

Ministry of Higher Education and Scientific Researches  
Al-Mansour University College  
Department of Computer Technology Engineering  
Fourth Class



# Computer Networks Protocols

## Lecture Three: Network Layer (Routing Concept & Algorithms)

**Dr. Mahmoud Shuker Mahmoud**

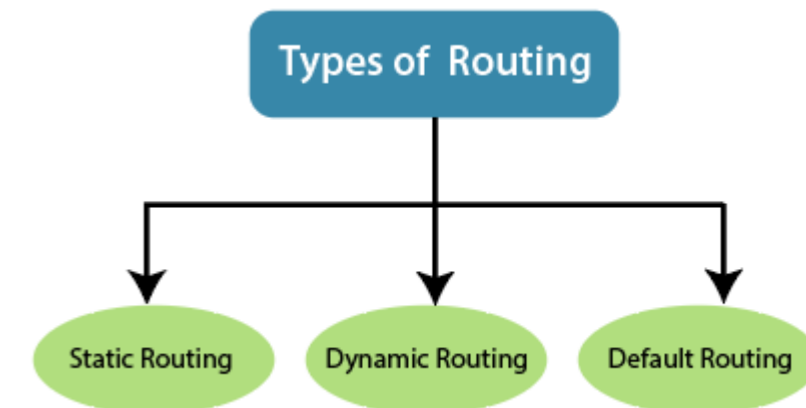
## Routing Concept

**ROUTING**: is **forwarding** of packets from one network to another network choosing the **best path** from the routing table.

**Routing table** consist of only the *best routes* for every destination.

### Types of Routing:

Static	<ul style="list-style-type: none"><li>• It is configured by Administrator <b>manually</b></li><li>• Need for <b>destination network ID</b></li><li>• It is <b>secure and fast</b></li><li>• Used for <b>small organization</b> which have network of <b>10-15</b> routers</li></ul>
Dynamic	<ul style="list-style-type: none"><li>• Means <b>automatically</b> routing</li><li>• Dynamic routes mean that the router <b>learns</b> the paths of destinations by receiving <b>periodic updates</b> from other routers</li><li>• Is <b>automatically</b> choose the best shortest path</li><li>• Can be done by using <b>routing protocol</b></li></ul>
Default	<ul style="list-style-type: none"><li>• Is configured for <b>unknown</b> destination</li><li>• When there is <b>no entry</b> for the destination network in a routing table, the router will forward the packet to its <b>default router</b>.</li><li>• It is <b>last preferred routing</b></li></ul>



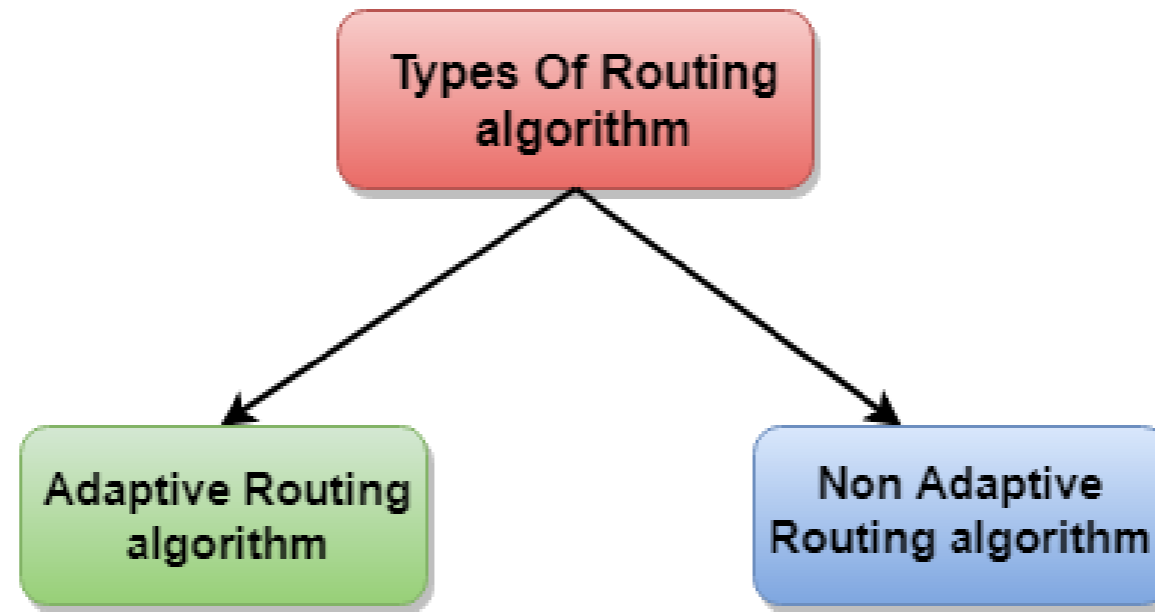
### Q: list the Advantages of dynamic over static routing?

