Computer Network(CSC 503)

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Lecture 27 and 28

- 4.2 **Routing algorithms :** Shortest Path (Dijkastra‘s), Link state routing, Distance Vector Routing
- 4.3 **Protocols -** ARP,RARP, ICMP, IGMP
- 4.4 **Congestion control algorithms:** Open loop congestion control, Closed loop congestion control, QoS parameters, Token & Leaky bucket algorithms

Routing Algorithm

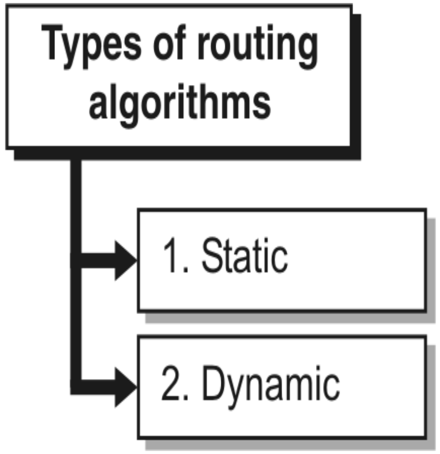
- A Routing Algorithm is that part of network layer software responsible for deciding which output line and incoming packet should be transmitted on.
- Example: : Distance Vector Routing, Link State Routing

Routing algorithms

- Responsible for deciding which output line an incoming packet should be transmitted on.
- There are **two** processes inside router:
    - i) looking up the outgoing line to use for it in the routing table→**Forwarding**
    - Ii) Responsible for filling in and updating the routing tables →**Routing algo**

- **Desirable properties routing algorithm**
    - Correctness
    - Simplicity
    - Robustness
    - Stability
    - Fairness
    - Efficiency

Routing Styles:



- **Routing Styles:** Two major classes
- 1. **Static :** A static routing table contains information entered manually. Usually remains unchanged.
    - Also called **Non Adaptive Algorithms.**
    - **A**dministrator adds route to routing table.

- 2. **Dynamic Routing:** A dynamic routing table is updated periodically or whenever necessarily using one of the **dynamic routing** protocols such as RIP, OSPF, or BGP.
    - Also called **Adaptive Algorithms**
    - Dynamic routers get their information locally, from adjacent routers, or from all routers
    - Decided metric is used for optimization (e.g., distance, number of hops, or estimated transit time).

Shortest Path (Dijkastra‘s)

- Each node is labelled (in parentheses) with its distance.
- The distances must be **non-negative**.
- Initially, no paths are known, so all nodes are labelled with **infinity**.
- A label may be either tentative or permanent. Initially, all labels are tentative.
- When it is discovered that a label represents the shortest possible path from the source to that node, it is made permanent and never changed thereafter.
- Network can have more than one shortest **Path**

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- 1. Start with the local node (router) as the root of the tree. Assign a cost of 0 to this node and make it the first permanent node.
- 2. Examine each neighbor of the node that was the last permanent node.
- 3. Assign a cumulative cost to each node and make it tentative
- 4. Among the list of tentative nodes

    a. Find the node with the smallest cost and make it Permanent

    b. If a node can be reached from more than one route then select the route with the shortest cumulative cost.
- 5. Repeat steps 2 to 4 until every node becomes permanent

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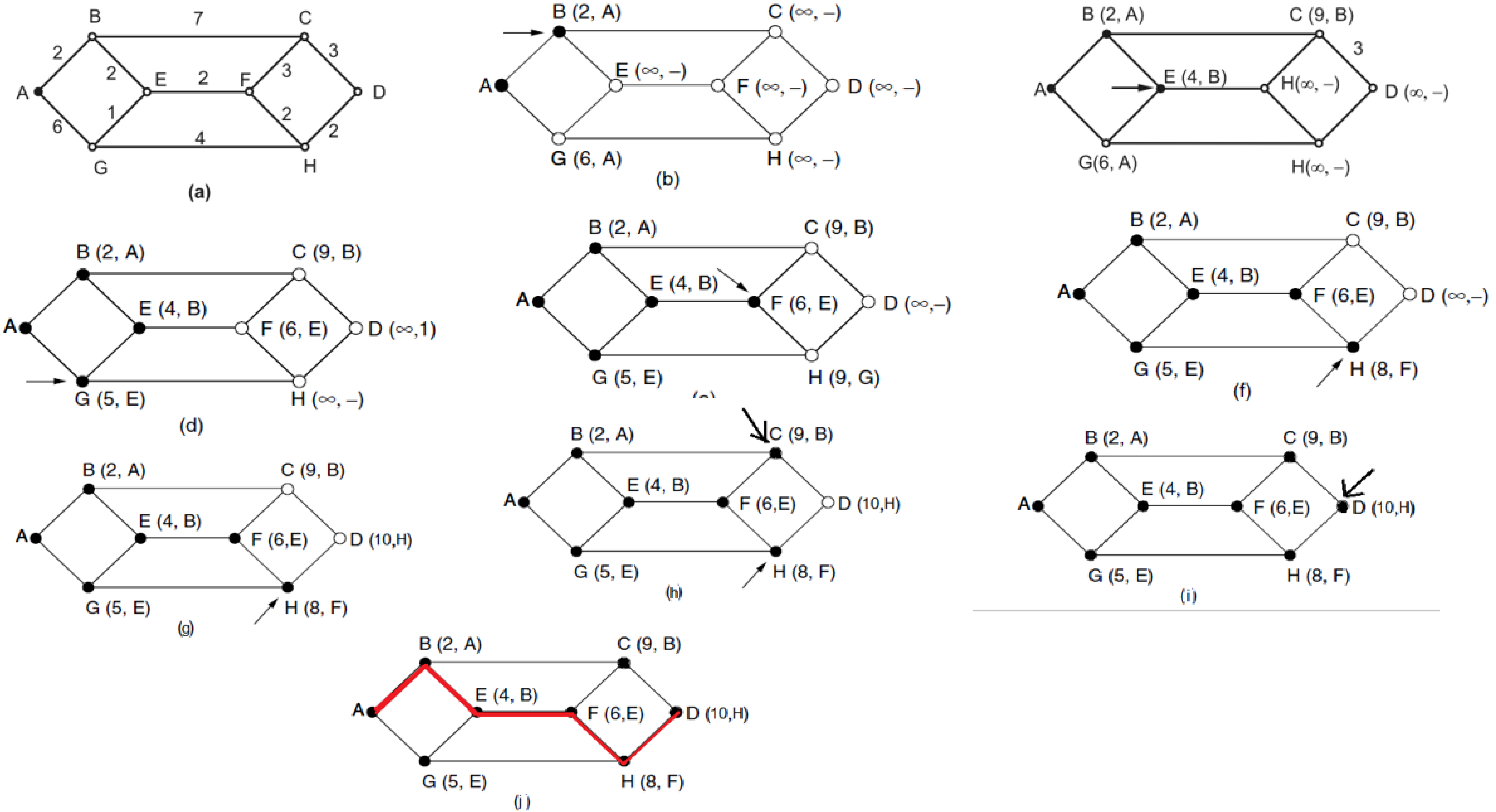


