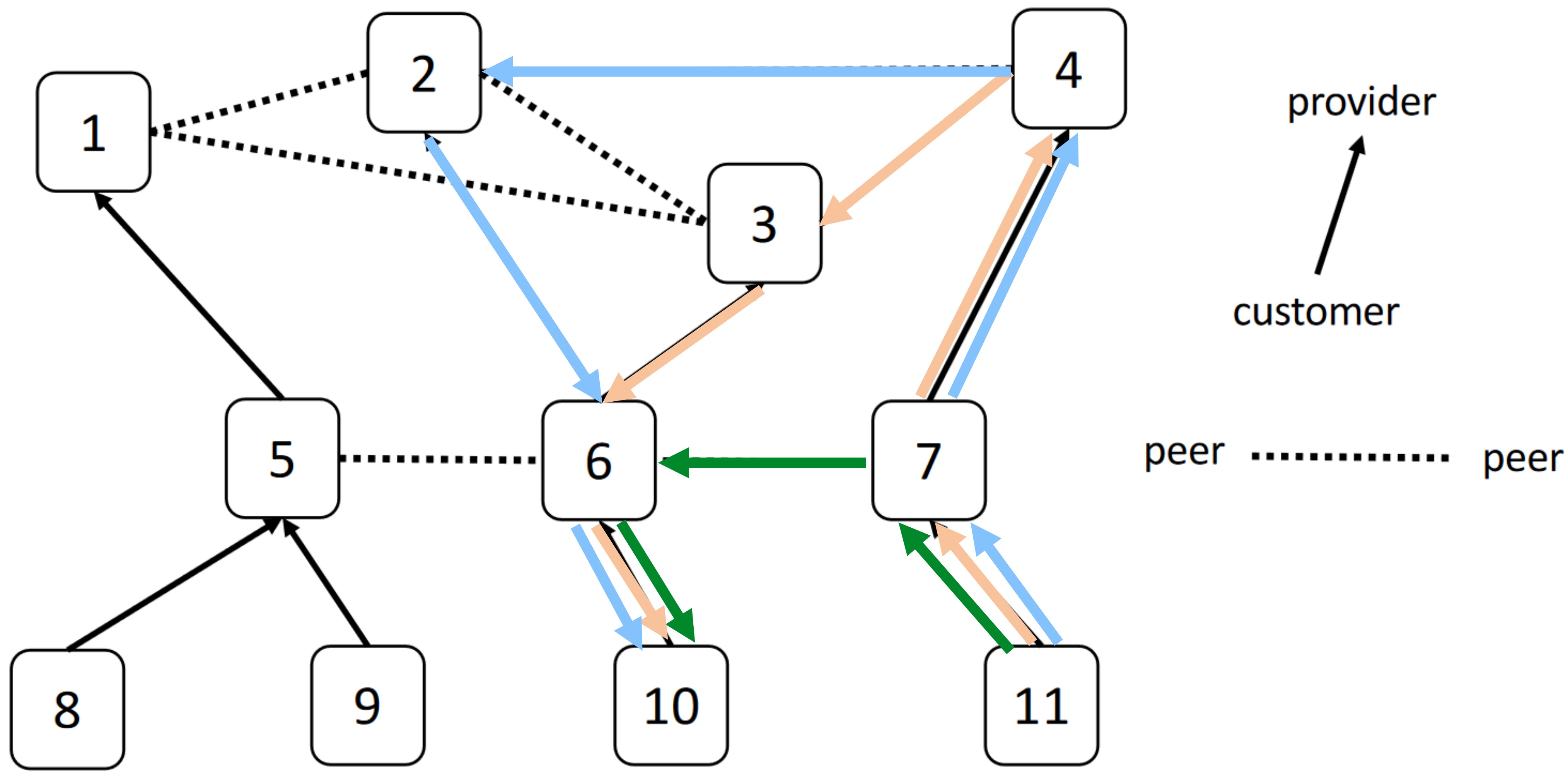
b) What possible valley-free paths exist from AS11 to AS10?



- AS11 → AS7 → AS6 → AS10
- AS11 → AS7 → AS4 → AS3 → AS6 → AS10
- AS11 → AS7 → AS4 → AS2 → AS6 → AS10

Problem Set 4 Question 2

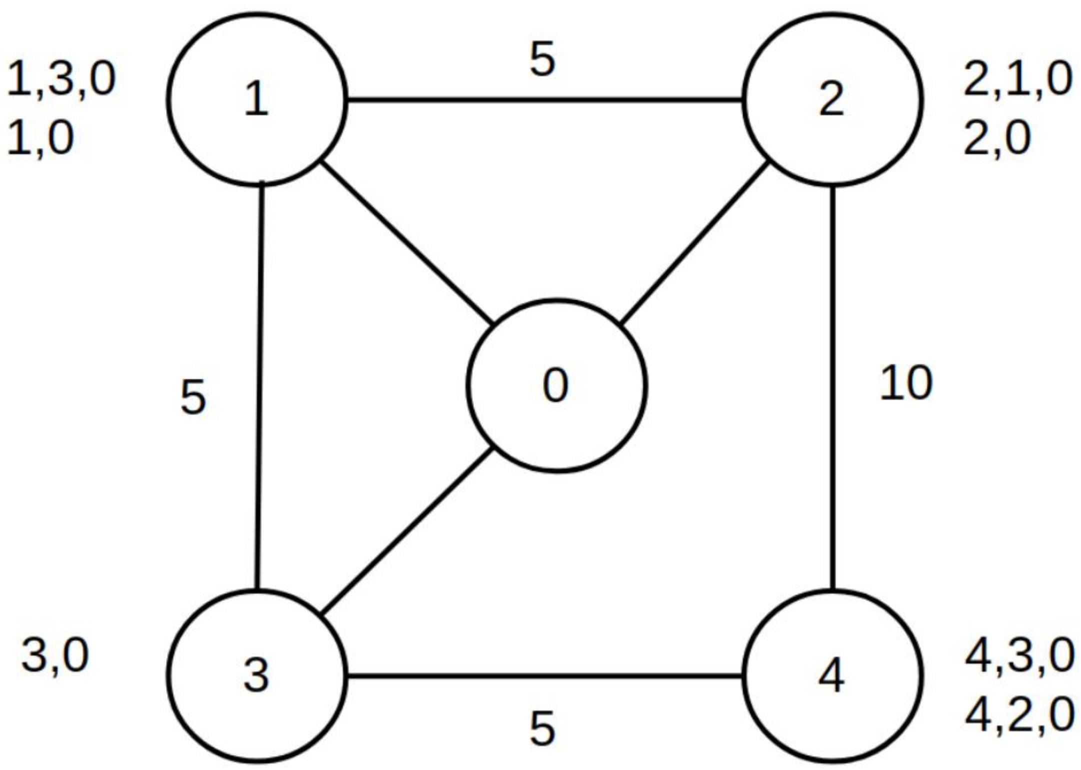
b) Which path will be used for sending traffic?



