

COMP90007 Internet Technology

Week8

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Question 1

- A router has just received the following IP addresses:

57.6.96.0/21

57.6.104.0/21

57.6.112.0/21

57.6.120.0/21

- If all of them use the same outgoing line, can they be aggregated? If so, to what? If not, why not?

CIDR

- Before we talk about 'aggregate', how about we introduce CIDR first.
- Problem: table explosion
- CIDR: Classless Inter-Domain Routing

University	First address	Last address	How many	Prefix
Cambridge	194.24.0.0	194.24.7.255	2048	194.24.0.0/21
Edinburgh	194.24.8.0	194.24.11.255	1024	194.24.8.0/22
(Available)	194.24.12.0	194.24.15.255	1024	194.24.12.0/22
Oxford	194.24.16.0	194.24.31.255	4096	194.24.16.0/20

Figure 5-50. A set of IP address assignments.

Aggregation

- Allocation
Supernet -> subnet
- Aggregation
Subnet -> Supernet

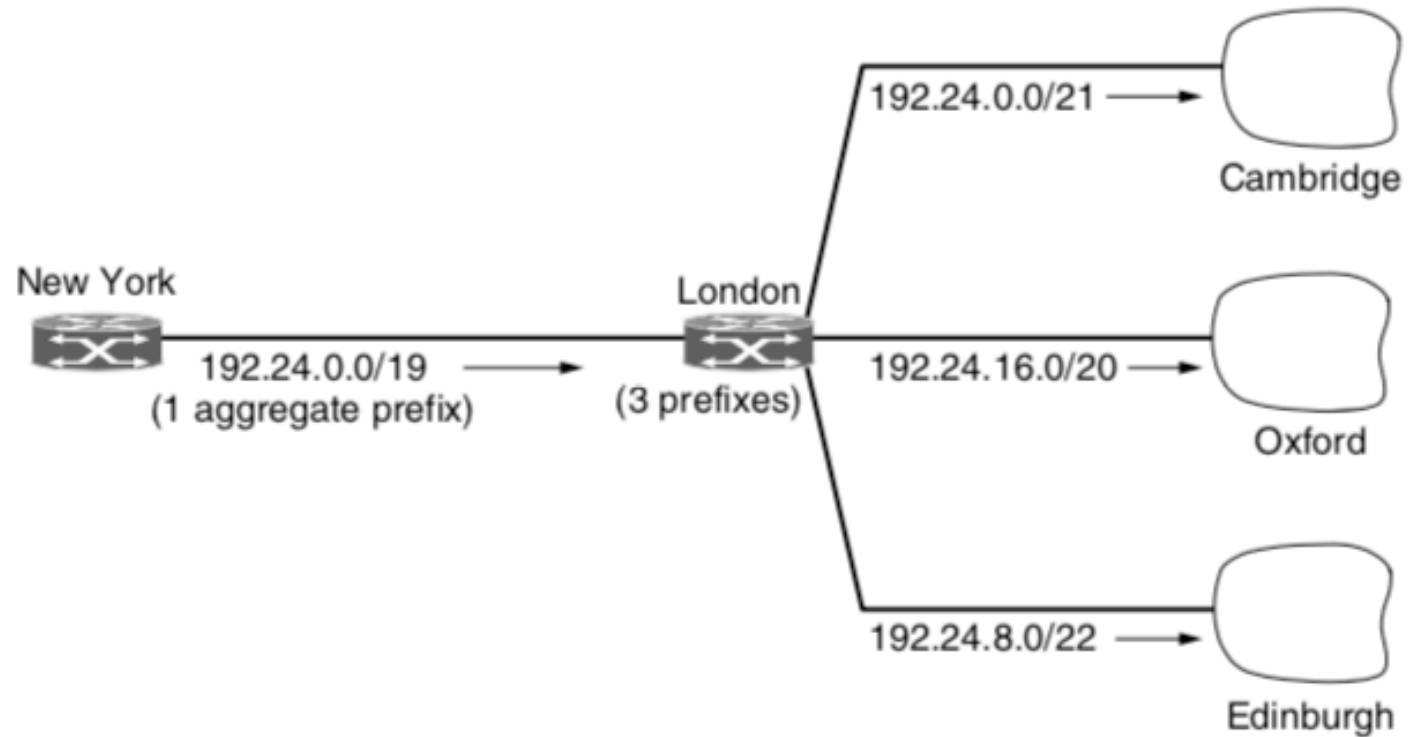


Figure 5-51. Aggregation of IP prefixes.

Aggregation

- The routing process in London combines the three prefixes into a single aggregate entry for the prefix.
- Reduce the prefixes in New York router and the routing table entries in the New York router.

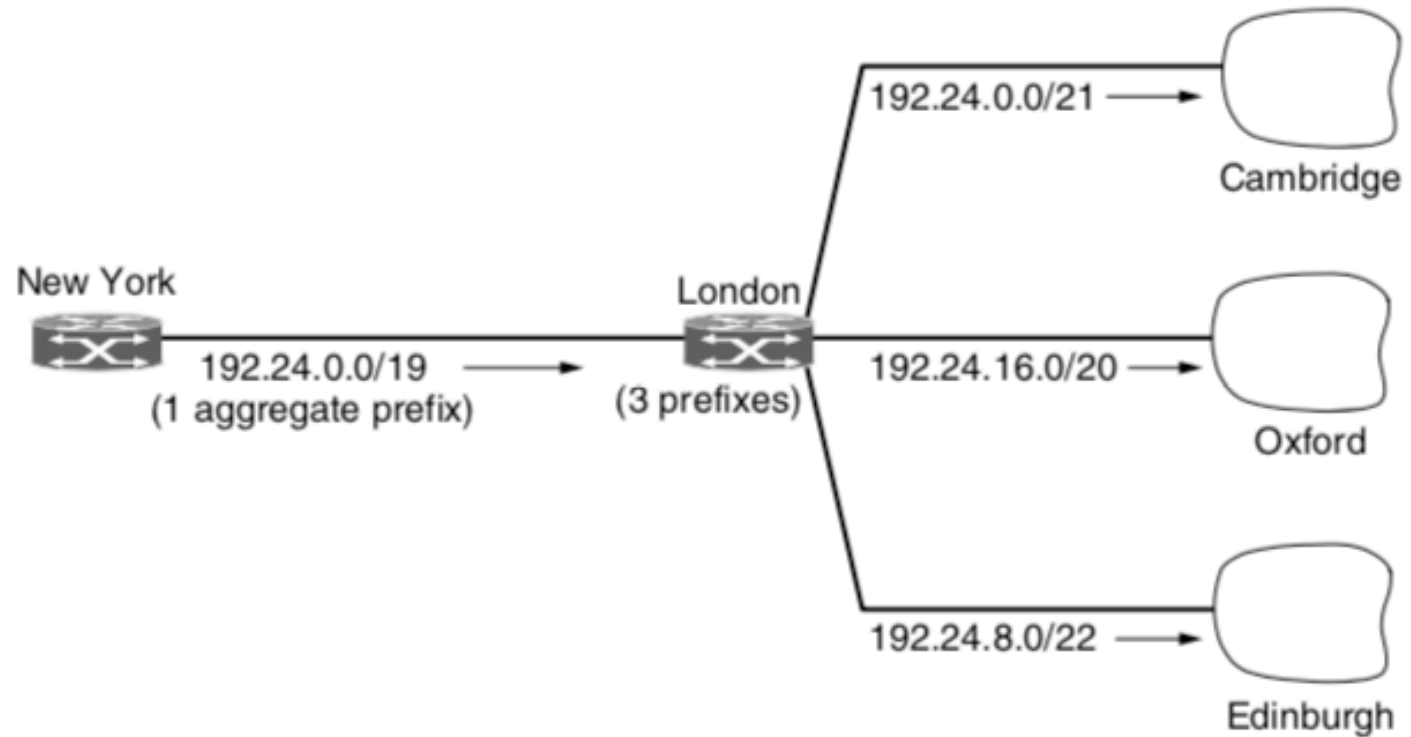


Figure 5-51. Aggregation of IP prefixes.