(a)
A B C D E F G H
2 7 3 2 2 3 1 2 6 4 2
(b)
B (2, A) C (∞, –) E (∞, –) F (∞, –) D (∞, –) G (6, A) H (∞, –)
B (2, A) C (9, B) E (4, B) H(∞, –) D (∞, –) G(6, A) H(∞, –) 3
(d)
B (2, A) C (9, B) E (4, B) F (6, E) D (∞,1) G (5, E) H (∞, –)
B (2, A) C (9, B) E (4, B) F (6, E) D (∞,–) G (5, E) H (9, G)
(f)
B (2, A) C (9, B) E (4, B) F (6,E) D (∞,–) G (5, E) H (8, F)
(g)
B (2, A) C (9, B) E (4, B) F (6,E) D (10,H) G (5, E) H (8, F)
(h)
B (2, A) C (9, B) E (4, B) F (6,E) D (10,H) G (5, E) H (8, F)
(i)
B (2, A) C (9, B) E (4, B) F (6,E) D (10,H) G (5, E) H (8, F)
(j)
B (2, A) C (9, B) E (4, B) F (6,E) D (10,H) G (5, E) H (8, F)

Contd...

Iteration	Permanent	Tentative	B	G	C	E	F	H	D
Initial(0)	{A}	{B,G}	2#	6	∞	∞	∞	∞	∞
1	{A,B}	{G,E,C}	2*	6	9	4#	∞	∞	∞
2	{A,B,E}	{G,C,F}	2*	5#	9	4*	6	∞	∞
3	{A,B,E,G}	{C,F,H}	2*	5*	9	4*	6#	9	∞
4	{A,B,E,G,F}	{C,H}	2*	5*	9	4*	6*	8#	∞
5	{A,B,E,G,F,H}	{C,D}	2*	5*	9#	4*	6*	8*	10
6	{A,B,E,G,F,H,C}	{D}	2*	5*	9*	4*	6*	8*	10#
7	{A,B,E,G,F,H,C,D}	{}	2*	5*	9*	4*	6*	8*	10*

Note : In above table '*' indicates permanent and # indicates current working node(least value).

Flooding

- Every router should make decisions based on **local knowledge**, not on the basis of the entire network. To implement this is flooding is used.
- **In flooding**, every incoming packet is sent out on every outgoing line except the one it arrived on. But it produces vast numbers of duplicate packets.
- These duplicate packet should be handle and needed to be discarded.

- **(a) HOP COUNT :** One measure is to decrease the hop count till it reaches zero. At zero router drops packet. This will prevent packet from circulating infinitely in the network.
- **(b) SELECTIVE FLOODING :** keep track of which packets have been flooded, to avoid sending them out a second time.

Routing Protocols

- A Routing Protocol is a combination of rules and procedures that lets routers in an internet inform each other of changes.
- It allows routers to share whatever they know about the internet or their neighbourhood.
- Example: RIP, OSPF, BGP