- <u>AS11 → AS7 → AS6 → AS10</u>
- AS11 → AS7 → AS4 → AS3 → AS6 → AS10
- AS11 → AS7 → AS4 → AS2 → AS6 → AS10

Problem Set 4 Question 3

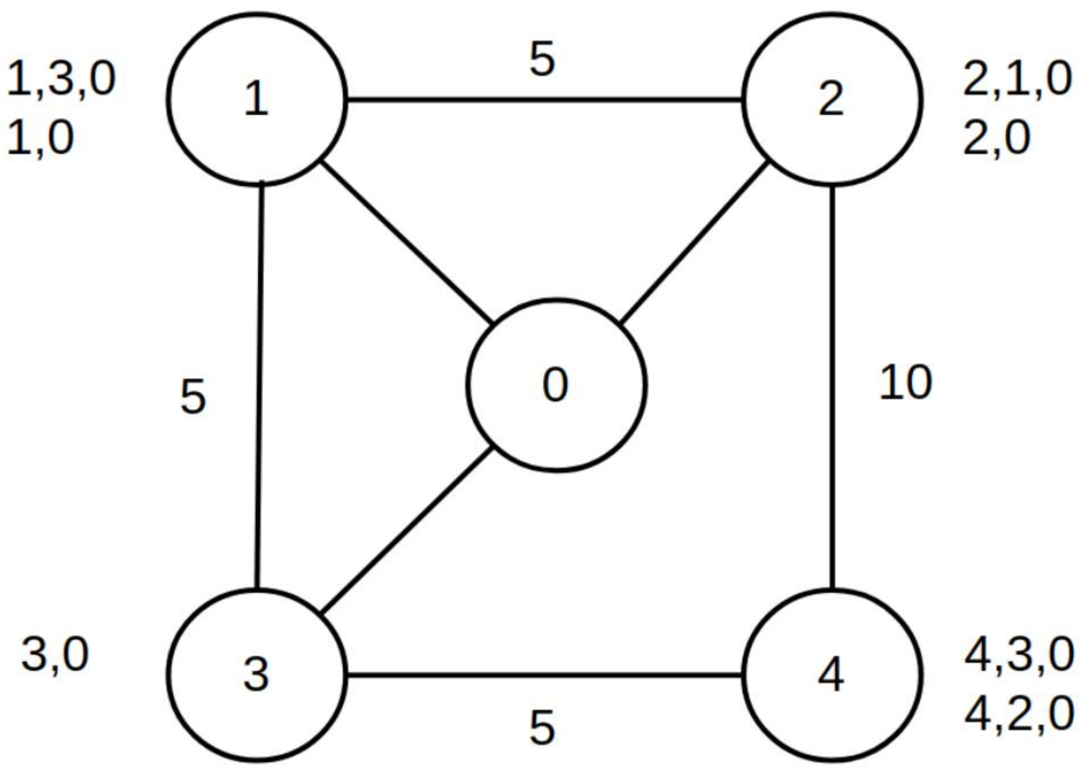
a) **Nodes prefer their top path. At t=0, any node with a direct path to 0 chooses that path and starts running BGP. What messages get sent?**



	Sent				Received			
t	1	2	3	4	1	2	3	4
0	1,0	2,0	3,0					
5					2,0 3,0	1,0	1,0	3,0
10								2,0
15								
20								

Problem Set 4 Question 3

a) **Nodes prefer their top path. At t=0, any node with a direct path to 0 chooses that path and starts running BGP. What messages get sent?**



	Sent				Received			
t	1	2	3	4	1	2	3	4
0	1,0	2,0	3,0					
5	1,3,0	2,1,0		4,3,0	2,0 3,0	1,0	1,0	3,0
10					2,1,0	1,3,0	1,3,0 4,3,0	2,0
15						4,3,0		2,1,0
20								

