CSC361

Computer Networking

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Unit 7

Network Layer & Routing

Important Concepts

- What is a Router?
- Routing Algorithms
- Route Propagation
- Distance-Vector (Bellman-Ford) Routing
- Link-State (Dijkstra) Routing
- Autonomous System Concept
- Exterior Gateway Protocol

What We Learned So Far

- TCP/UDP are end-to-end protocols.
- The Internet is built around the IP (Network) layer, which provides packet forwarding and routing.
- Each router works independently and knows only its directly connected neighbors.
- Each router uses a **forwarding table** to determine how to forward packets to the destination network id.

Routing Basic (17:55)

Summary

- How packets are routed?
  - Flooding
  - Source routing
  - Forwarding table
  - Spanning tree minimizing (e.g., distance, delay, hop-count, throughput, lowest-cost, etc.)
  - Multipath
  - Multicast

Routers, Switches, Packets and Frames (9:11)

(how packets move across networks)

Summary

- A router has **multiple** interfaces, each has its IP address.
- When a router connects two networks, it must have two IP addresses, one from each network.
- When a client sends a packet to a (local) router, it uses the MAC address to deliver the packet.
- When a router receives a packet, it must identify the destination `network id` and forwards it via the **correct** interface.

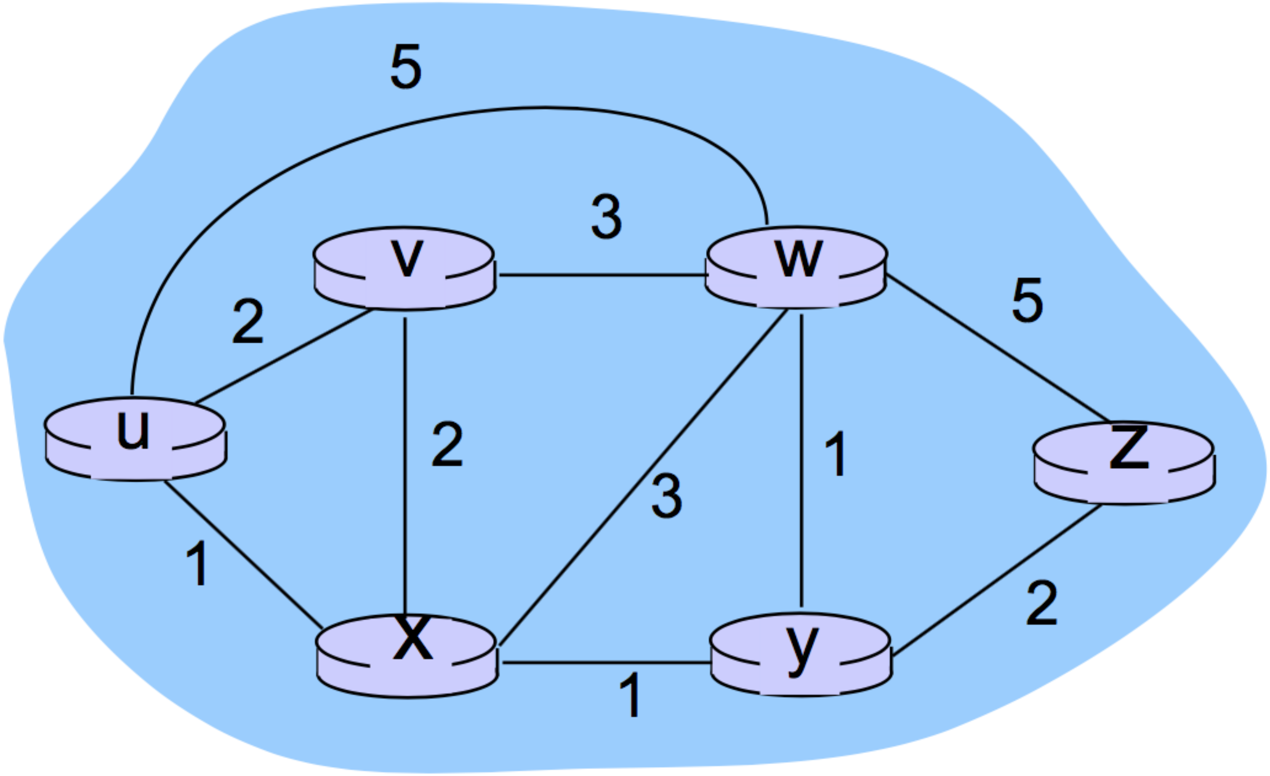
Summary (continued)

- A packet moves hop-by-hop, from source to destination.
- Along each hop, the MAC addresses are used for delivering the packet inside a frame.
- By examining the packet **dest** IP address (or `network id`), a router can decide how to forward this packet to the next hop.
- The Link layer does hop-by-hop `MAC address` **frame** forwarding; the IP Layer does `network id` **packet** forwarding.