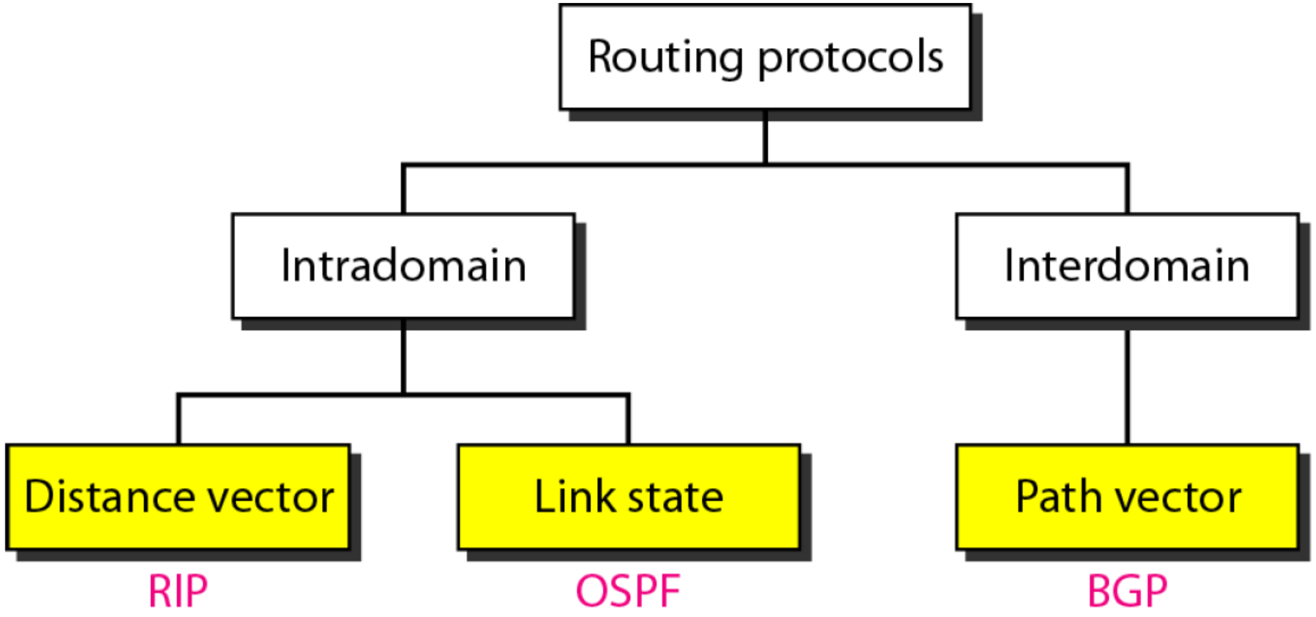
Intra- and Inter domain Routing

1)Intra- domain routing : Routing **inside** an autonomous system is referred to as **intra-domain routing**.

- **E.g. :** Distance Vector, Link State.

2)**Inter- domain routing :** Routing between autonomous systems referred to as **inter-domain routing**.

- **E.g. :** Path Vector



Autonomous System (AS)

- An **Autonomous System (AS)** is a group of networks and routers under the authority of a single administration.

Distance Vector Routing

- DVR (Distance vector routing) was used in the ARPANET until 1979, then replaced by link state routing.
- The distance vector routing algorithm is **Dynamic routing** algorithm and it takes current network load into account.
- The distance vector routing algorithm is also called **distributed Bellman-Ford** routing algorithm.
- **Bellman-Ford** routing algorithm works with negative weights also.
- In distance vector routing, the least cost route between any two nodes is the route with **minimum distance**
- Mainly 3 things in this
  - ***Initialization***
  - ***Sharing***
  - ***Updating***