Problem Set 4 Question 3

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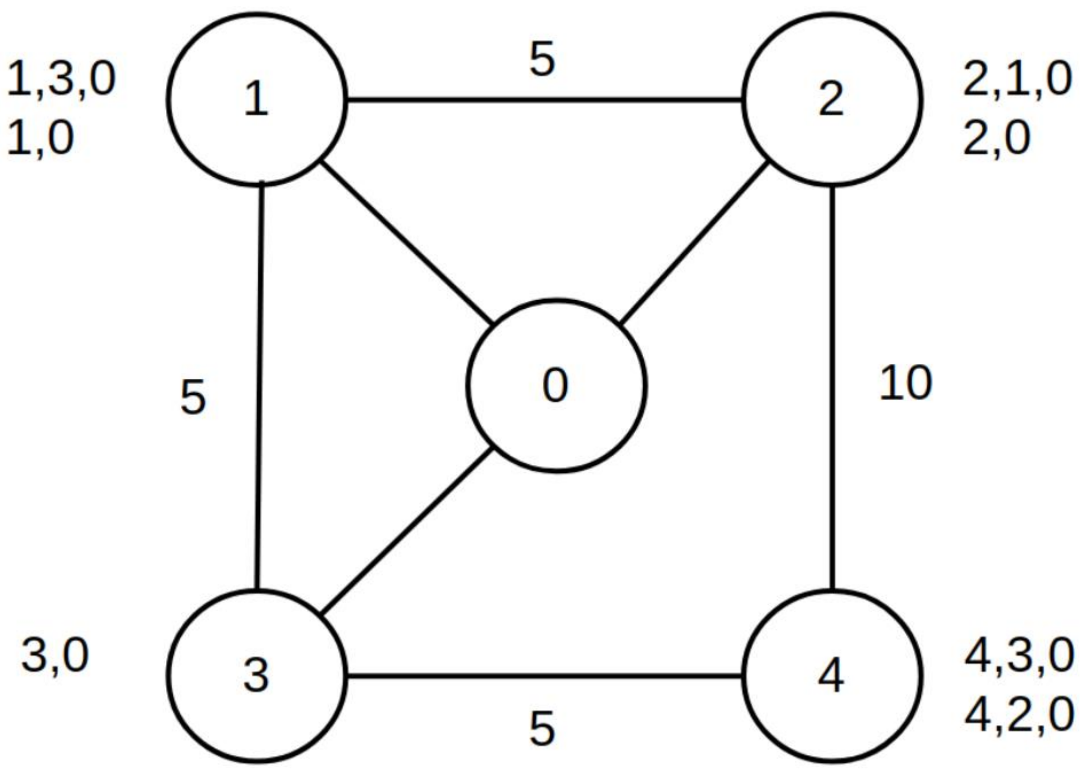
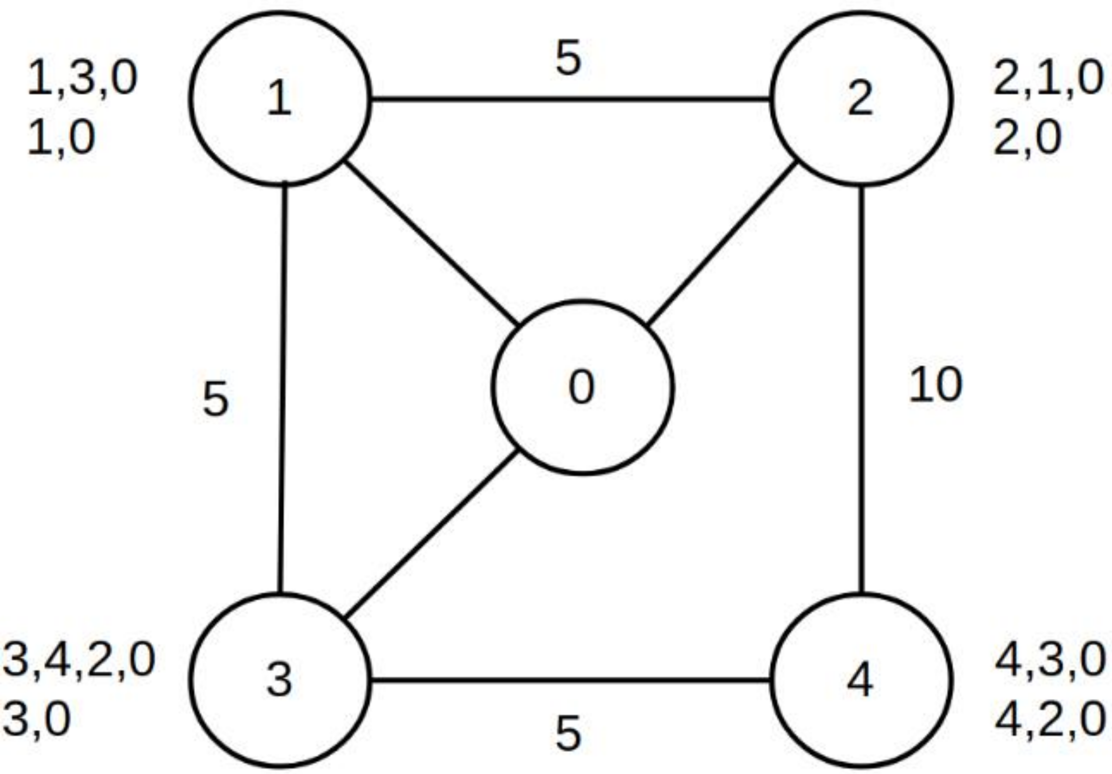


	Sent				Received			
t	1	2	3	4	1	2	3	4
0	1,0	2,0	3,0					
5	1,3,0	2,1,0		4,3,0	2,0 3,0	1,0	1,0	3,0
10		2,0			2,1,0	1,3,0	1,3,0 4,3,0	2,0
15					2,0	4,3,0		2,1,0
20								2,0

Problem Set 4 Question 3

b) Now we add another possible path from node 3 to node 0 to obtain the following network. What messages get sent?



	Sent				Received			
t	1	2	3	4	1	2	3	4
0	1,0	2,0	3,0					
5					2,0 3,0	1,0	1,0	3,0
10								2,0
15								
20								