Question 1

- A router has just received the following IP addresses:

57.6.96.0/21

57.6.104.0/21

57.6.112.0/21

57.6.120.0/21

- If all of them use the same outgoing line, can they be aggregated? If so, to what? If not, why not?

Solution 1

- 57 6 96 0 / 21
• 00111001 00000110 01100000 00000000
- 57 6 104 0 / 21
• 00111001 00000110 01101000 00000000
- 57 6 112 0 / 21
• 00111001 00000110 01110000 00000000
- 57 6 120 0 / 21
• 00111001 00000110 01111000 00000000

Solution 1

Prefix

- 57 6 96 0 / 21
- 00111001 00000110 01100000 00000000
- 57 6 104 0 / 21
- 00111001 00000110 01101000 00000000
- 57 6 112 0 / 21
- 00111001 00000110 01110000 00000000
- 57 6 120 0 / 21
- 00111001 00000110 01111000 00000000

Solution 1

Network portion

- 57 6 96 0 / 21
- 00111001 00000110 01100 | 000 00000000
- 57 6 104 0 / 21
- 00111001 00000110 01101 | 000 00000000
- 57 6 112 0 / 21
- 00111001 00000110 01110 | 000 00000000
- 57 6 120 0 / 21
- 00111001 00000110 01111 | 000 00000000

Solution 1

- 0011100100000110011 | 00000000000000
- 0011100100000110011 | 01000000000000
- 0011100100000110011 | 10000000000000
- 0011100100000110011 | 11000000000000



19

- 00111001 00000110 01100000 00000000 -> 57.6.96.0/19

They can be aggregated to 57.6.96.0/19

Question 2

- A router has the following entries in its routing table:

Address/mask	Next hop
151.46.184.0/22	Interface 0
151.46.188.0/22	Interface 1
151.53.40.0/23	Router 1
default	Router 2

- For each of the following IP addresses, what does the router do If a packet with that address arrives?
- (a) 151.46.191.10
- (b) 151.46.187.2

Longest matching prefix

University	First address	Last address	How many	Prefix
Cambridge	194.24.0.0	194.24.7.255	2048	194.24.0.0/21
Edinburgh	194.24.8.0	194.24.11.255	1024	194.24.8.0/22
San Francisco	194.24.12.0	194.24.15.255	1024	194.24.12.0/22
Oxford	194.24.16.0	194.24.31.255	4096	194.24.16.0/20

Figure 5-50. A set of IP address assignments.

Longest matching prefix

- Hold 4 specific prefixes in routing (Non-aggregation)
- =====> Hold only 2 entries (After aggregation)

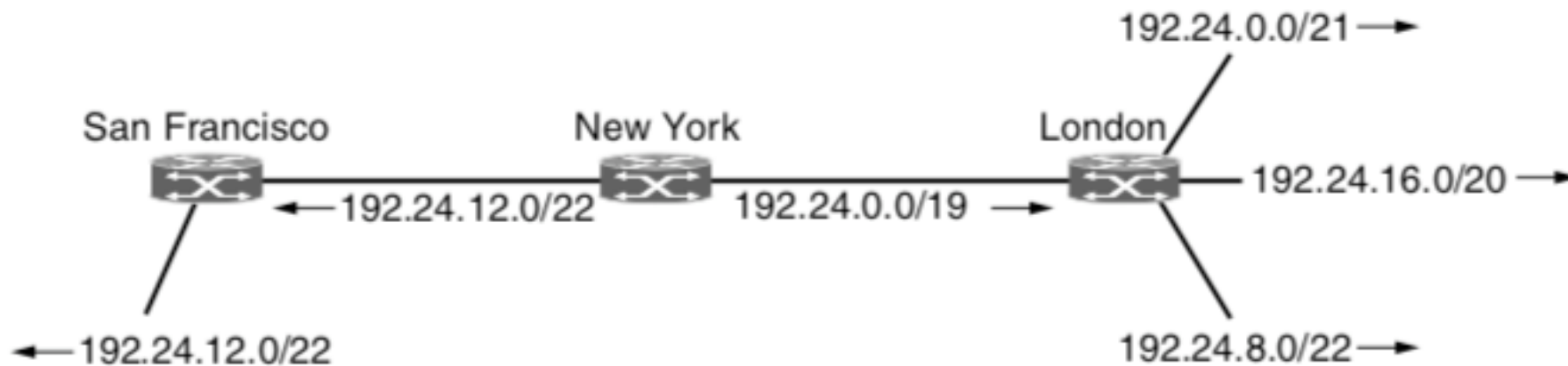


Figure 5-52. Longest matching prefix routing at the New York router.

Longest matching prefix

- One overall prefix is used to direct traffic for the entire block to London. One more specific prefix is also used to direct a portion of the larger prefix to San Francisco.

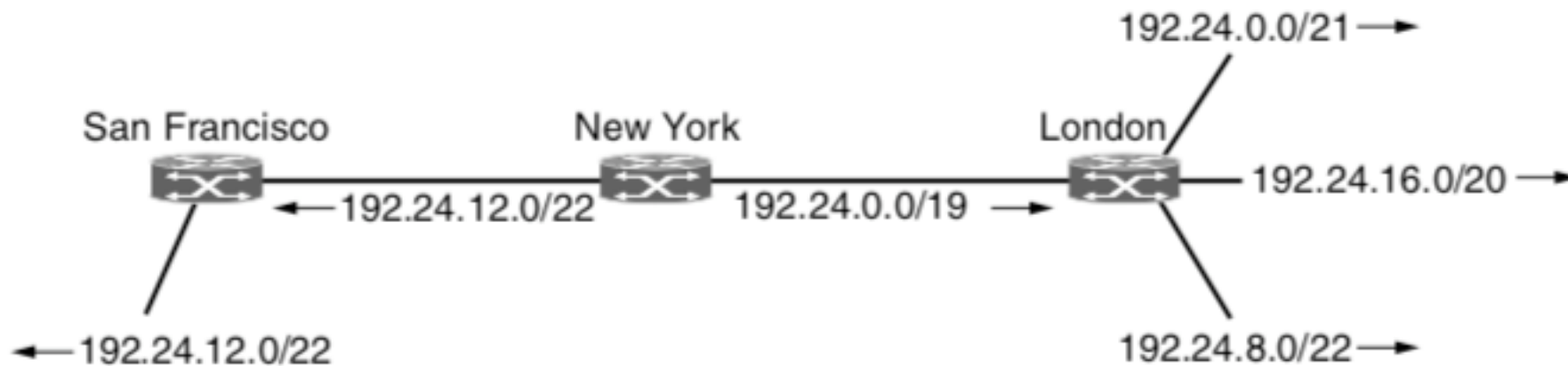


Figure 5-52. Longest matching prefix routing at the New York router.