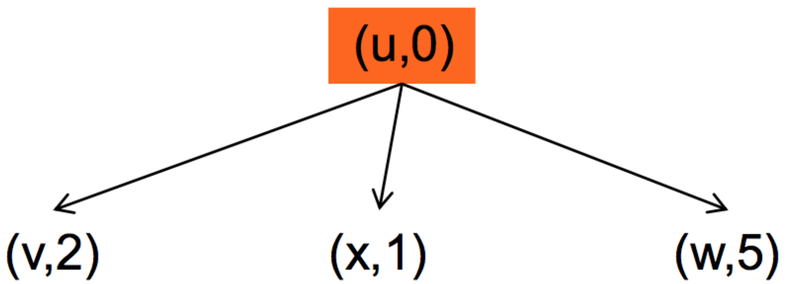
Link State Routing (Dijkstra)

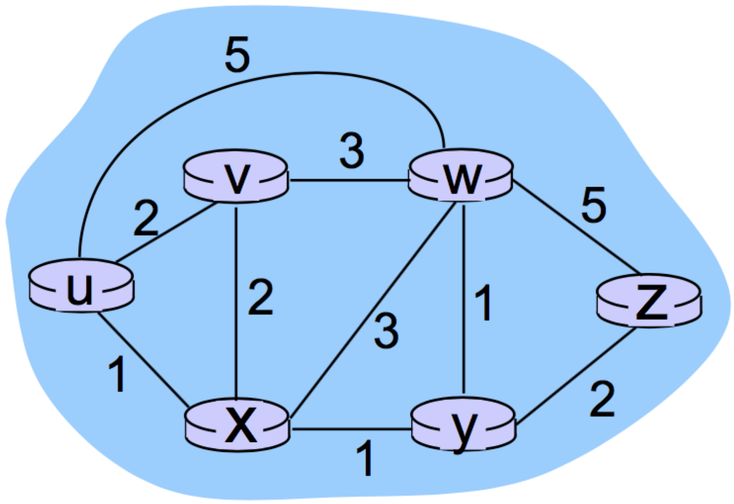
Summary

- Interconnected routers flood each other with the states of its links **periodically** or whenever a link changes its state.
- Each calculates its short-path-spanning-tree to every other nodes.
- When there is an update, a router re-calculates all over again.
- It is the basis of the **OSPF** (Open Short Path First) routing protocol.

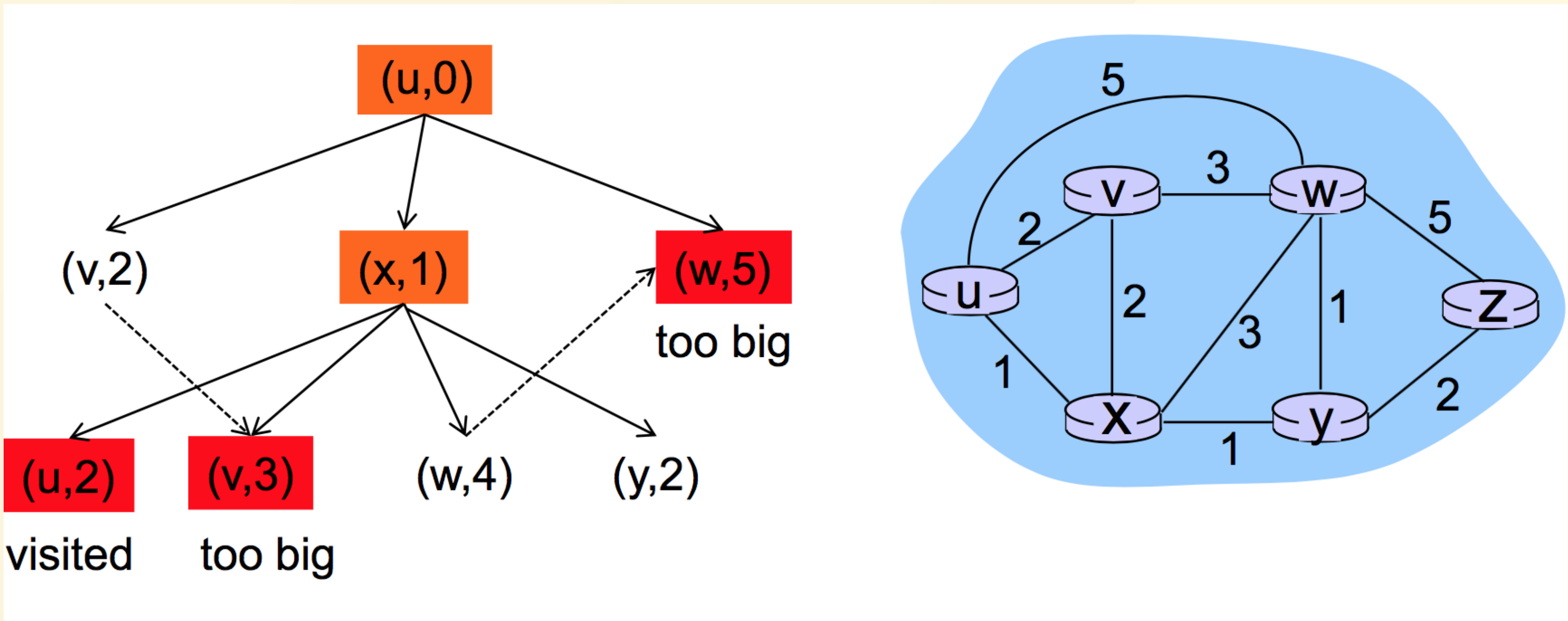


Let us try this starting from u!





Q. Which neighbors of u has the “least cost” path?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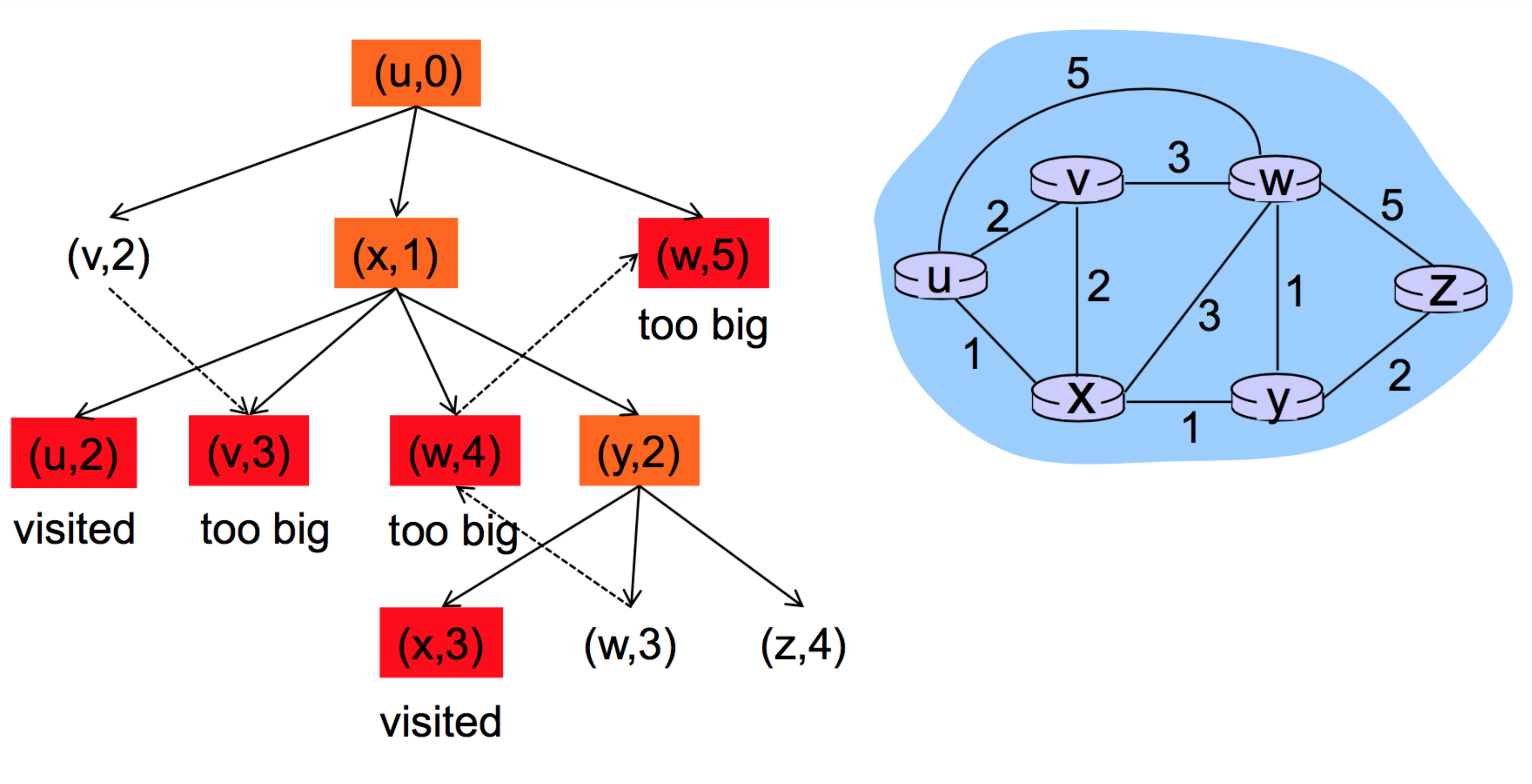
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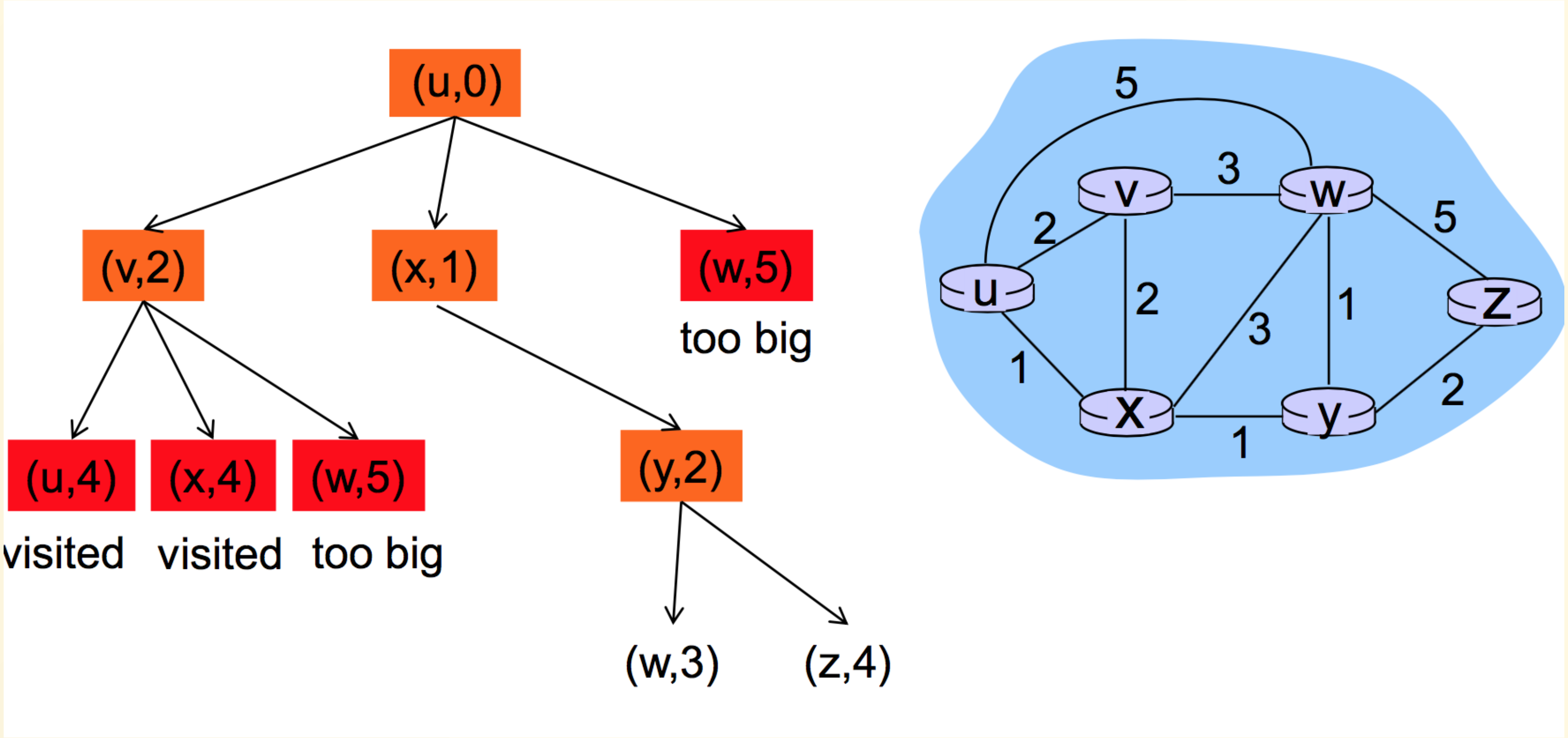