Problem Set 4 Question 3

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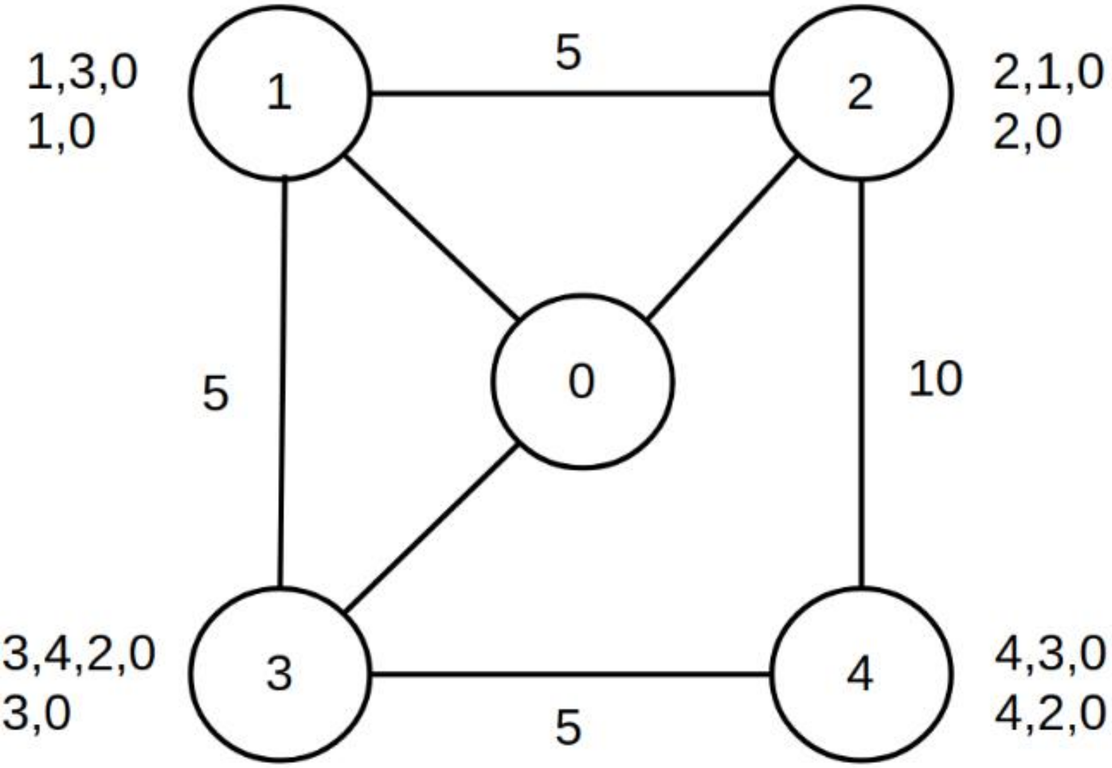

	Sent				Received			
t	1	2	3	4	1	2	3	4
0	1,0	2,0	3,0					
5	1,3,0	2,1,0		4,3,0	2,0 3,0	1,0	1,0	3,0
10					2,1,0	1,3,0	1,3,0 4,3,0	2,0
15						4,3,0		2,1,0
20								

Problem Set 4 Question 3

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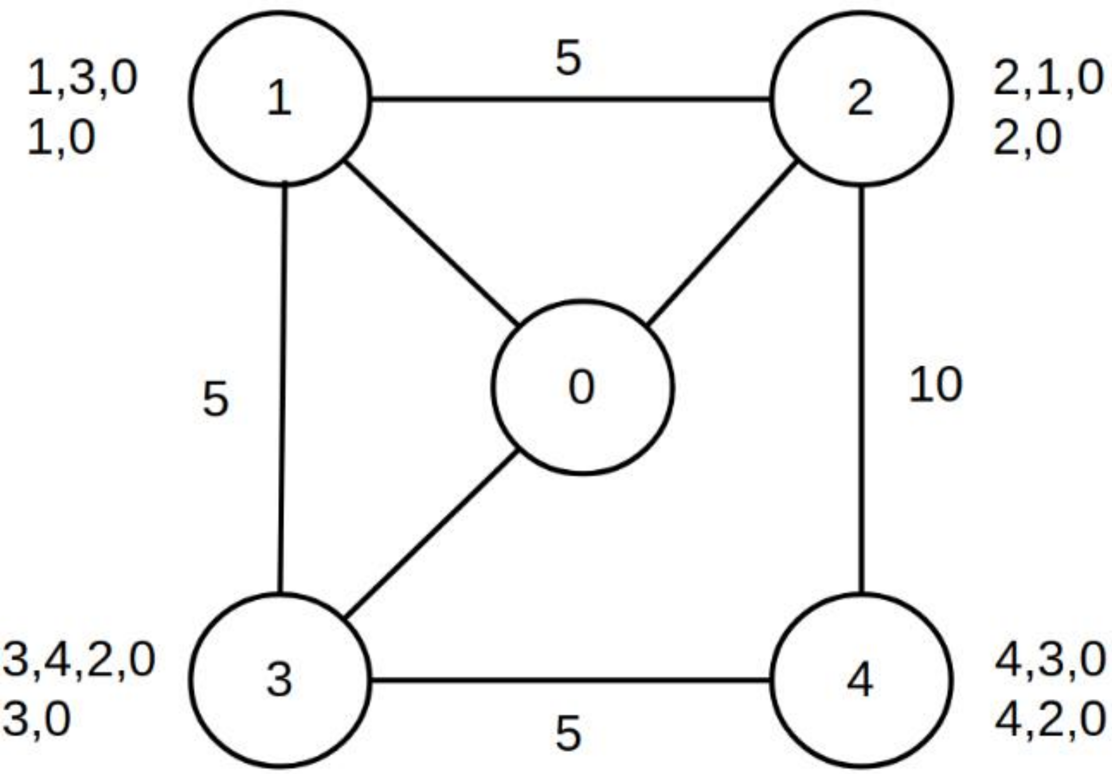
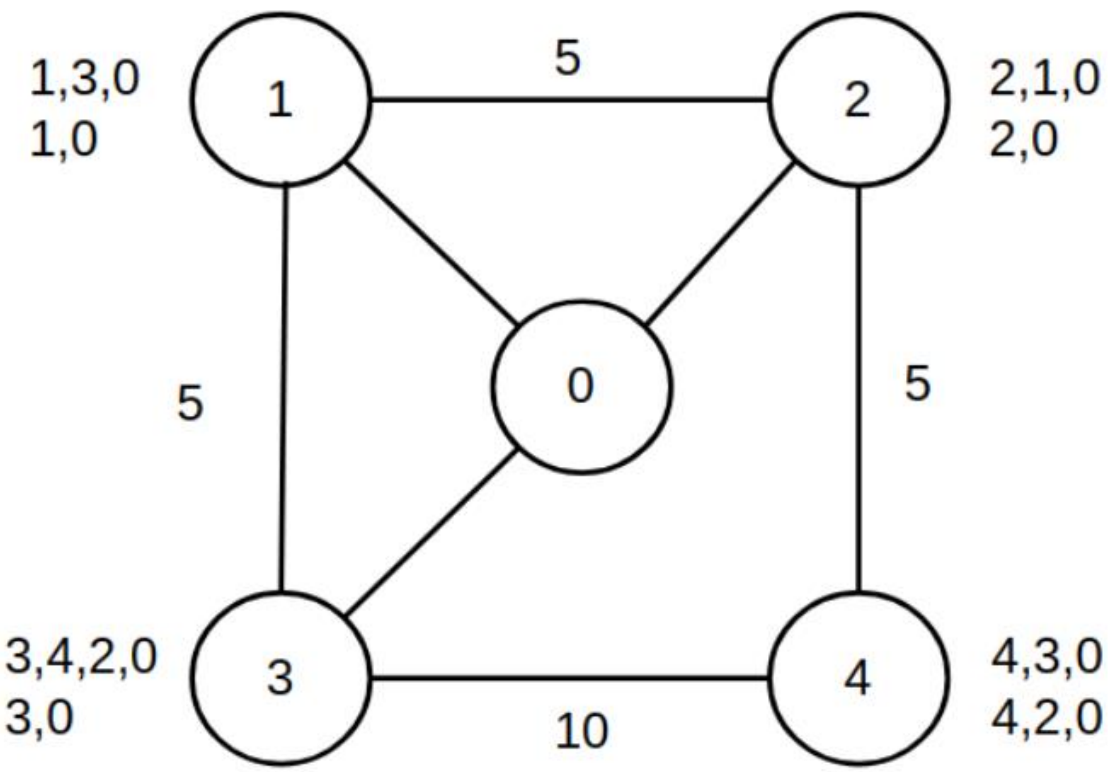