Longest matching prefix

- With the longest matching prefix rule, IP addresses within the San Francisco network will be sent on the outgoing line to San Francisco, and all other IP addresses **in the larger prefix** will be sent to London.

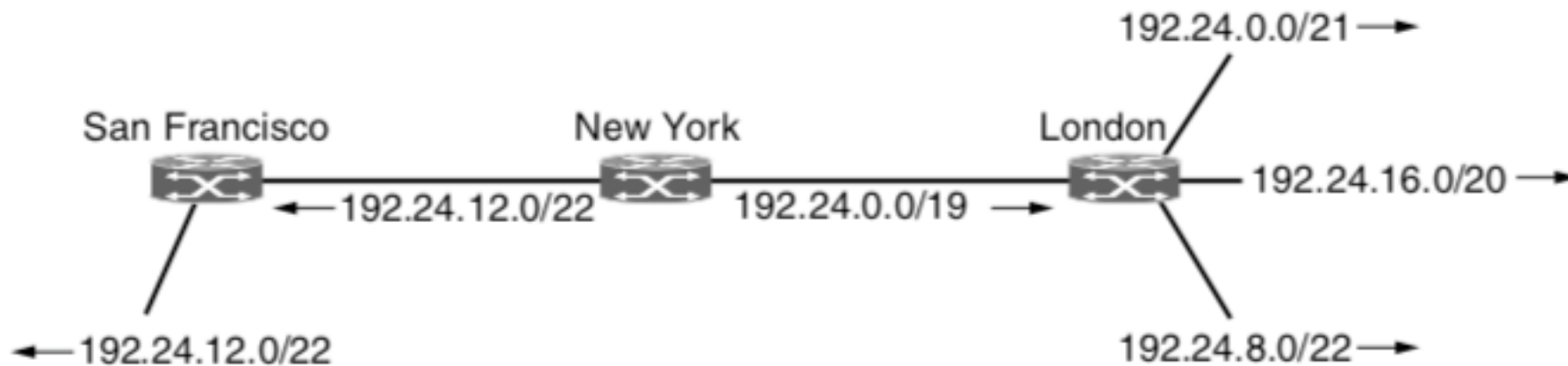


Figure 5-52. Longest matching prefix routing at the New York router.

Question 2

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default	Router 2

- For each of the following IP addresses, what does the router do if a packet with that address arrives?
- (a) 151.46.191.10
- (b) 151.46.187.2

Solution 2

- 151.46.191.10
- =====>10010111 00101110 10111111 00001010
- 151.46.184.0/22
- =====>10010111 00101110 10111000 00000000
- 151.46.188.0/22
- =====>10010111 00101110 10111100 00000000
- 151.53.40.0/23
- =====>10010111 00110101 00101000 00000000

Solution 2

- 151.46.191.10
- =====>10010111 00101110 101111 | 11 00001010
- 151.46.184.0/22
- =====>10010111 00101110 10111000 00000000
- 151.46.188.0/22
- =====>10010111 00101110 101111 | 00 00000000
- 151.53.40.0/23
- =====>10010111 00110101 00101000 00000000

Solution 2

- 151.46.187.2
- =====>10010111 00101110 10111011 00000010
- 151.46.184.0/22
- =====>10010111 00101110 10111000 00000000
- 151.46.188.0/22
- =====>10010111 00101110 10111100 00000000
- 151.53.40.0/23
- =====>10010111 00110101 00101000 00000000

Solution 2

- 151.46.187.2
- =====>10010111 00101110 101110 | 11 00000010
- 151.46.184.0/22
- =====>10010111 00101110 101110 | 00 00000000
- 151.46.188.0/22
- =====>10010111 00101110 10111100 00000000
- 151.53.40.0/23
- =====>10010111 00110101 00101000 00000000

Solution 2

- A router has the following entries in its routing table:

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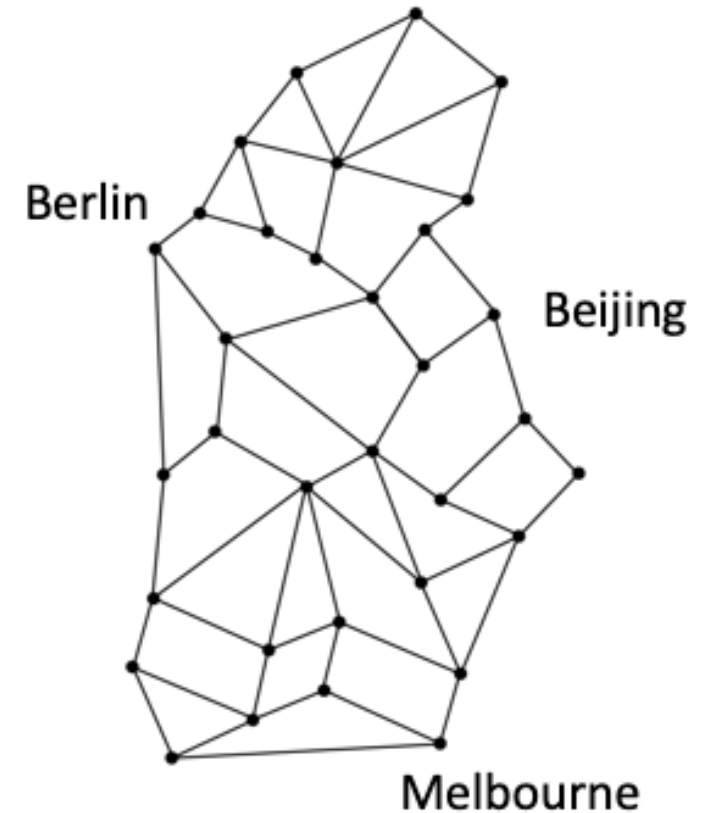
- For each of the following IP addresses, what does the router do If a packet with that address arrives?
- (a) 151.46.191.10 -----> Interface 1
- (b) 151.46.187.2 -----> Interface 0

Question 3

- Why do we need routing algorithms in the Network layer? What are the key categories of routing algorithms?

Solution 3

- Routing algorithms are needed to help decide on which output line an incoming packet should be transmitted.