- There is **no need** to know the destination networks
- **Updates** the topology changes **dynamically**
- Administrative work **reduced**
- Used for **large organizations**

## Routing Algorithms

In the world of computers, any procedure can be illustrated through step by step, which is called an algorithm. Similarly, the **routing algorithm** is a step-by-step procedure for transferring data from one location to another over the network.

- The main function of the network layer is **routing packets from source to destination**.
- The **routing algorithm** is that part of the network layer software responsible for **deciding** which output line an incoming packet should be transmitted on.
- Routing algorithms can be grouped into two major classes: *non adaptive* and *adaptive*.

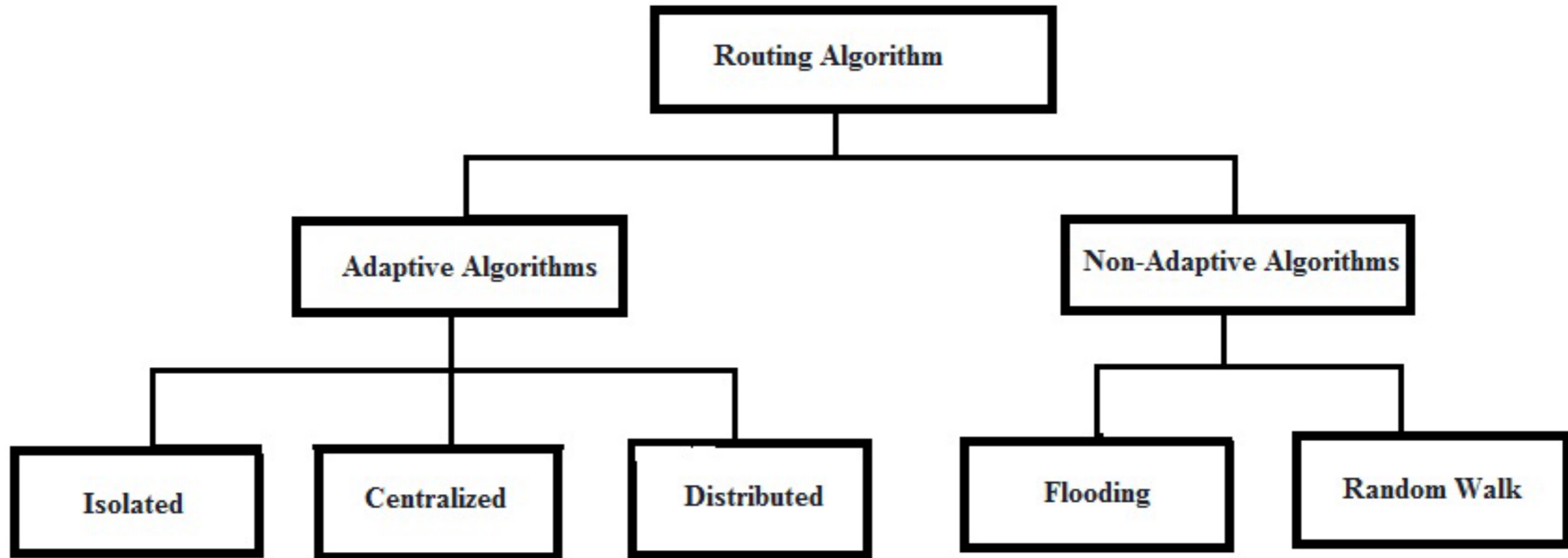


Non adaptive algorithms (Static Routing)	Adaptive algorithms (Dynamic Routing)
<ul style="list-style-type: none"><li>• Network administrator manually enters routing path into the router.</li><li>• <b>Do not</b> base their routing decisions on measurements or estimates of the current traffic and topology.</li><li>• Used by static Routing</li></ul>	<ul style="list-style-type: none"><li>• Routers exchange updates and router table information.</li><li>• <b>Change</b> their routing decisions to reflect changes in the topology, and usually the traffic as well.</li><li>• Used by dynamic routing</li></ul>

## Types of Routing Algorithm

Routing algorithms are classified into two types which include the following.