	Sent				Received			
t	1	2	3	4	1	2	3	4
0	1,0	2,0	3,0					
5	1,3,0	2,1,0		4,3,0	2,0 3,0	1,0	1,0	3,0
10		2,0			2,1,0	1,3,0	1,3,0 4,3,0	2,0
15					2,0	4,3,0		2,1,0
20								2,0

Problem Set 4 Question 3

c) **Now we update the latencies of some of the links. What messages get sent? Does the network converge?**



	Sent				Received			
t	1	2	3	4	1	2	3	4
0	1,0	2,0	3,0					
5					2,0 3,0	1,0	1,0	2,0
10								3,0
15								
20								
25								
30								
35								

Problem Set 4 Question 3

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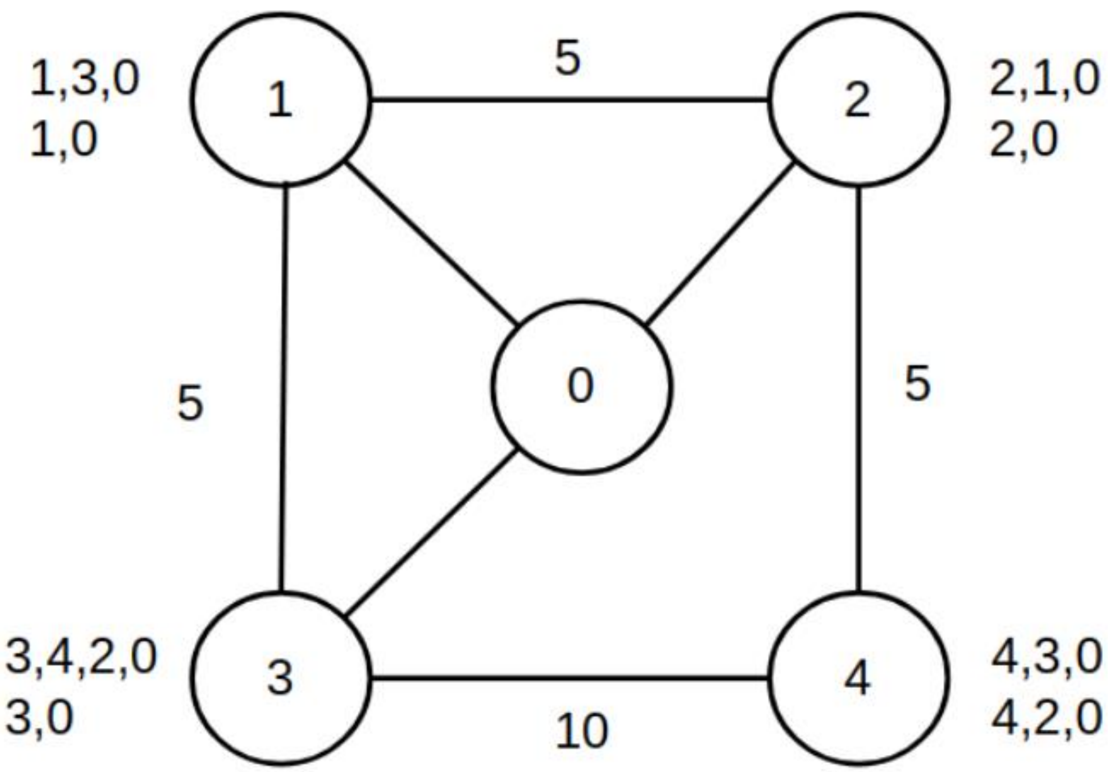
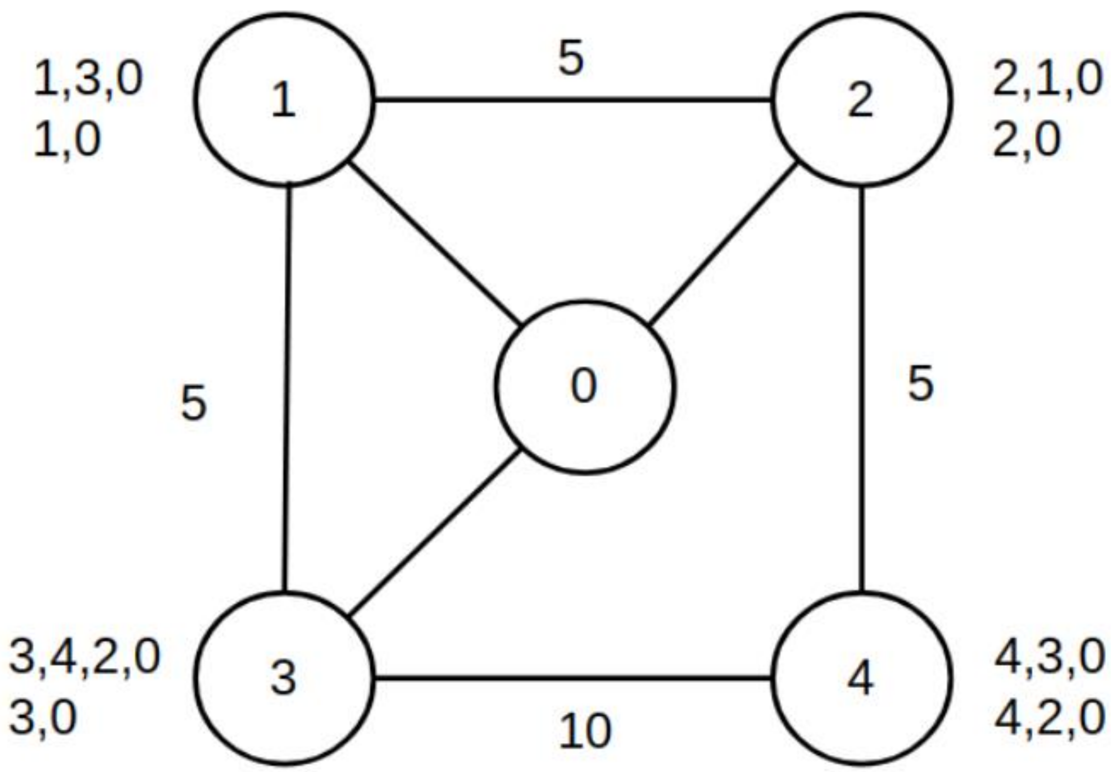