Routing algorithms

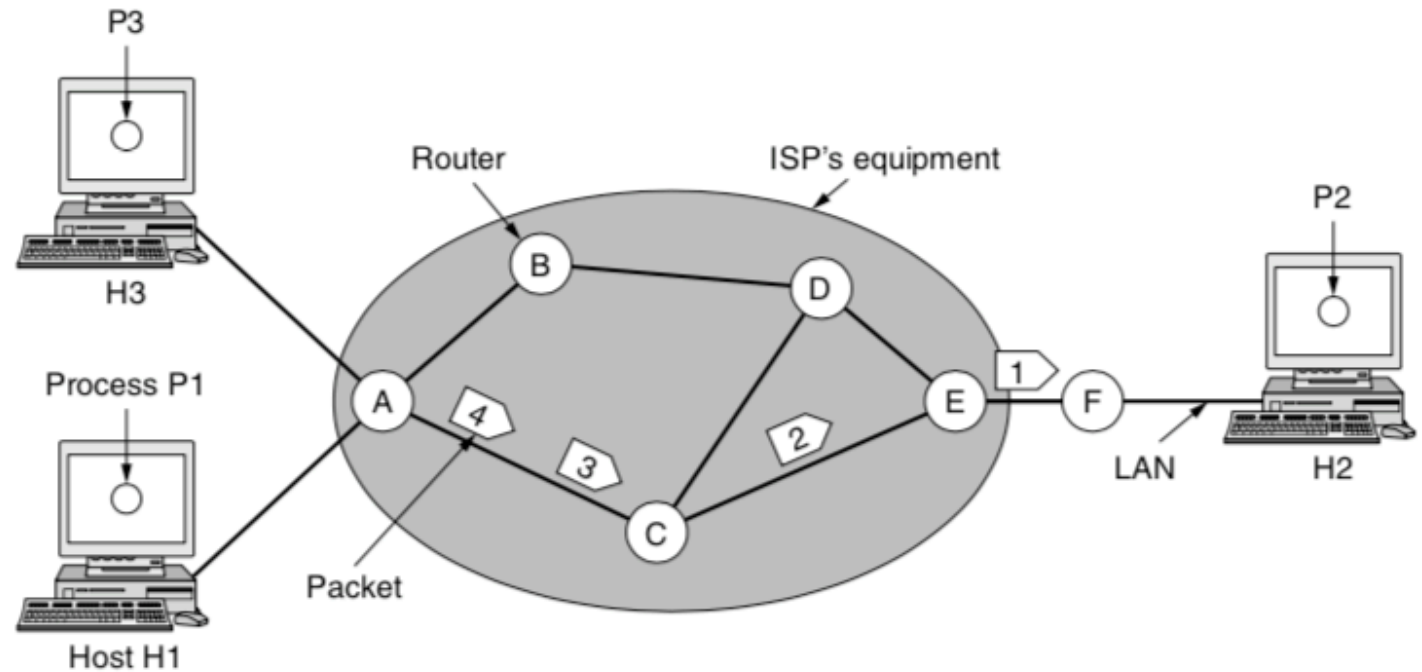
- Routing algorithms can be grouped into two major classes: non-adaptive and adaptive.
- Key Categories:
 - Non-Adaptive Algorithms
 - Adaptive Algorithms

Non-adaptive algorithms

- Do not base their routing decisions on any measurements or estimates of the current topology and traffic. Instead, the choice of the route to use to get from I to J (for all I and J) is **computed in advance, offline**, and downloaded to the routers when the network is booted.
- Advantage:
 - it does not respond to failures, non-adaptive routing is mostly useful for situations in which the routing choice is clear.

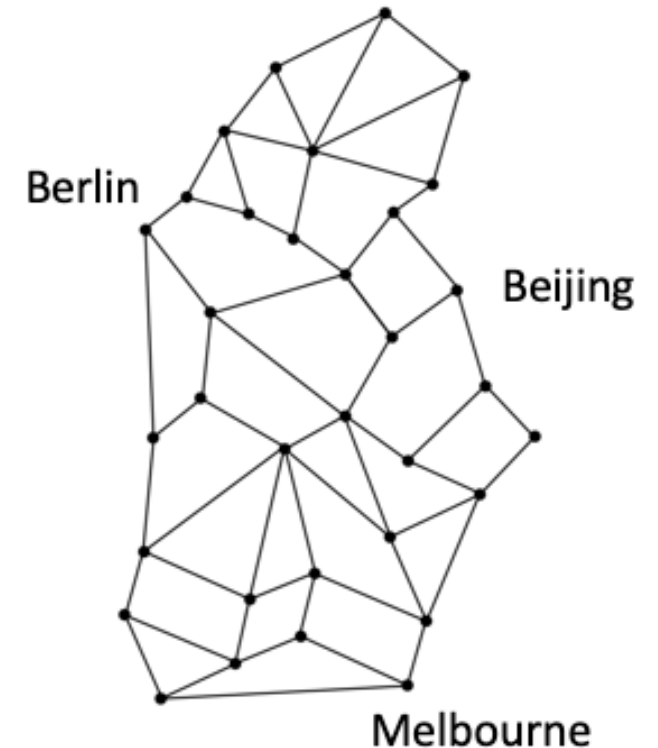
Non-adaptive algorithms

- router *F* should send packets headed into the network to router *E* regardless of the ultimate destination.



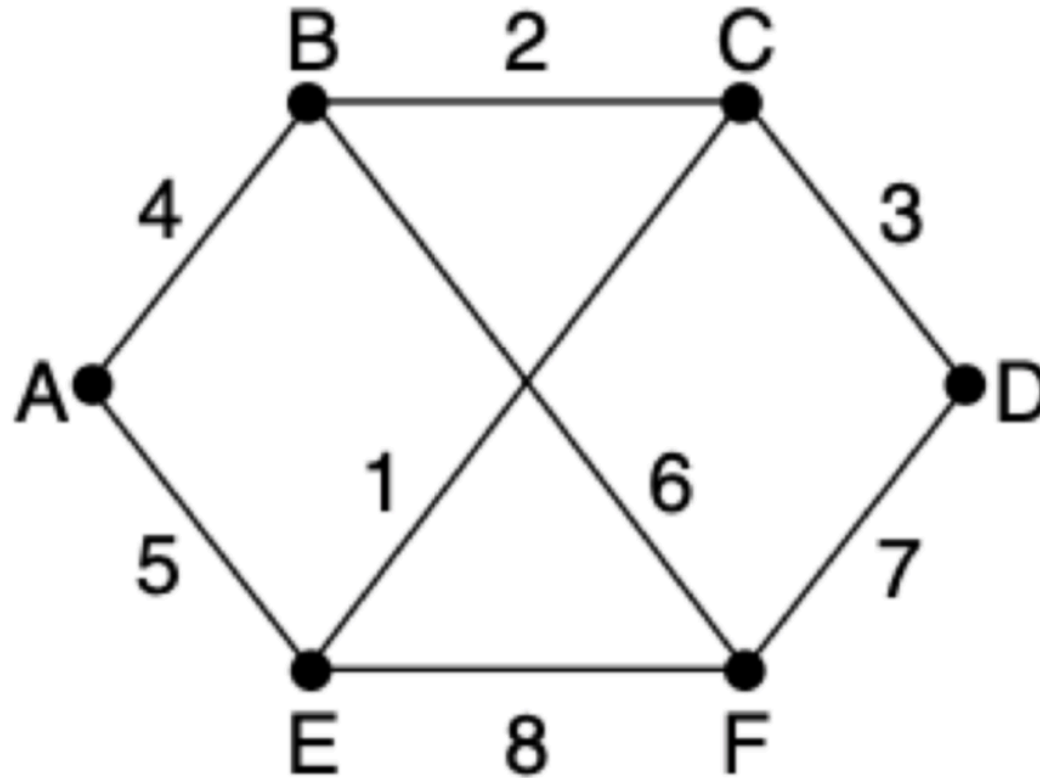
Adaptive algorithms

- In contrast, adaptive algorithms change their routing decisions to reflect changes in the topology, and sometimes changes in the traffic as well.
- Differ in:
 - where they get their information (e.g., locally, from adjacent routers, or from all routers)
 - when they change the routes (e.g., when the topology changes, or every ΔT seconds as the load changes)
 - what metric is used for optimization (e.g., distance, number of hops, or estimated transit time).