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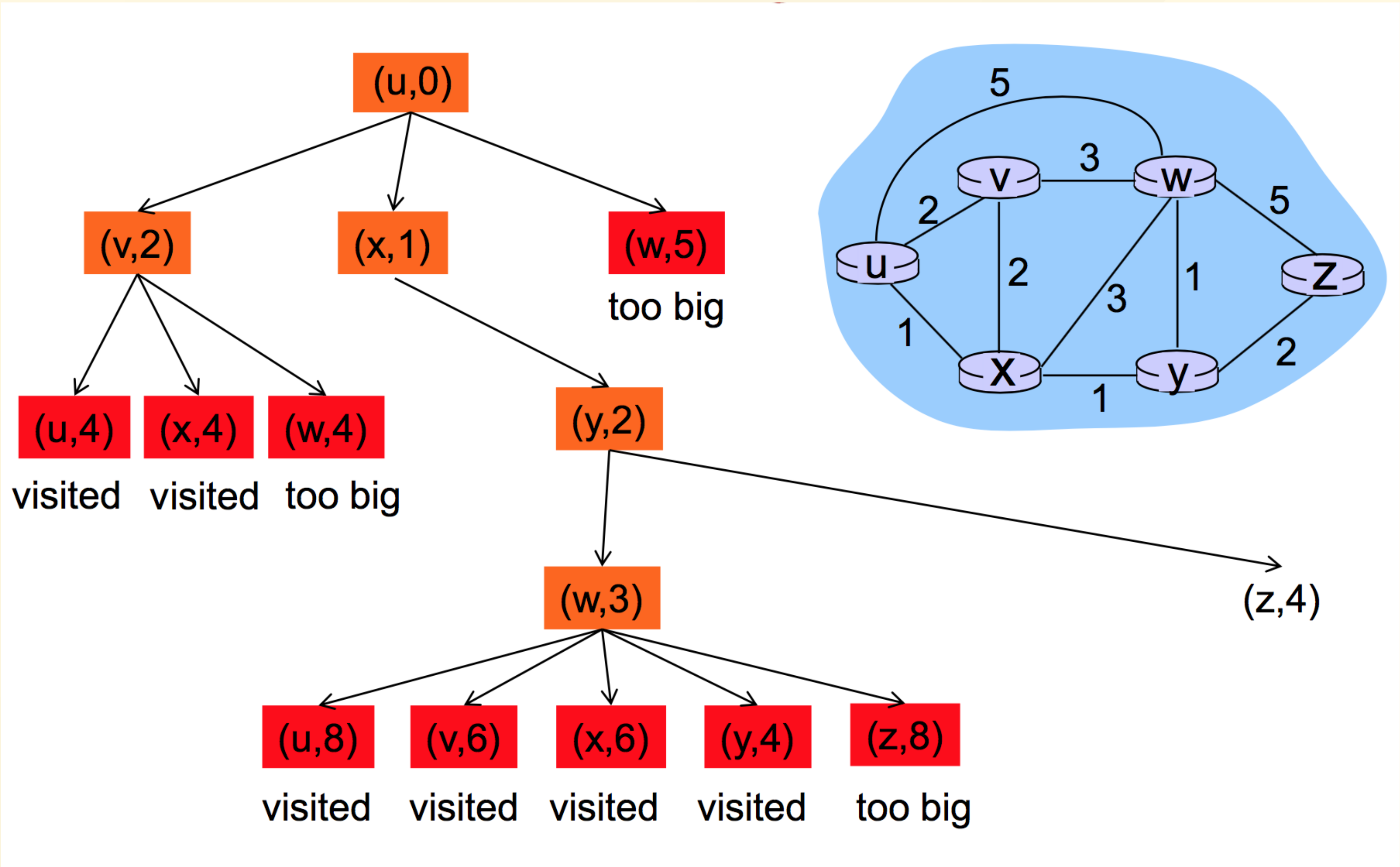

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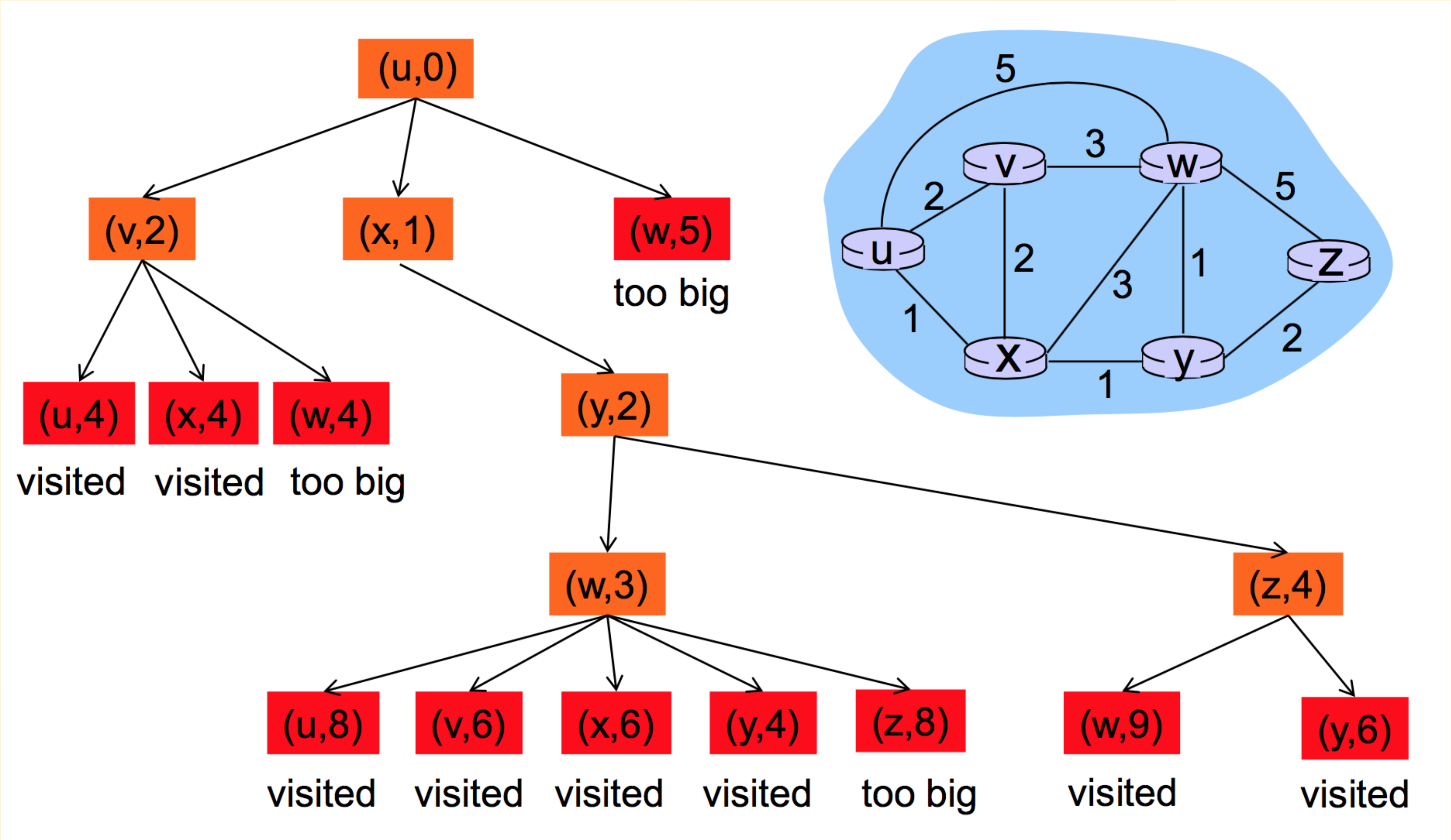

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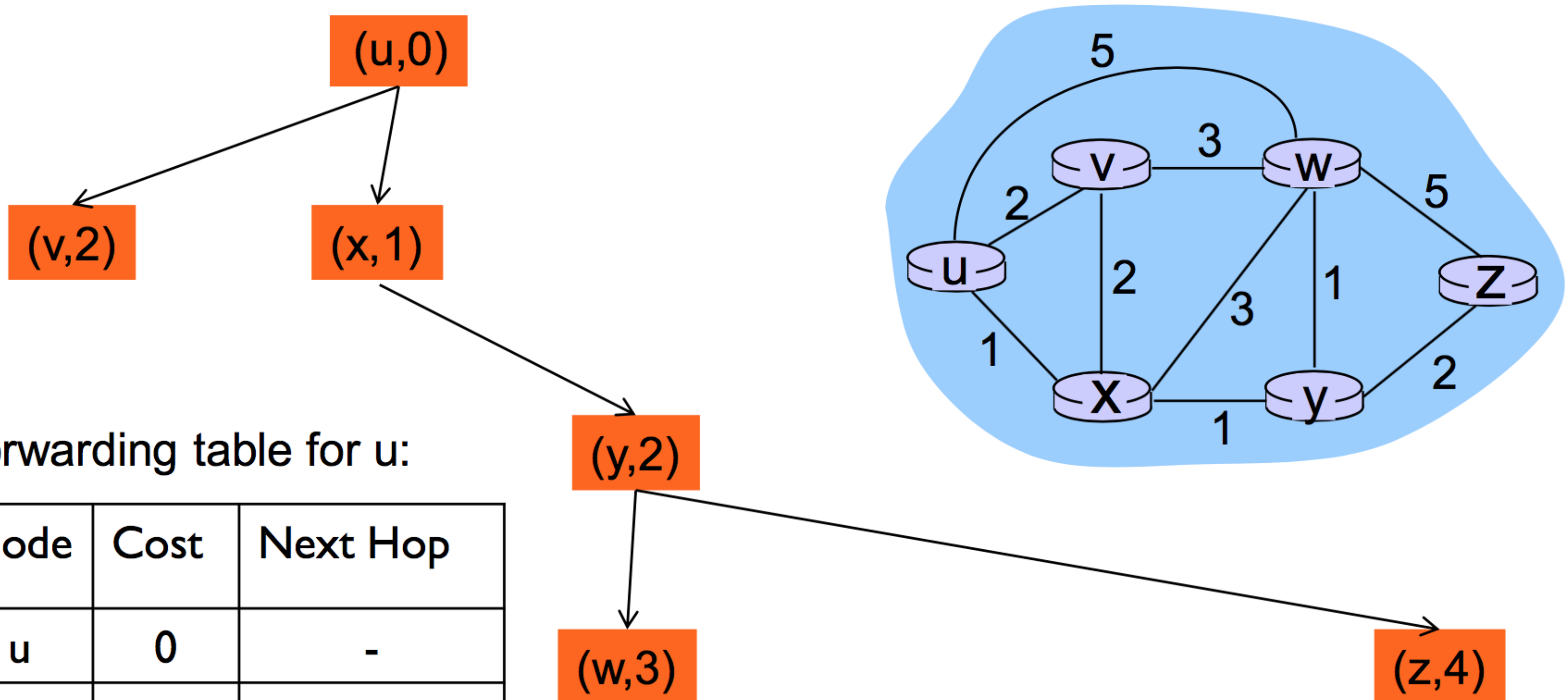
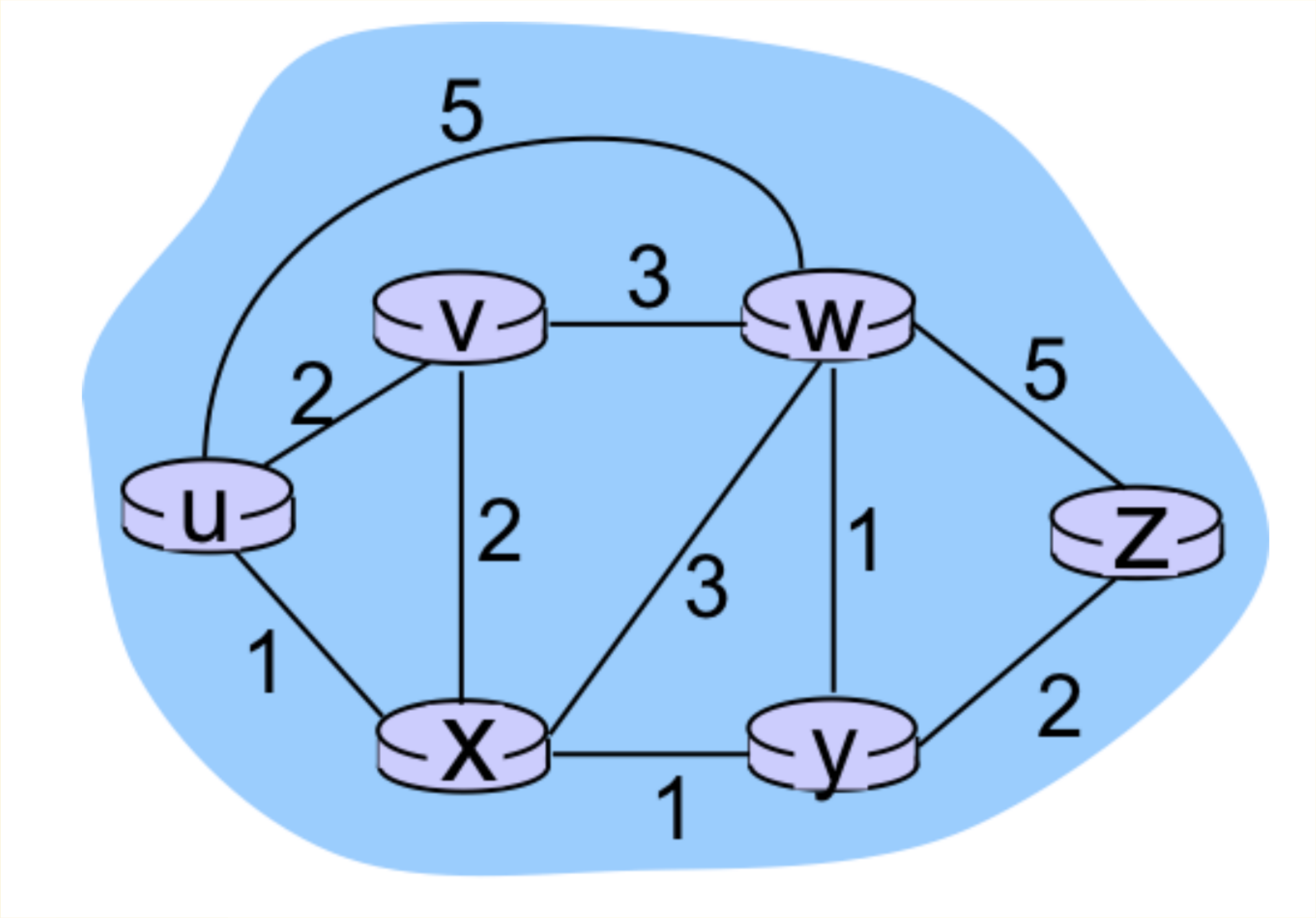


Forwarding table for u:

Node	Cost	Next Hop
u	0	-
v	2	v
w	3	x
x	1	x
y	2	x
z	4	x

Try this starting from z!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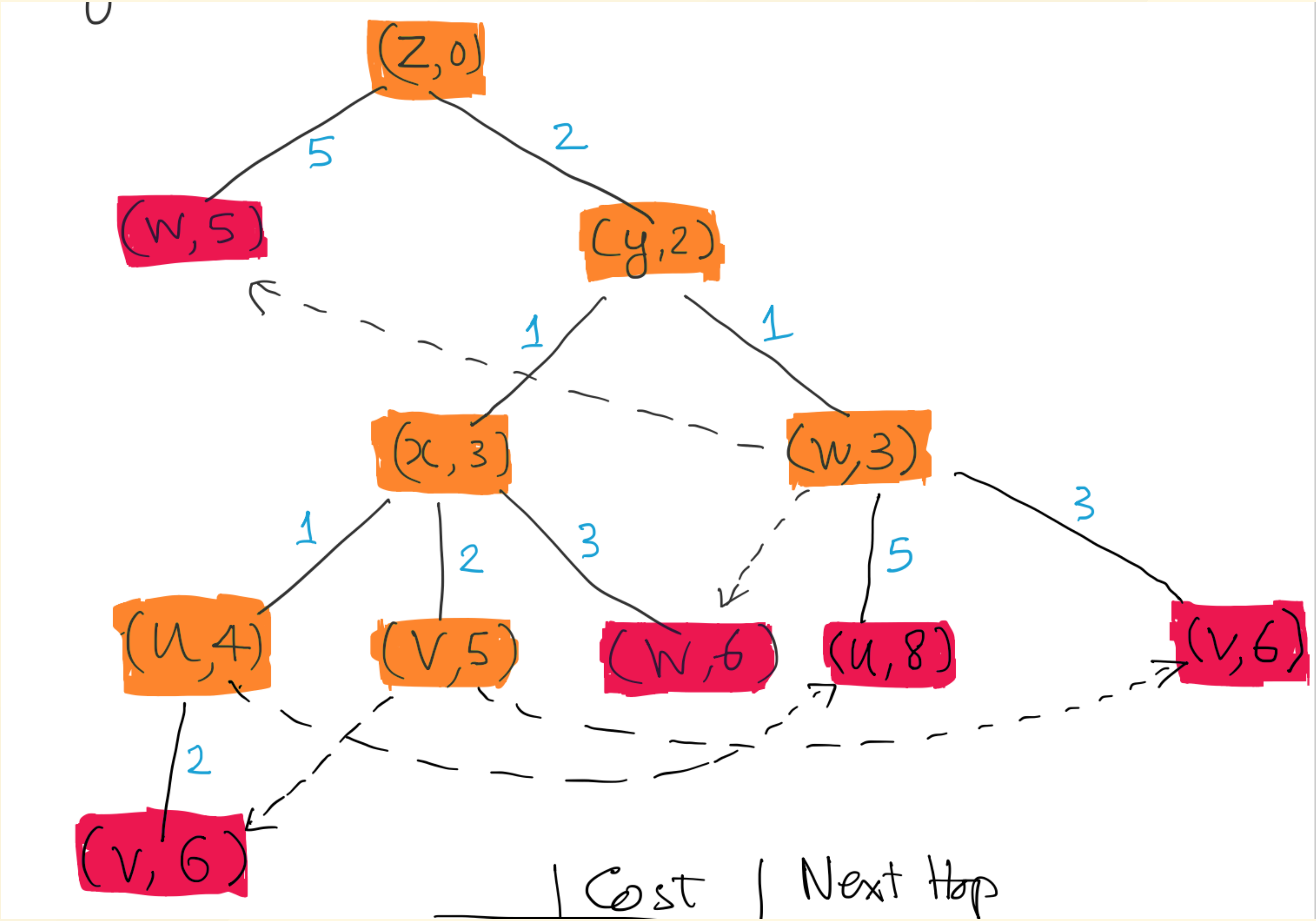

(Z,0)
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(w,5)
(y,2)
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(x,3)
(w,3)
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3
(u,4)
(v,5)
(w,6)
(u,8)
(v,6)
2
(v,6)
| Cost | Next Hop

Distance Vector Routing (Bellman-Ford) (16:48)

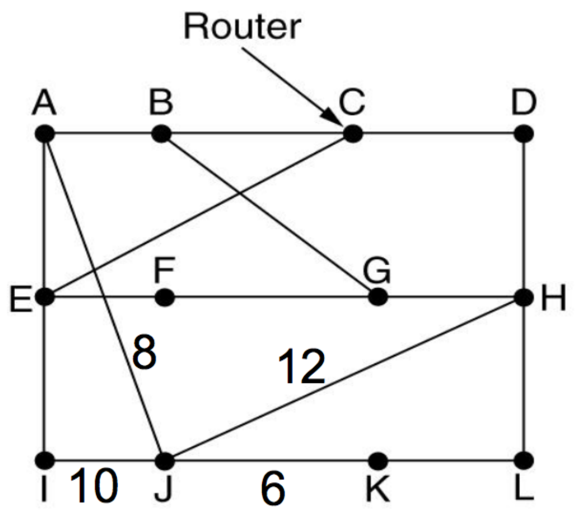
Summary

- Bellman-Ford Equation:

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

where $D(x,y)$=**least cost** path from x to y, and $c(x,v)$=**cost** from x to neighbor v.

- It is the basis of Routing Information Protocol (**RIP**).



(a)

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	New routing table for J	

Vectors received from J's four neighbors

(b)

J receives 4 updates from A,I,H and K. It updates its DV table with next hop. It then transmits its new estimated to all its neighbors.

Routing Autonomous Systems (21:56)

(Internet Routing in Practice)

Summary

- The Internet is decomposed into many **Autonomous Systems**, each has a **globablly unique** `AS` number.
- Each AS is a self-contained collection of private networks, e.g., Stanford (32), AT&T (797), Google (15169), etc.
- Within an `AS`, it runs its routing protocols (e.g.,RIP, OSPF).
- Between `AS`es, the Internet uses **BGP** (Border Gateway Protocol) for `AS` routing.

Border Gateway Protocol (16:38)

Summary

- Each router knows all its **prefixes** within its `AS`.
- **BGP** is the routing protocol used to route to exterior `AS`es.
- **BGP** is primarily **policy-driven** routing protocol, not **cost-drive**.
- Each `AS` **must** trust its peer `AS`es in order to allow their traffic to get through.
- BGP uses `AS-PATH`es to determine how to reach the destination `AS`es.

The End