	Sent				Received			
t	1	2	3	4	1	2	3	4
0	1,0	2,0	3,0					
5	1,3,0	2,1,0		4,2,0	2,0 3,0	1,0	1,0	2,0
10					2,1,0	1,3,0 4,2,0	1,3,0	3,0 2,1,0
15							4,2,0	
20								
25								
30								
35								

Problem Set 4 Question 3

c) **Now we update the latencies of some of the links. What messages get sent? Does the network converge?**



	Sent				Received			
t	1	2	3	4	1	2	3	4
0	1,0	2,0	3,0					
5	1,3,0	2,1,0		4,2,0	2,0 3,0	1,0	1,0	2,0
10		2,0		4,3,0	2,1,0	1,3,0 4,2,0	1,3,0	3,0 2,1,0
15					2,0	4,3,0	4,2,0	2,0
20							4,3,0	
25								
30								
35								

Problem Set 4 Question 3

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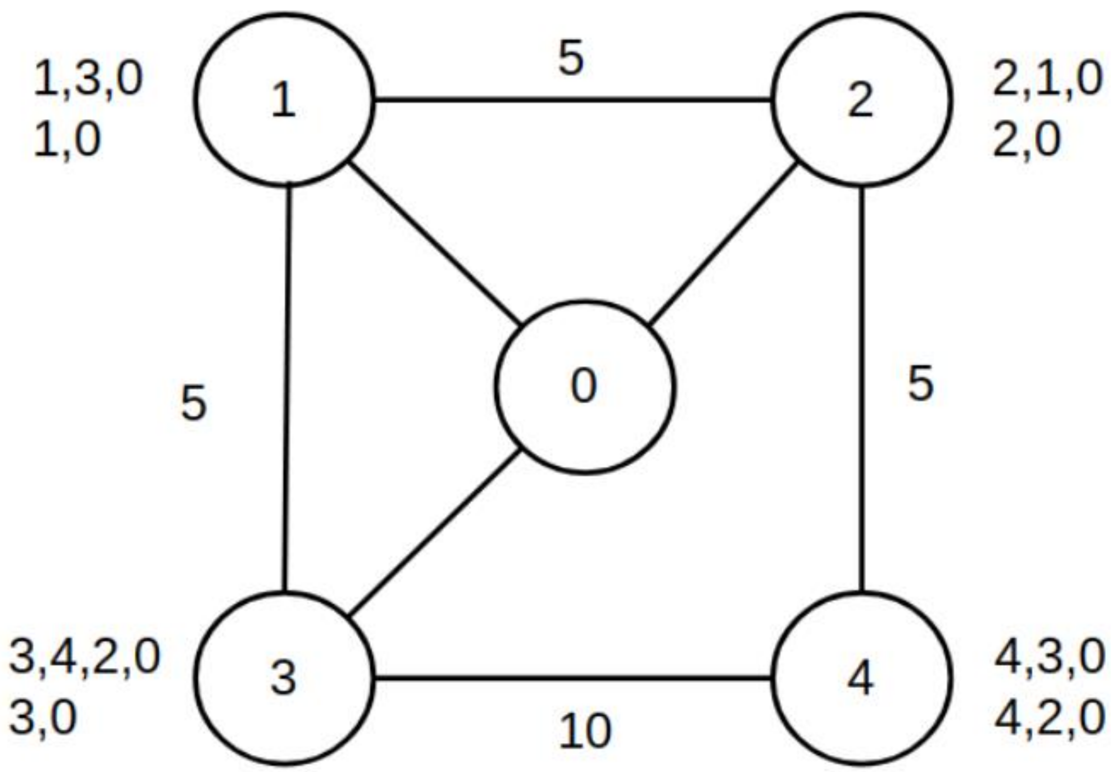