Question 4

- Compute the sink tree for Node F in the graph below:

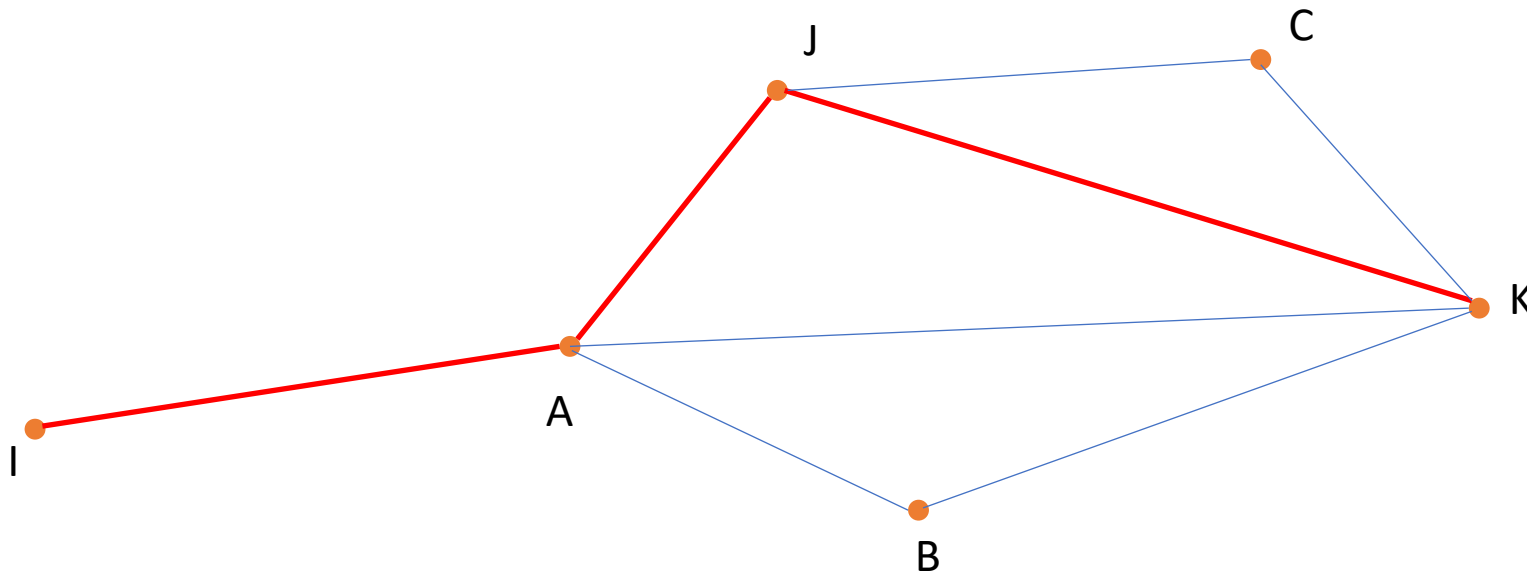


Routing Algorithms

- Shortest Path Algorithm
- Flooding
- Distance Vector Routing
- Link State Routing
- Hierarchical Routing
- Broadcast Routing
- Anycast Routing
-

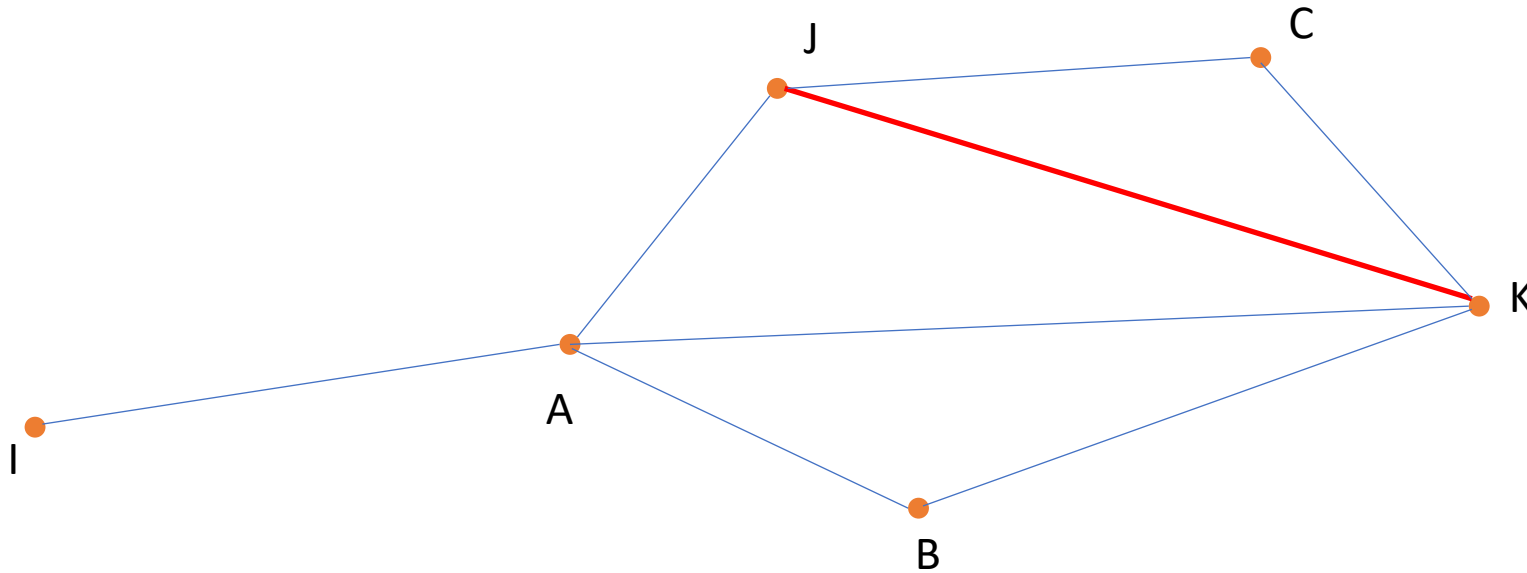
Optimality Principle

- a general statement about optimal routes without regard to network topology or traffic.
- It states that if router *J* is on the optimal path from router *I* to router *K*, then the optimal path from *J* to *K* also falls along the same route