Iteration 1

Table for Router A

Dest	Dist	Next Hop
A	0	A
B	15	B
C	5	C
D	∞	--

Table for Router B

Dest	Dist	Next Hop
A	15	A
B	0	B
C	8	C
D	1	D

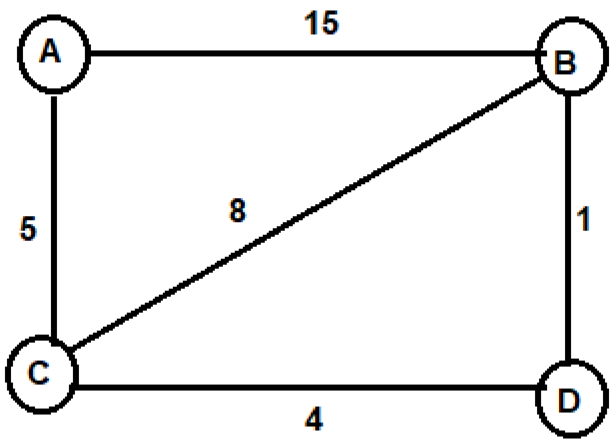


Table for Router C

Dest	Dist	Next Hop
A	5	A
B	8	B
C	0	C
D	4	D

Table for Router D

Dest	Dist	Next Hop
A	∞	--
B	1	B
C	4	C
D	0	D

Iteration 2

Table for Router A

Dest	Dist	Next Hop
A	0	A
B	13	C
C	5	C
D	9	C

Table for Router B

Dest	Dist	Next Hop
A	13	C
B	0	B
C	5	D
D	1	D

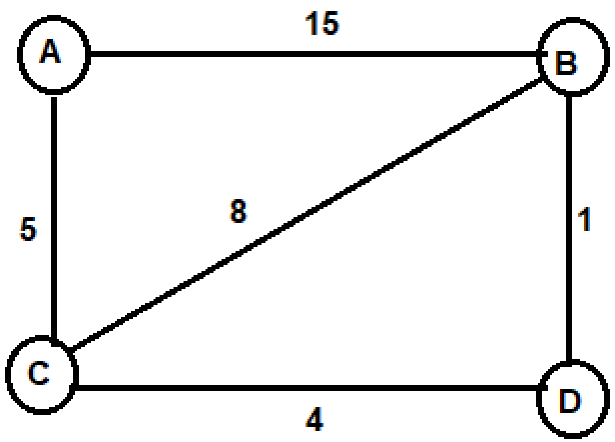


Table for Router C

Dest	Dist	Next Hop
A	5	A
B	5	D
C	0	C
D	4	D

Table for Router D

Dest	Dist	Next Hop
A	9	C
B	1	B
C	4	C
D	0	D

Iteration 3

Table for Router A

Dest	Dist	Next Hop
A	0	A
B	10	C
C	5	C
D	9	C

Table for Router B

Dest	Dist	Next Hop
A	10	D
B	0	B
C	5	D
D	1	D

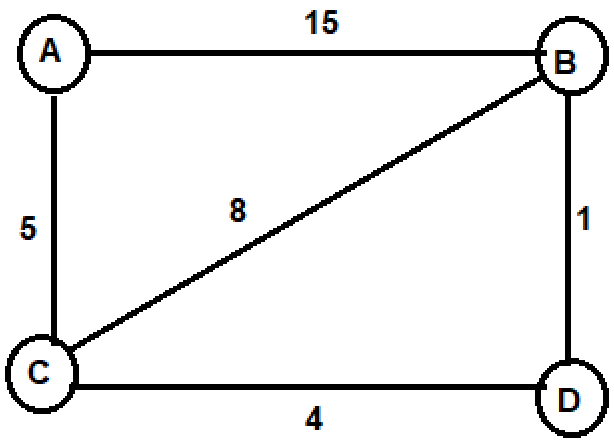


Table for Router C

Dest	Dist	Next Hop
A	5	A
B	5	D
C	0	C
D	4	D

Table for Router D

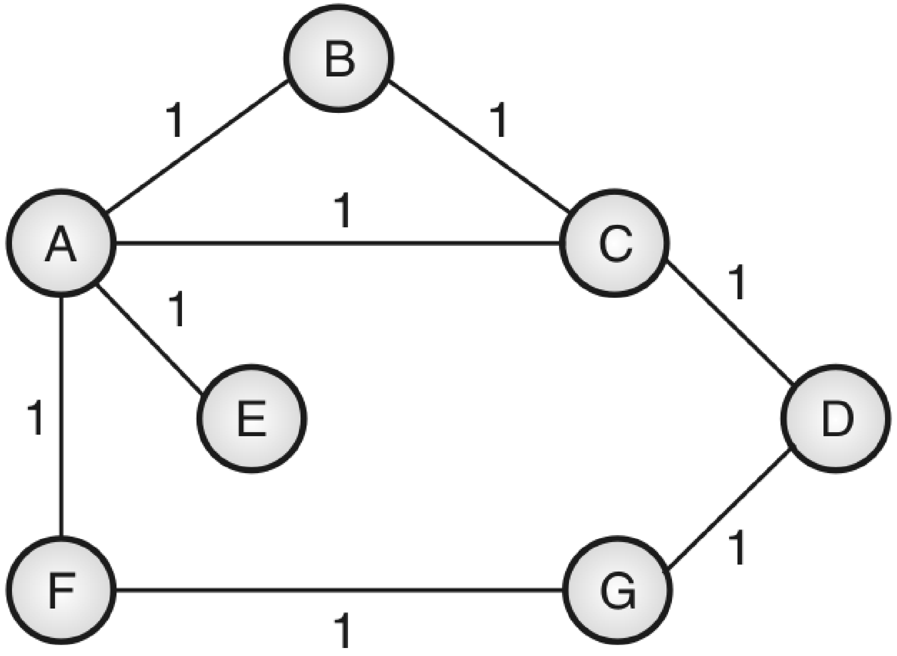
Dest	Dist	Next Hop
A	9	C
B	1	B
C	4	C
D	0	D

Distance Vector Routing

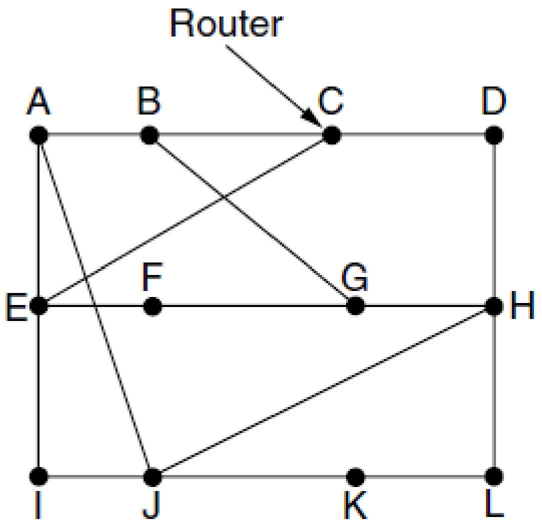
Three keys to understand how this algorithm works:

- Sharing knowledge about the entire AS: Each router shares its knowledge about the entire AS with neighbours. It sends whatever it has.
- Sharing only with immediate neighbours: Each router sends whatever knowledge it has through all its interface.
- Sharing at regular intervals: Each router sends information at fixed intervals, e.g. every 30 sec.