- Adaptive Algorithms
- Non-Adaptive Algorithms



## Non-Adaptive Algorithms

Non-adaptive algorithms do not modify their routing decisions when they have been preferred. This kind of algorithm is also called **static routing** because the route which is used can be calculated in advance & downloaded to routers once the router is booted. These types of algorithms are classified into two types which include the following:

- Flooding
- Random Walk

### Flooding

This algorithm uses the technique where each incoming packet can be transmitted on each outgoing line excluding from where it appears. The main drawback of this is, the packets may travel in the loop & consequently a node may collect carbon copy packets. To overcome this problem, sequence numbers, spanning tree & hop count are used.

### Random Walk

In this type of algorithm, data packets are transmitted through the node by node or host by host randomly to one of its neighbors. This method is extremely strong which is frequently executed by transmitting data packets over the network link which is queued least.

## Adaptive Algorithms

Adaptive algorithms are used to change the decisions of routing when traffic load & network topology changes. This is known as **dynamic routing**. The parameter optimizations are distance, no. of hops & expected transit time. These algorithms are classified into three types which include the following:

- Isolated
- Centralized
- Distributed

### Isolated Algorithm

In this kind of algorithm, every node is used to make its routing decisions using the data from other nodes. The nodes which are transmitting don't include any data regarding link status.

### Centralized

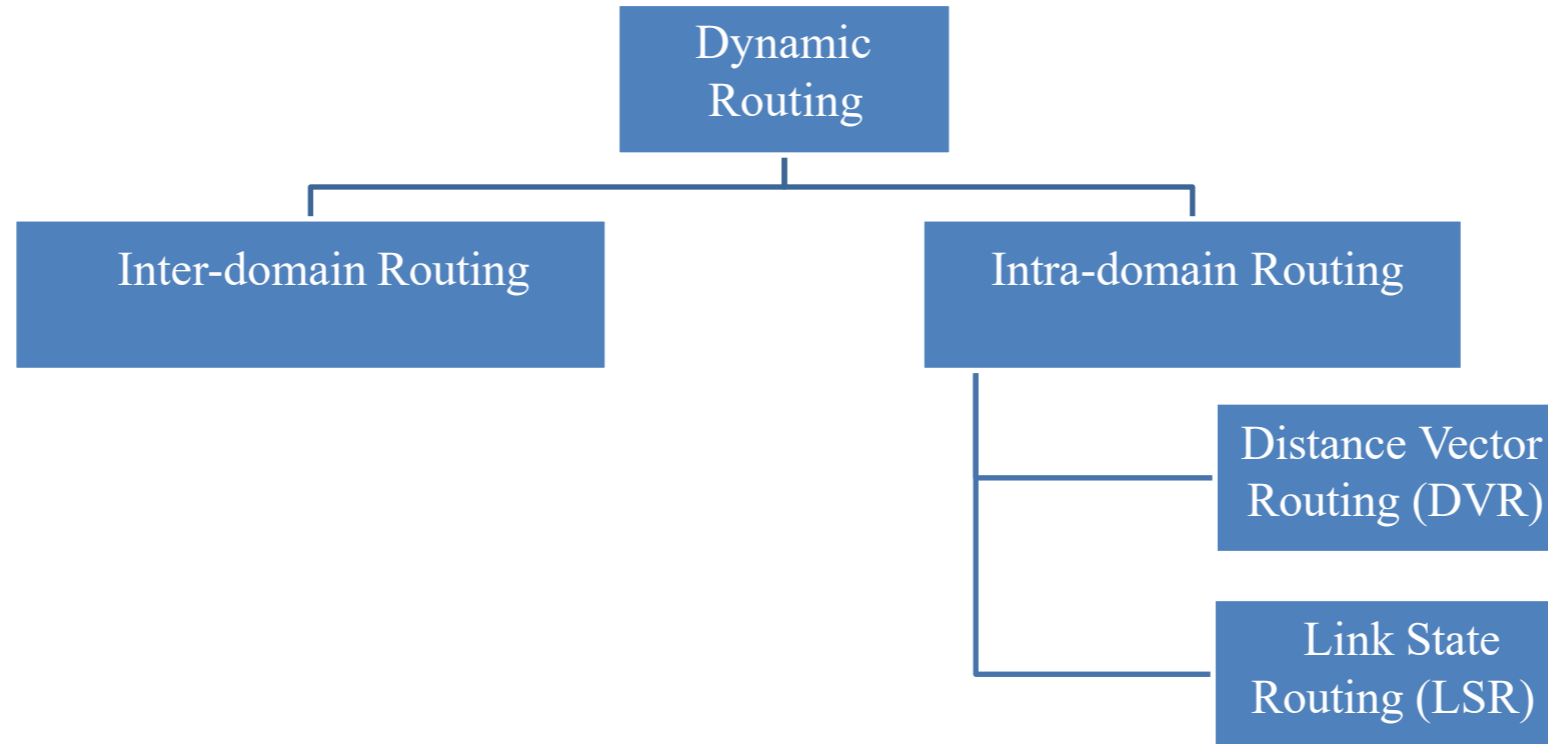
In the centralized method, a node has whole information regarding the network so that it can make all the decisions of routing. The main benefit of this algorithm is it requires the only single node to keep the data of the complete network.