Optimality Principle

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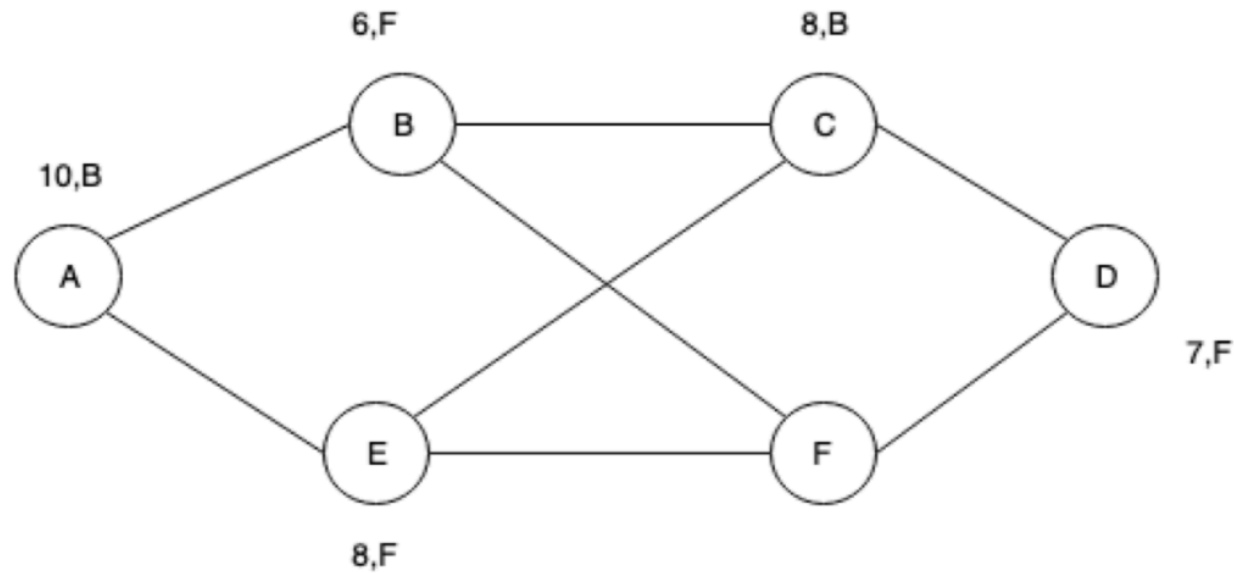
Shortest Path: Dijkstra

- Algorithm:

1. Create a **set P , tracking the nodes added in the tree**. Initialize it as empty.
2. For each node, assign a **distance value d from the node to sink**. Initialize the distance for all nodes as infinity.
3. Start from the sink node, assign distance as 0.
4. Repeat when P doesn't include all nodes:
 - For all the nodes not in P , compare distance d
 - Pick a node v with min distance and add it to P
 - Update d for all the adjacent nodes of v (newly added node)

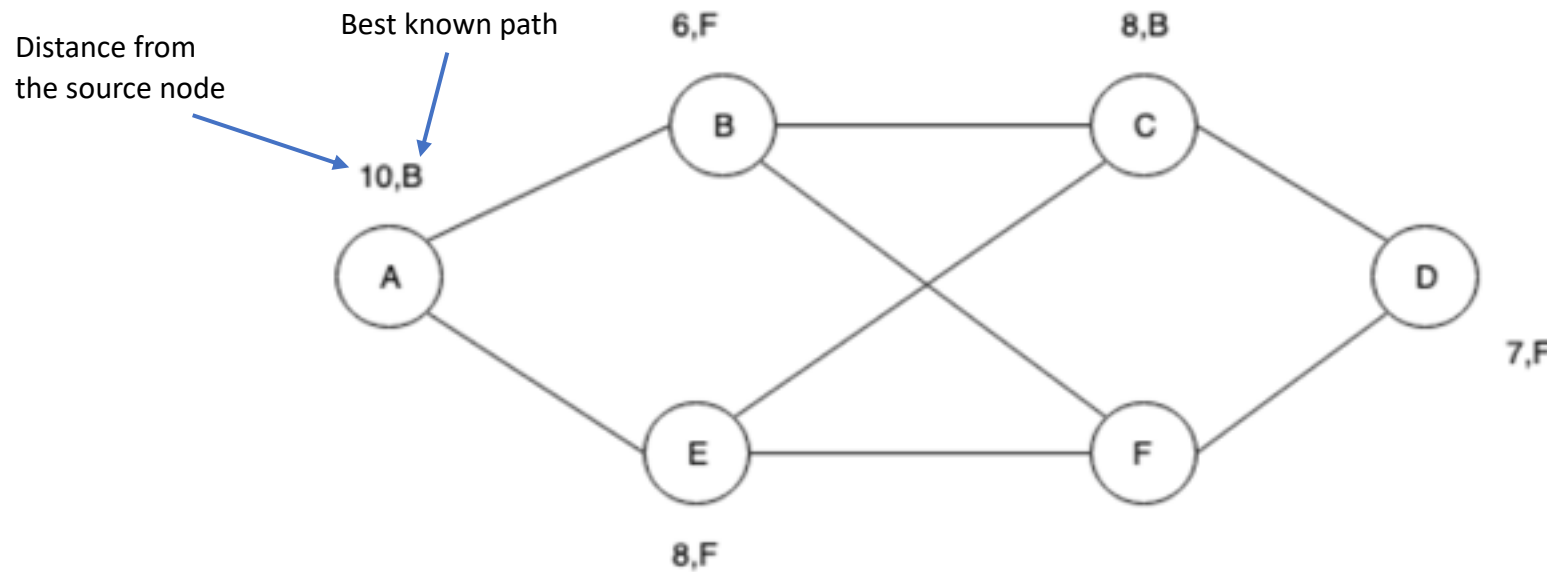
Solution 4

- Refer to Week 6 - Network Layer (3) of the Lecture



Routing Algorithms

- **Shortest Path Algorithm:** finds the shortest paths between a source and all destinations in the network (Dijkstra)



Initially,
labels: Tentative
distance: Infinity

After Dijkstra,
labels: Permanent
distance: Shortest

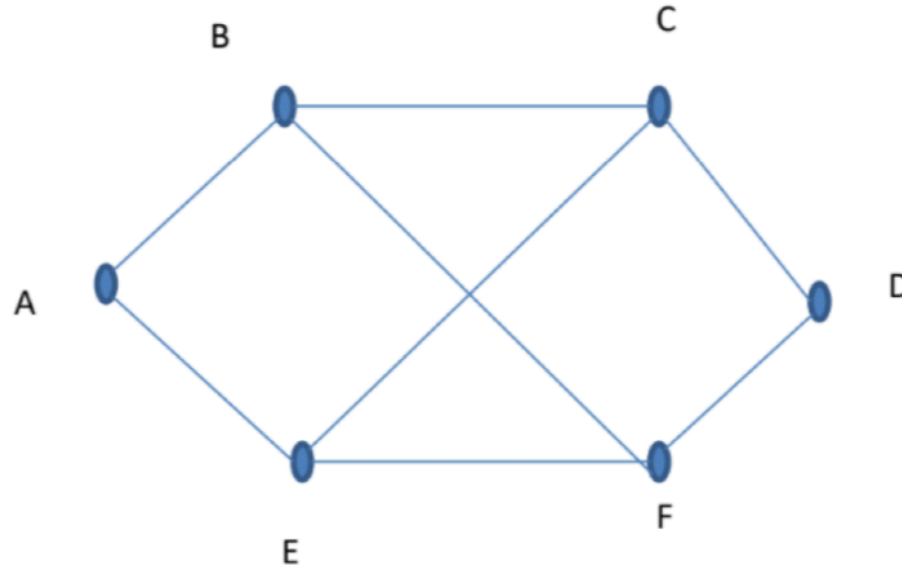
Routing Algorithms

- **Distance Vector Routing Algorithm**

- Dynamic algorithm
- More efficient than flooding algorithm
- each router maintain a table (i.e., a vector) giving the best known distance to each destination and which link to use to get there. These tables are updated by exchanging information with the neighbours. (why?) Eventually, every router knows the best link to reach each destination.