Example: Write the Routing table maintained at all node(Routers)



Example 2:



(a) A network

To	A	I	H	K	New estimated delay from J	Line
A	0	24	20	21	8	A
B	12	36	31	28	20	A
C	25	18	19	36	28	I
D	40	27	8	24	20	H
E	14	7	30	22	17	I
F	23	20	19	40	30	I
G	18	31	6	31	18	H
H	17	20	0	19	12	H
I	21	0	14	22	10	I
J	9	11	7	10	0	–
K	24	22	22	0	6	K
L	29	33	9	9	15	K
	JA delay is 8	JI delay is 10	JH delay is 12	JK delay is 6		

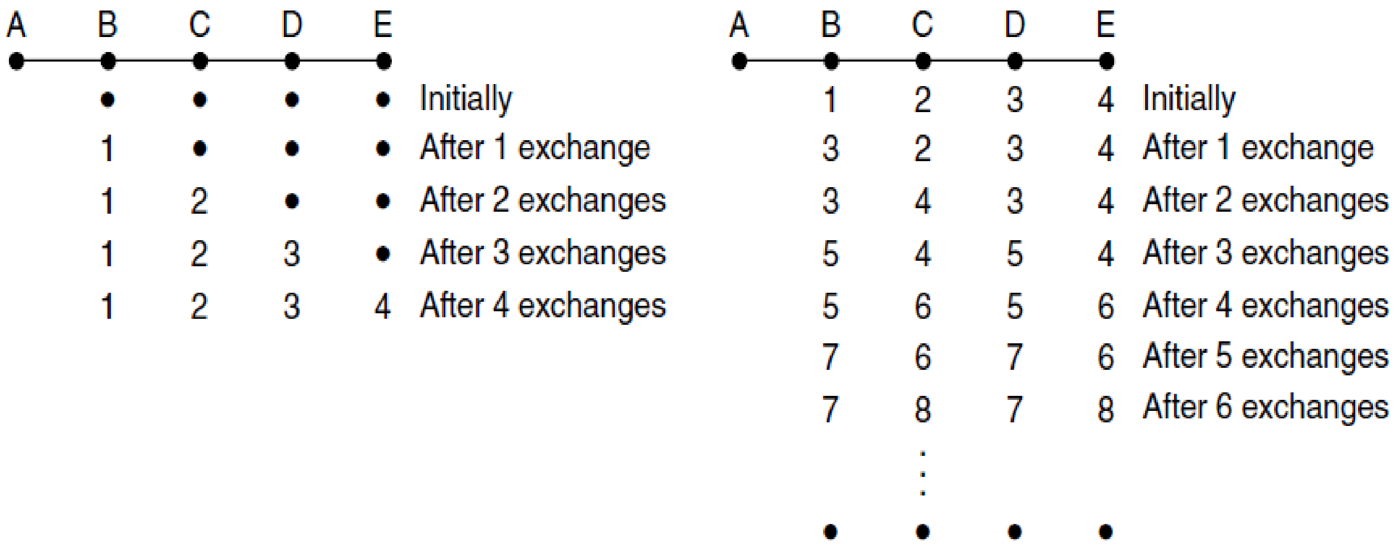
Vectors received from J's four neighbors

New routing table for J

(b) Input from *A*, *I*, *H*, *K*, and the new routing table for *J*.

THE COUNT-TO-INFINITY PROBLEM (DEMERITS OF DVR)

- The routes settle down for best paths across the network is called **convergence**. DVR (Distance Vector Routing) is useful as a simple technique used by routers to collectively compute shortest paths, however, it has a major drawback.



(a) (b)

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- Count to Infinity Problem:

➢ Any decrease in cost propagates quickly but any increase in cost propagates slowly

➢ In a network, If a link is broken, the cost becomes infinity

➢ All routers should be aware immediately but in DVR this takes some time

➢ This problem is referred to as count to infinity

➢ It sometimes takes several updates before the cost for a broken link is recorded as infinity by all routers

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Demerits

- 1. Distance vector algorithm is **slower** to converge than link state.
- 2. This algorithm is at risk from the **count-to-infinity** problem.
- 3. It creates **more traffic than** link state since a hop count change must be propagated to all routers and processed on each router.
- 4. Hop count updates take place on a **periodic basis**, even if there are no changes in the network topology, so bandwidth gets wasted due to broadcasting.
- 5. Distance vector routing results in **larger routing tables in large network** than link state since each router must know about all other routers. This can also lead to congestion.

Routing Information Protocol(RIP)

- RIP is based on distance vector routing, which uses the Bellman-Ford algorithm for calculating the routing table.
- RIP treats all network equally
- The cost of passing through a network is the same: one hop count per network.
- Each router/node maintains a vector (table) of minimum distances to every node.
- The hop-count is the number of networks that a packet encounters to reach its destination. Path costs are based on number of hops.

Contd…

- Infinity is defined as 16,hence any route using RIP can not be more than 15 hops
- In distance vector routing, each router periodically shares its knowledge about the entire internet with its neighbour.
- Each router keeps a routing table that has one entry for each destination network of which the router is aware.
- The entry consists of Destination Network Address/id, Hop-Count and Next-Router.