### Distributed

In this method, the node receives information from its neighbors and then decides to route the packets. The disadvantage is that the packet may be delayed if there is a change in between interval in which it receives information and sends the packet.

## Dynamic Routing Algorithms

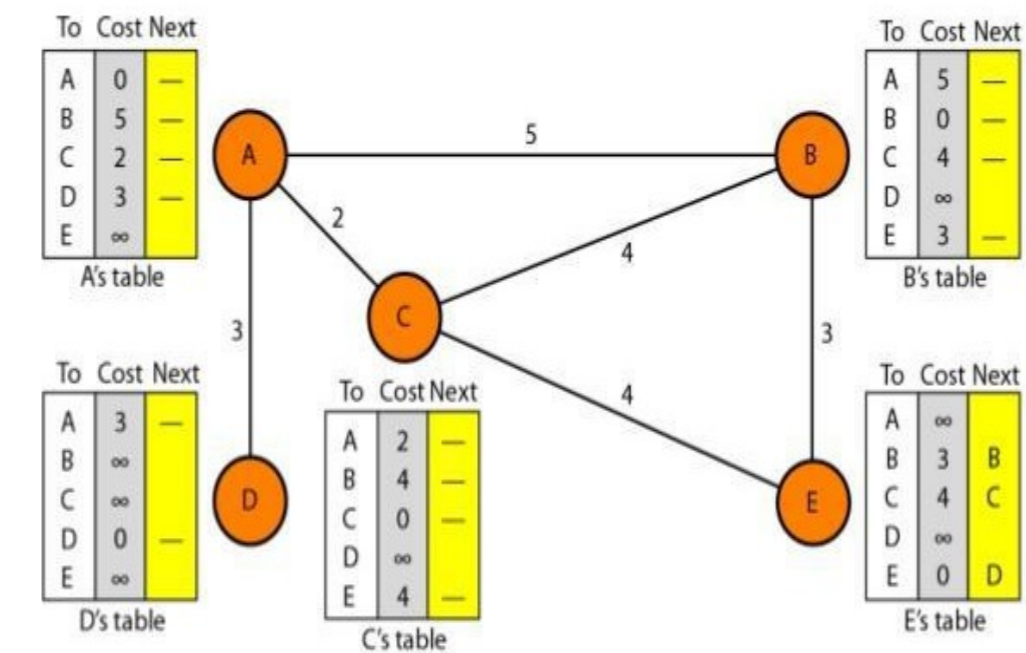
1. Distance Vector Routing (DVR).
2. Link State Routing (LSR).



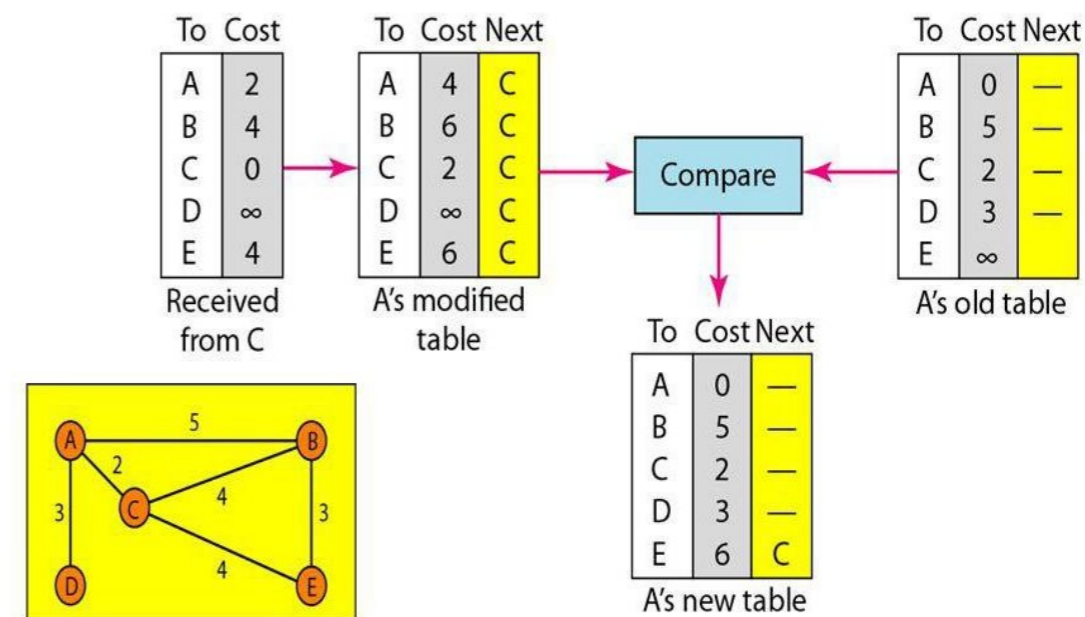
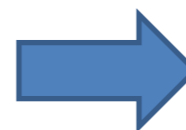
## Distance Vector Routing

- Distance Vector routing is **intra-domain** protocols, **inside** Autonomous system, but not between Autonomous system.
- distance-vector routing is based on the **least-cost** goal.
- Distance Vector developed by **Bellman-Ford** algorithm.
- Bellman **equation** is used to find the **least cost (shortest distance)** between a source to destination.
- A **distance vector routing algorithm** operates by having each router **maintain a table** (i.e., a **vector**) giving the best known distance to each destination.
- These tables are **updated by exchanging** information with the neighbors router. Every router knows the **best link** to reach each destination.
- **RIP** based on distance vector routing, each router **shares, at regular intervals**, its knowledge about entire AS with its neighbor.
- It is so **slow** and does not take **Bandwidth** into consideration when choose the root.

# Q: Update the Router (A) using Distance vector algorithm



**Initialization of Tables in Distance Vector Routing (DVR)**



**Final Update of Tables in Distance Vector Routing (DVR)**

# Distance vector algorithm

*Bellman-Ford equation (dynamic programming)*

let

$d_x(y) := \text{cost of least-cost path from } x \text{ to } y$

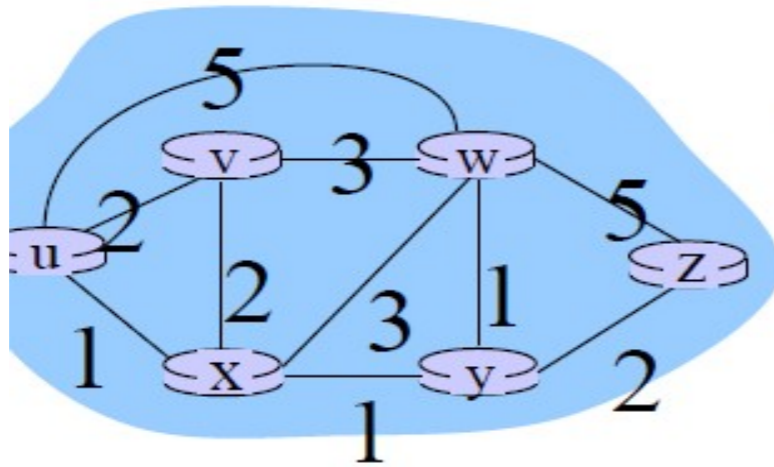
Then

$$d_x(y) = \min_v \{ c(x,v) + d_v(y) \}$$

$v$   
|  
 $\min$  taken over all neighbors  $v$  of  $x$   
  
 $c(x,v)$   
|  
cost to neighbor  $v$   
  
 $d_v(y)$   
|  
cost from neighbor  $v$  to destination  $y$

- $D_x(y)$  = estimate of least cost from  $x$  to  $y$   
   $x$  maintains distance vector  $\mathbf{D}_x = [D_x(y): y \in \mathbf{N}]$
- node  $x$ :
  - knows cost to each neighbor  $v$ :  $c(x,v)$
  - maintains its neighbors' distance vectors. For each neighbor  $v$ ,  $x$  maintains  $\mathbf{D}_v = [D_v(y): y \in \mathbf{N}]$

# Bellman-Ford example



clearly,  $d_v(z) = 5$ ,  $d_x(z) = 3$ ,  $d_w(z) = 3$

B-F equation says:

$$\begin{aligned} d_u(z) &= \min \{ c(u,v) + d_v(z), \\ &\quad c(u,x) + d_x(z), \\ &\quad c(u,w) + d_w(z) \} \\ &= \min \{ 2 + 5, \\ &\quad 1 + 3, \\ &\quad 5 + 3 \} = 4 \end{aligned}$$

node achieving minimum is next  
hop in shortest path, used in forwarding table

## Link State Routing

The **primary problem in distance vector** that the algorithm often took **too long to converge** after the network topology changed (due to the count-to-infinity **problem**). Consequently, it was **replaced by** a new algorithm, now called link state routing.

**The idea behind link state routing** is simple and can be stated as five parts. Each router must:

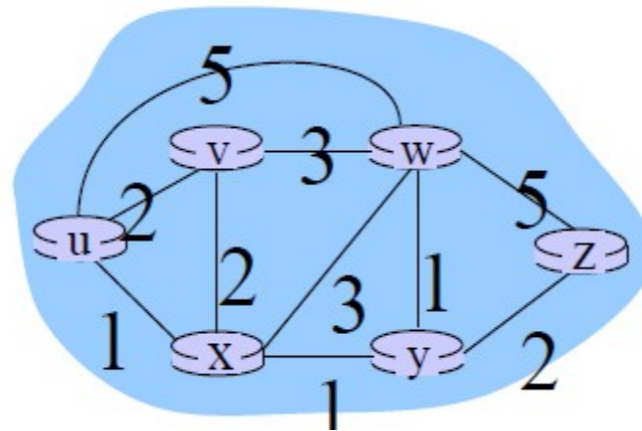
- 1) **Discover** its neighbors and learn their network addresses.
- 2) **Measure** the delay or cost to each of its neighbors.
- 3) **Construct** a packet telling all it has just learned.
- 4) **Send** the packet to all other routers.
- 5) **Compute** the shortest path to every other router.

**Compared to distance vector routing**, link state routing requires **more memory and computation**. Also, the **computation time** grows faster. Nevertheless, in many practical situations, link state routing works **well because it does not suffer from slow convergence problems**.

**Q: Consider the following network, construct shortest path tree from u to z using Dijkstra algorithms**

## Dijkstra's algorithm: example

Step	N'	D(v),p(v)	D(w),p(w)	D(x),p(x)	D(y),p(y)	D(z),p(z)
0	u	2,u	5,u	1,u	$\infty$	$\infty$
1	ux	2,u	4,x		2,x	$\infty$
2	uxy	2,u	3,y			4,y
3	uxyv		3,y			4,y
4	uxyvw					4,y
5	uxyvwz					



## Q: Compare between LSR & DVR

LSR	DVR
<ul style="list-style-type: none"><li>• All routers have complete topology, link cost info.</li><li>• Updates are incremental and entire routing table is not sent as update.</li><li>• Convergence is fast because of triggered updates.</li><li>• <b>More difficult to configure.</b></li></ul>	<ul style="list-style-type: none"><li>• Router knows physically-connected neighbors, link costs to neighbors</li><li>• Entire routing table is sent as an update</li><li>• Slow Convergence due to the count to infinity problem.</li><li>• <b>Easy to configure.</b></li></ul>

## Broadcast Routing

- For some applications, hosts need to send messages to **many or all other hosts**. **Broadcast routing** is used for that purpose.
- The source should send the packet to **all** the necessary destinations. **One of the problems of this method** is that the source has to have the complete list of destinations.
- We have already seen a better broadcast routing technique: **flooding**.

## Multicast Routing

- Sending a message to such a **group** is called **multicasting**, and the routing algorithm used is called **multicast routing**.
- All multicasting schemes require some way to **create and destroy groups and to identify which routers are members of group**.

### Q: Compare between broadcast and Multicast Routing?

Multicast Routing	Broadcast Routing
<ul style="list-style-type: none"><li>• Sending a message to such a <b>group</b> is called <b>multicasting</b>, and the routing algorithm used is called <b>multicast routing</b>.</li><li>• All multicasting schemes require some way to <b>create and destroy groups and to identify which routers are members of group</b>.</li></ul>	<ul style="list-style-type: none"><li>• Send messages to <b>many or all other hosts</b>.</li><li>• The source should send the packet to <b>all</b> the necessary destinations. <b>One of the problems of this method</b> is that the source has to have the complete list of destinations. Therefore, the better broadcast routing technique is <b>flooding</b>.</li></ul>