Question 5

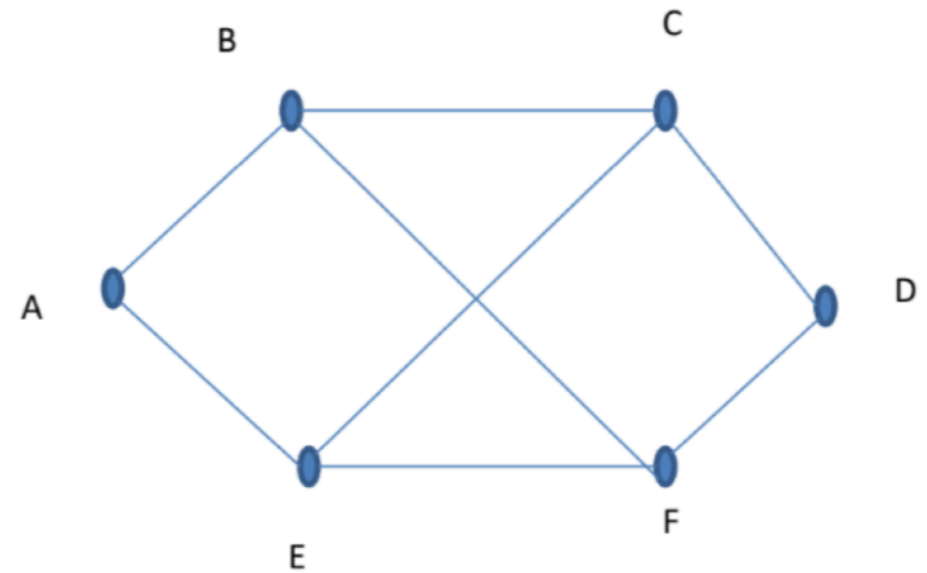
- Distance vector routing is used for the diagram shown below, and the following vectors have just come in to router C: from B: (5, 0, 8, 12, 6, 2); from D: (16, 12, 6, 0, 9, 10); and from E: (7, 6, 3, 9, 0, 4). The cost of the links from C to B, D, and E, are 6, 3, and 5, respectively. What is C's new routing table? Give both the outgoing line to use and the expected delay.