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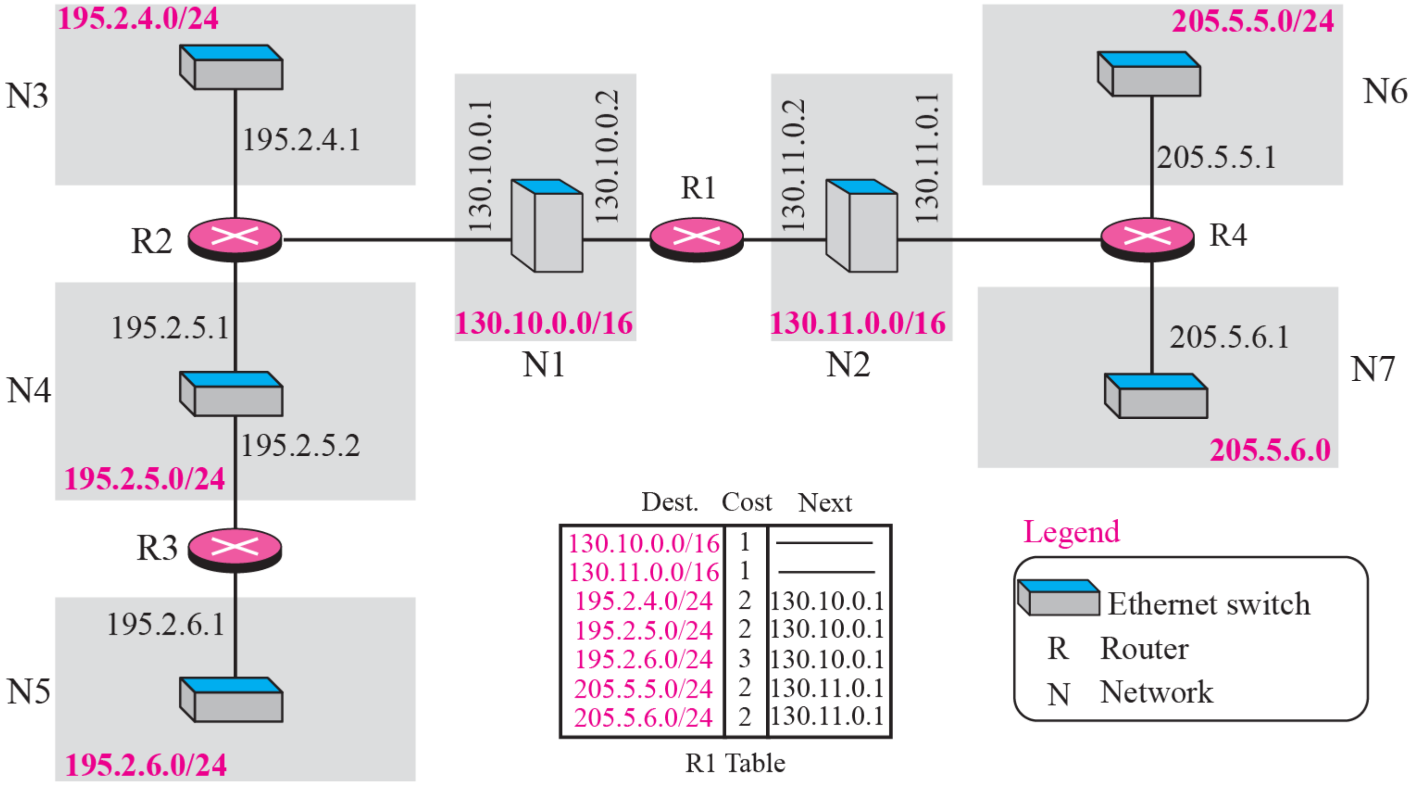
Advantage

- It is easy to configure, because RIP does not require any parameters on a router unlike other protocols

Disadvantages

- Time to converge and scalability are poor compared to OSPF
- A hop limit severely limits the size of network it can be used in.

Routing Information Protocol (RIP)



Dest.	Cost	Next
130.10.0.0/16	1	——
130.11.0.0/16	1	——
195.2.4.0/24	2	130.10.0.1
195.2.5.0/24	2	130.10.0.1
195.2.6.0/24	3	130.10.0.1
205.5.5.0/24	2	130.11.0.1
205.5.6.0/24	2	130.11.0.1

R1 Table

Dest.	Cost	Next
130.10.0.0/16	1	——
130.11.0.0/16	2	130.10.0.2
195.2.4.0/24	1	——
195.2.5.0/24	1	——
195.2.6.0/24	2	195.2.5.2
205.5.5.0/24	3	130.10.0.2
205.5.6.0/24	3	130.10.0.2

R2 Table

Dest.	Cost	Next
130.10.0.0/16	2	195.2.5.1
130.11.0.0/16	3	195.2.5.1
195.2.4.0/24	2	195.2.5.1
195.2.5.0/24	1	——
195.2.6.0/24	1	——
205.5.5.0/24	4	195.2.5.1
205.5.6.0/24	4	195.2.5.1

R3 Table

Dest.	Cost	Next
130.10.0.0/16	2	130.11.0.2
130.11.0.0/16	1	——
195.2.4.0/24	3	130.11.0.2
195.2.5.0/24	3	130.11.0.2
195.2.6.0/24	4	130.11.0.2
205.5.5.0/24	1	——
205.5.6.0/24	1	——

R4 Table

Link state routing

- Distance vector routing was used in the ARPANET until 1979, when it was replaced by link state routing.
- Variants of link state routing called IS-IS and OSPF are the routing algorithms that are most widely used inside large networks and the Internet today.