	Sent				Received			
t	1	2	3	4	1	2	3	4
0	1,0	2,0	3,0					
5	1,3,0	2,1,0		4,2,0	2,0 3,0	1,0	1,0	2,0
10		2,0		4,3,0	2,1,0	1,3,0 4,2,0	1,3,0	3,0 2,1,0
15			**3,4,2,0**		2,0	4,3,0	4,2,0	2,0
20					**3,4,2,0**		4,3,0	
25								**3,4,2,0**
30								
35								

Problem Set 4 Question 3

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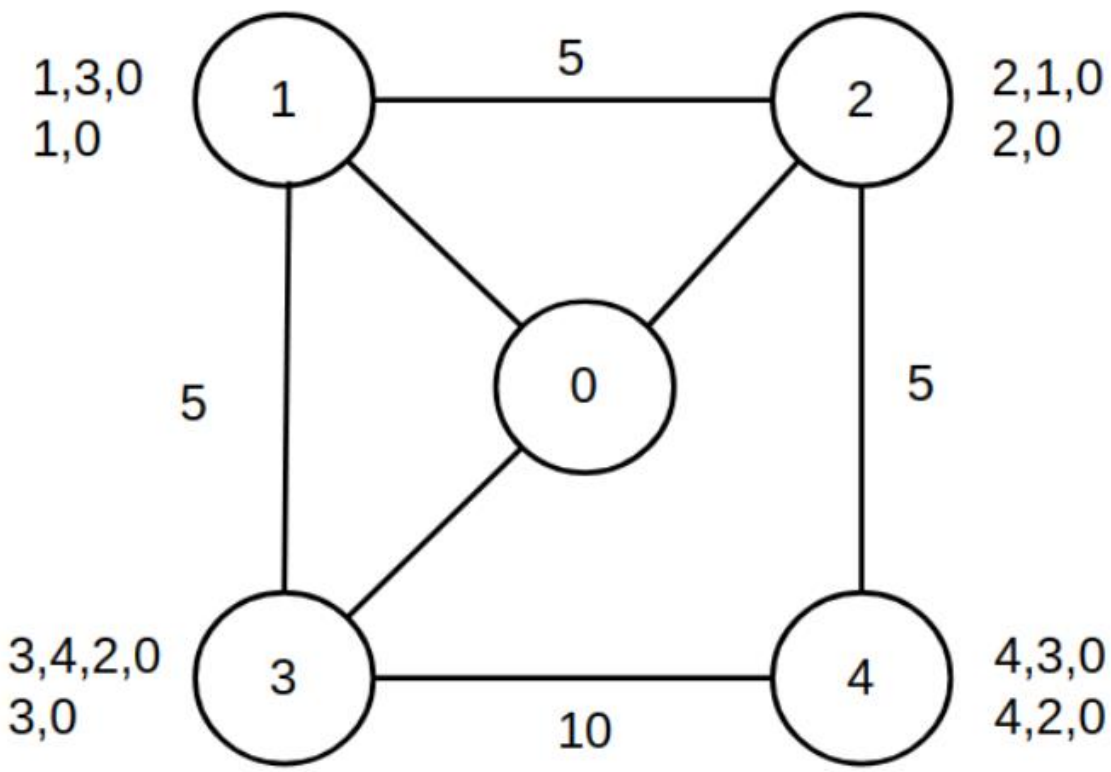
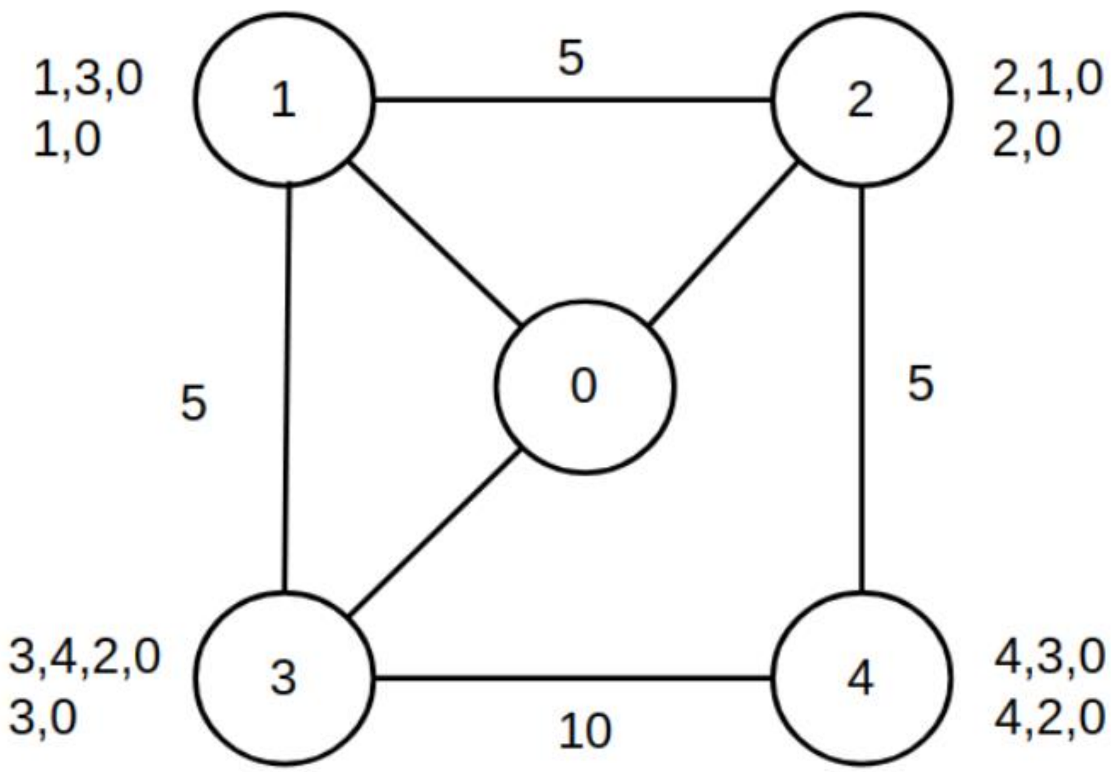


	Sent				Received			
t	1	2	3	4	1	2	3	4
0	1,0	2,0	3,0					
5	1,3,0	2,1,0		4,2,0	2,0 3,0	1,0	1,0	2,0
10		2,0		4,3,0	2,1,0	1,3,0 4,2,0	1,3,0	3,0 2,1,0
15			**3,4,2,0**		2,0	4,3,0	4,2,0	2,0
20	1,0		3,0		**3,4,2,0**		4,3,0	
25					3,0	1,0	1,0	**3,4,2,0**
30								3,0
35								

Problem Set 4 Question 3

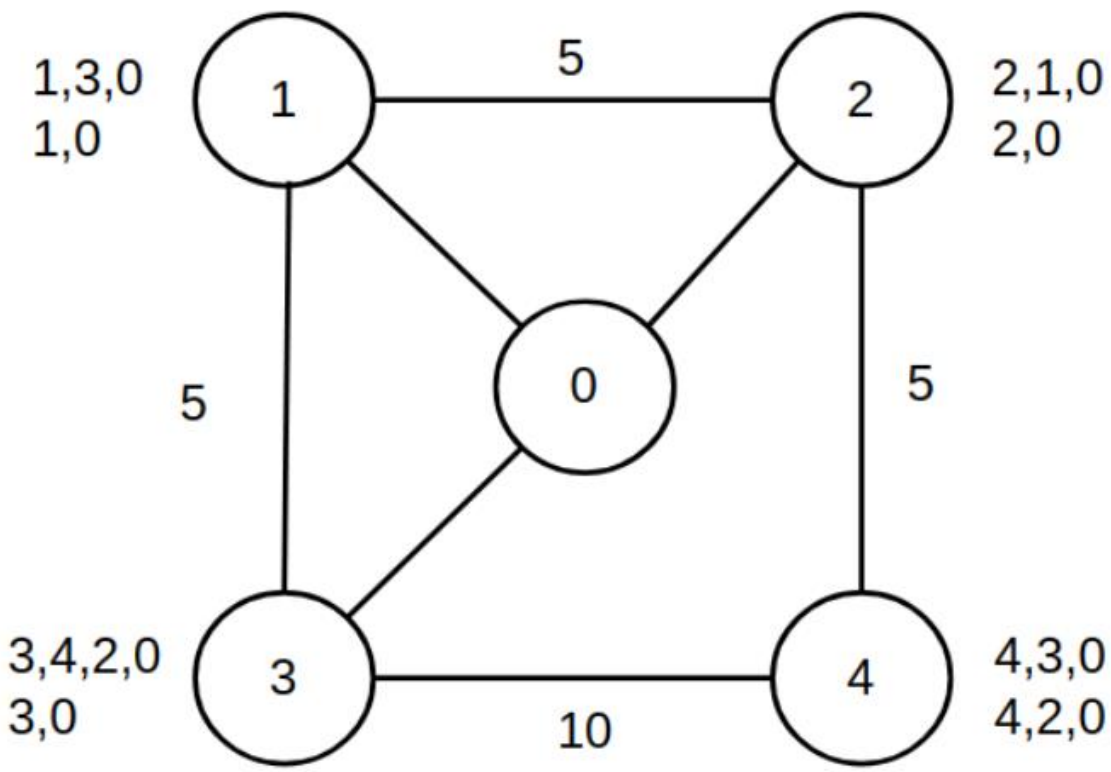
c) **Now we update the latencies of some of the links. What messages get sent? Does the network converge?**



	Sent				Received			
t	1	2	3	4	1	2	3	4
0	1,0	2,0	3,0					
5	1,3,0	2,1,0		4,2,0	2,0 3,0	1,0	1,0	2,0
10		2,0		4,3,0	2,1,0	1,3,0 4,2,0	1,3,0	3,0 2,1,0
15			**3,4,2,0**		2,0	4,3,0	4,2,0	2,0
20	1,0		3,0		**3,4,2,0**		4,3,0	
25	1,3,0	2,1,0		4,2,0	3,0	1,0	1,0	**3,4,2,0**
30					2,1,0	1,3,0 4,2,0	1,3,0	3,0 2,1,0
35							4,2,0	

Problem Set 4 Question 3

c) **Now we update the latencies of some of the links. What messages get sent? Does the network converge?**



	Sent				Received			
t	1	2	3	4	1	2	3	4
0	1,0	2,0	3,0					
5	1,3,0	2,1,0		4,2,0	2,0 3,0	1,0	1,0	2,0
10		2,0		4,3,0	2,1,0	1,3,0 4,2,0	1,3,0	3,0 2,1,0
15			3,4,2,0		2,0	4,3,0	4,2,0	2,0
20	1,0		3,0		3,4,2,0		4,3,0	
25	1,3,0	2,1,0		4,2,0	3,0	1,0	1,0	3,4,2,0
30		2,0		4,3,0	2,1,0	1,3,0 4,2,0	1,3,0	3,0 2,1,0
35					2,0	4,3,0	4,2,0	2,0

Problem Set 4 Question 4

a) What is the 32-bit binary equivalent of 223.1.3.27?

11011111 00000001 00000011 00011011

Problem Set 4 Question 4

a) **Consider a datagram network with 8-bit host addresses. A router using longest prefix matching has the following forwarding table. For each interface, give the range of host addresses, and the number of addresses in the range.**

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

Interface 0:

00000000 – 00111111 (64 addresses)

Interface 1:

01000000 – 01011111 (32 addresses)

Interface 2:

01100000 – 01111111

10000000 – 10111111 (96 addresses)

Interface 3:

11000000 – 11111111 (64 addresses)