Solution 5

	B	D	E
A	5	16	7
B	0	12	6
C	8	6	3
D	12	0	9
E	6	9	0
F	2	10	4
C ->	6	3	5

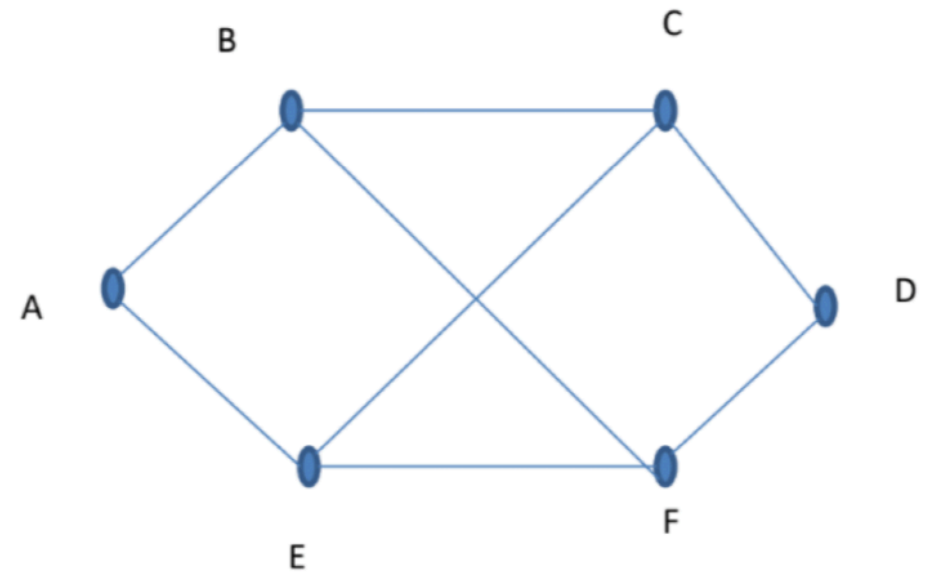
C	



Solution 5

	B	D	E
A	5	16	7
B	0	12	6
C	8	6	3
D	12	0	9
E	6	9	0
F	2	10	4
C ->	6	3	5

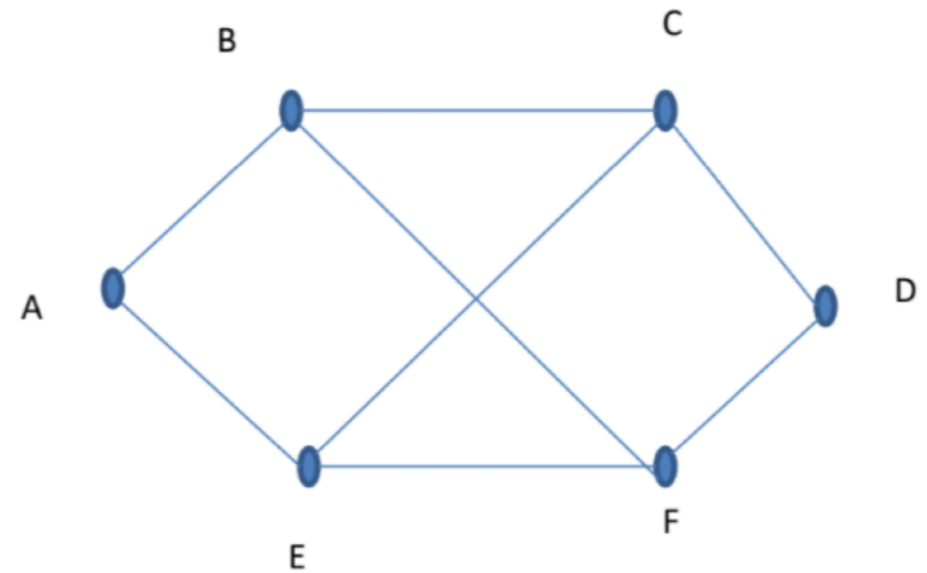
C	
11	B



Solution 5

	B	D	E
A	5	16	7
B	0	12	6
C	8	6	3
D	12	0	9
E	6	9	0
F	2	10	4
C ->	6	3	5

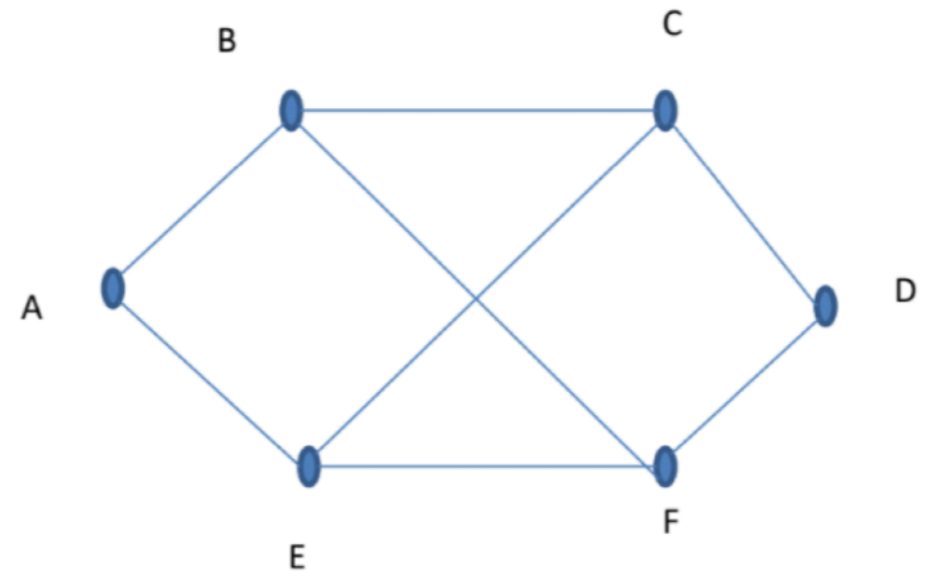
C	
11	B
6	B



Solution 5

	B	D	E
A	5	16	7
B	0	12	6
C	8	6	3
D	12	0	9
E	6	9	0
F	2	10	4
C ->	6	3	5

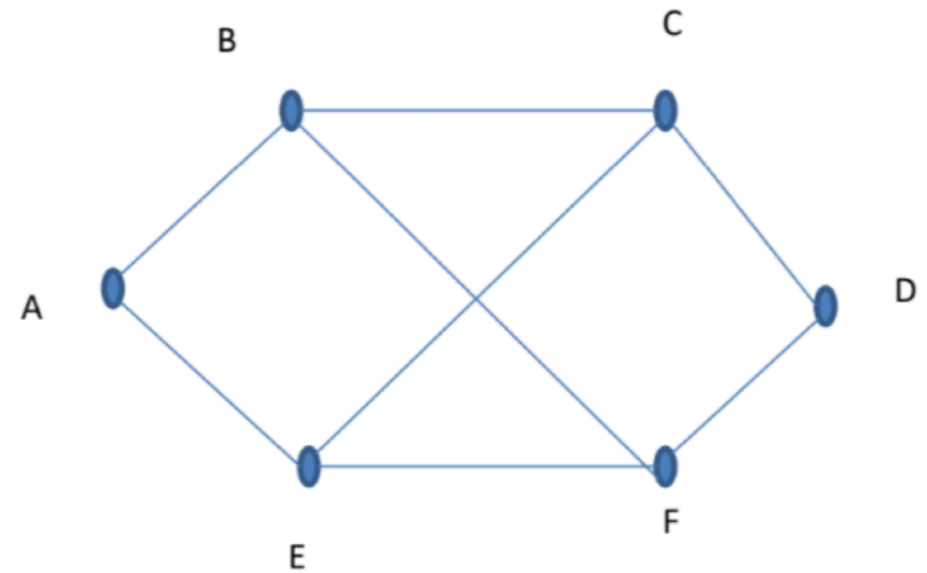
C	
11	B
6	B
0	-



Solution 5

	B	D	E
A	5	16	7
B	0	12	6
C	8	6	3
D	12	0	9
E	6	9	0
F	2	10	4
C ->	6	3	5

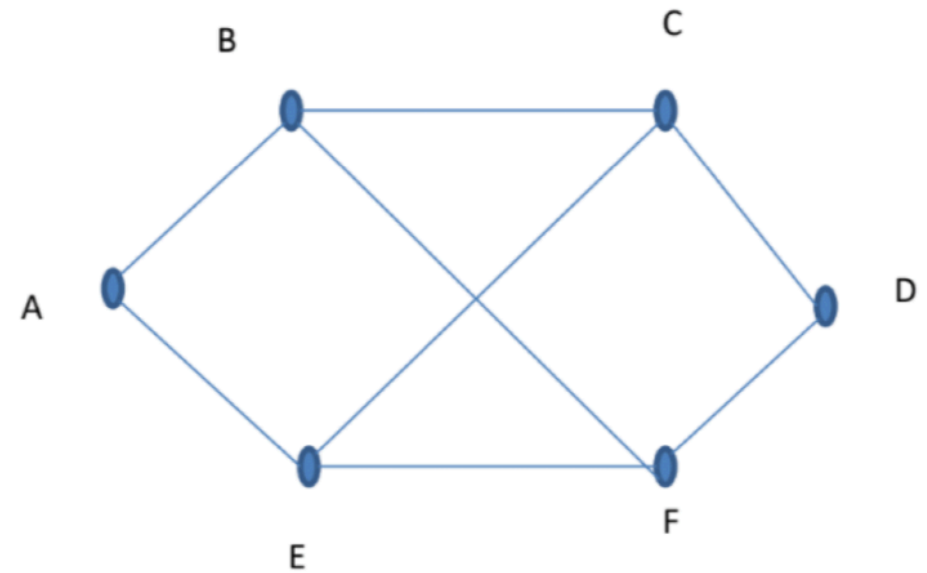
C	
11	B
6	B
0	-
3	D



Solution 5

	B	D	E
A	5	16	7
B	0	12	6
C	8	6	3
D	12	0	9
E	6	9	0
F	2	10	4
C ->	6	3	5

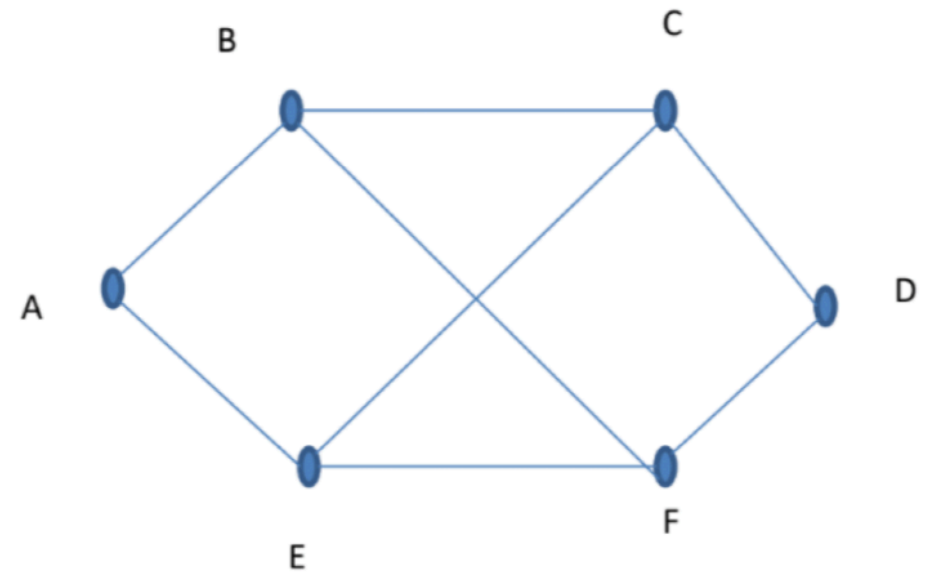
C	
11	B
6	B
0	-
3	D
5	E



Solution 5

	B	D	E
A	5	16	7
B	0	12	6
C	8	6	3
D	12	0	9
E	6	9	0
F	2	10	4
C ->	6	3	5

C	
11	B
6	B
0	-
3	D
5	E
8	B



Solution 5

- *Using the delays 6, 3, and 5 for B, D, and E, the vectors will be written as:*
- *B -> 11, 6, 14, 18, 12, 8*
- *D -> 19, 15, 9, 3, 12, 13*
- *E -> 12, 11, 8, 14, 5, 9*

All Routers	Outgoing Line	Expected Delay
A	B	11
B	B	6
C	-	0
D	D	3
E	E	5
F	B	8