The idea behind link state routing stated in **five** parts:

- 1. Discover its neighbors and learn their network addresses.
- 2. Set the distance or cost metric to each of its neighbors.
- 3. Construct a packet telling all it has just learned.
- 4. Send this packet to and receive packets from all other routers.
- 5. Compute the shortest path to every other router.

- In effect, the complete topology is distributed to every router. Then Dijkstra's algorithm can be run at each router to find the shortest path to every other router.

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Learning about the Neighbours

- When a router is booted, its first task is to learn who its neighbors are.
- sending a special HELLO packet on each point-to-point line

- **Setting Link Costs**
- A common choice is to make the cost inversely proportional to the bandwidth of the link.
- For example, **1-Gbps** Ethernet may have a cost of **1** and **100-Mbps** Ethernet a cost of **10**. This makes higher-capacity paths better choices.

Link State routing

- Like RIP, in link state routing, each router also shares its knowledge about its neighbourhood with every routers in the area.
- However, in LSR, the link-state packet (LSP) defines the best known network topology (of an area)
- This packet is sent to every routers (of other area) after it is constructed locally. Whereas RIP slowly converge to final routing list based information received from immediate neighbours.

Link State routing

- Three keys to understand how this algorithm works:

- **Sharing knowledge about the neighbourhood:** Each router sends the state of its neighbourhood toevery other router in the area.
- **Sharing with every other routers:** Through the process of flooding, each router sends the state of its neighbourhood through all its output ports and each neighbour sends to every other neighbours and so on until all routers received same full information eventually.
- **Sharing when there is a change:** Each router share its state of its neighbour only when there is a change; contrasting DVR results in lower traffic.

From the received LSPs and knowledge of entire topology, a router can then calculate the **shortest path between itself** and each network

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Creating LSP

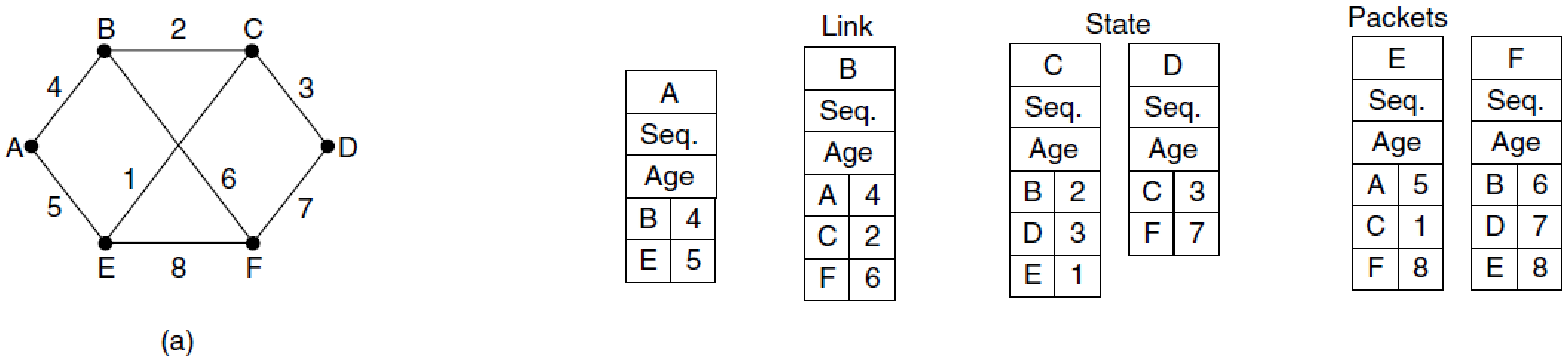
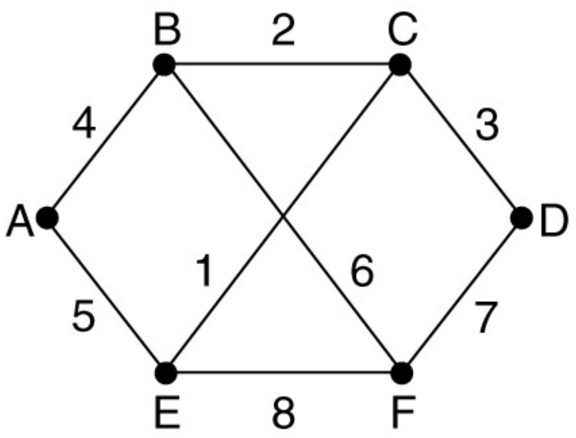


Figure (a) A network. (b) The link state packets for this network.

Link State routing

- Creating LSP



(a)

Link State Packets

A	
Seq.	
Age	
B	4
E	5

B	
Seq.	
Age	
A	4
C	2
F	6

C	
Seq.	
Age	
B	2
D	3
E	1

D	
Seq.	
Age	
C	3
F	7

E	
Seq.	
Age	
A	5
C	1
F	8

F	
Seq.	
Age	
B	6
D	7
E	8

(b)

- Building the link state packets is easy. The difficult part is to determine when to build them.
- One possibility is to build them periodically at regular intervals.
- The other is to build when some significant even occurs; i.e. a line or neighbour going down or coming back up again

Contd…

- **Distributing LSP**

Source	Seq.	Age	Send flags A	Send flags C	Send flags F	ACK flags A	ACK flags C	ACK flags F	Data
A	21	60	0	1	1	1	0	0	
F	21	60	1	1	0	0	0	1	
E	21	59	0	1	0	1	0	1	
C	20	60	1	0	1	0	1	0	
D	21	59	1	0	0	0	1	1	

- Above is the packet buffer at router B. Routers A, F, C are directly connected to B. Each row corresponds to a recently-arrived, but as yet not fully processed LSP.
- The table shows where the packet originated, sequence number, age and the data.
- The process of distributing the LSP is called **Flooding**

Link State routing

- **Link state Database (LSDB)**

- To create a least cost tree, each node needs to have a complete map of the network
- It needs to know the state of each link
- The collection of the states for all links is called **link state database**
- For the whole internet, there is only 1 link state database
- Link state database is created by the process of **Flooding**
- Each node collects **two** pieces of information
  - 1) **Identity** of the node
  - 2) **Cost** of the link

Contd…

Problems

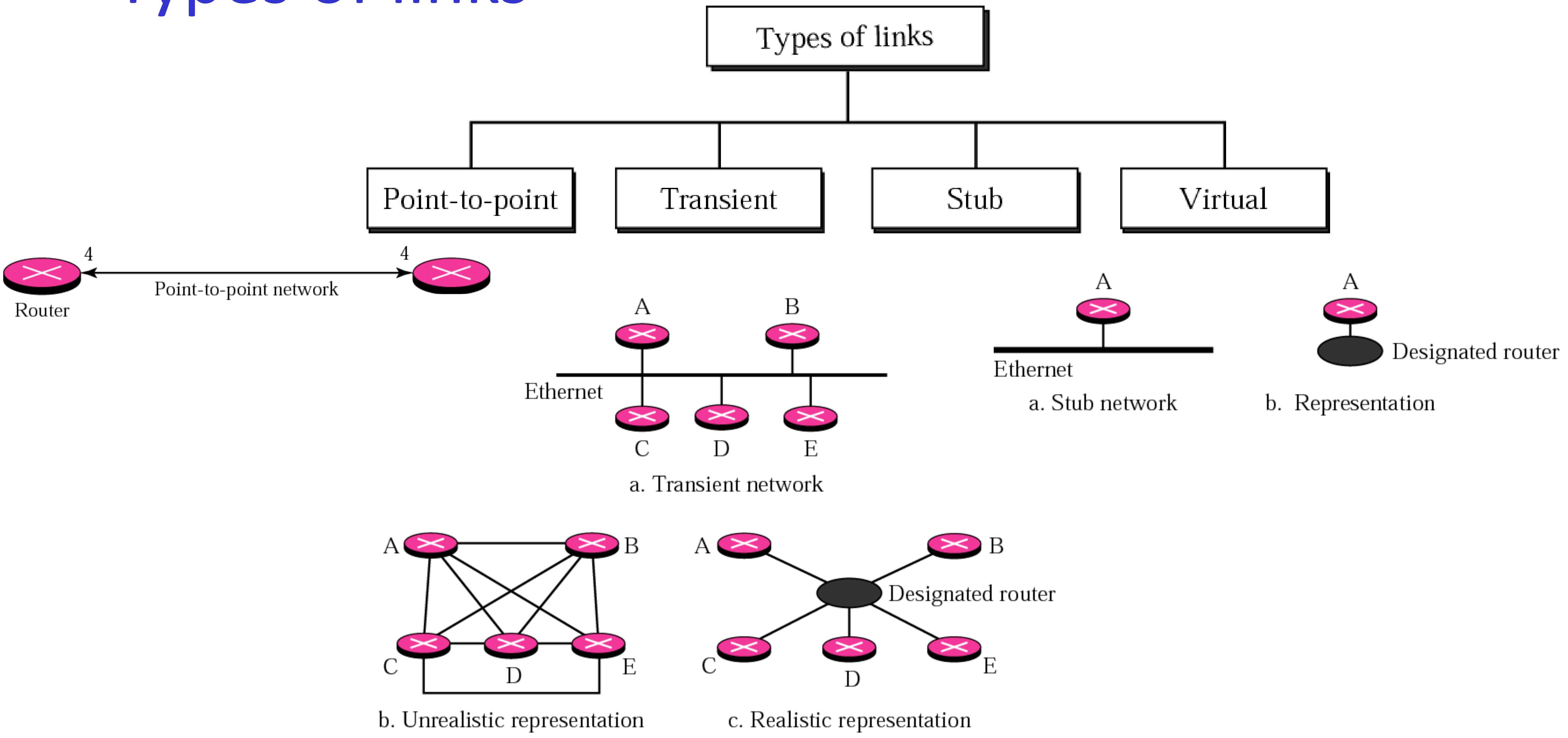
- 1. If a router ever crashes, it will lose track of its sequence number and starts from 0 again; next arriving good packet will be rejected as duplicate.
- 2. If a sequence number is ever corrupted.

Solution

- The solution is to introduce an 'Age' field for each packet after the sequence number
- Decrement it once per second.
- When the Age hits **zero**, the information from that router is **discarded**.
- The Age field is also decremented by each router during initial flooding process, to make sure no packets can get lose and live for indefinite period of time

- **Link state routing needs a huge amount of resources** to calculate routing tables.
- It also creates heavy traffic because of flooding.

Types of links



Link State Advertisement

- Share information about the neighbourhood, each entity **distribute link state advertisements (LSAs)**
- Types: