ECCS-3631
Networks and Data Communications

Module 2-1
Network Layer, Routing Fundamentals, Link State Routing Algorithm

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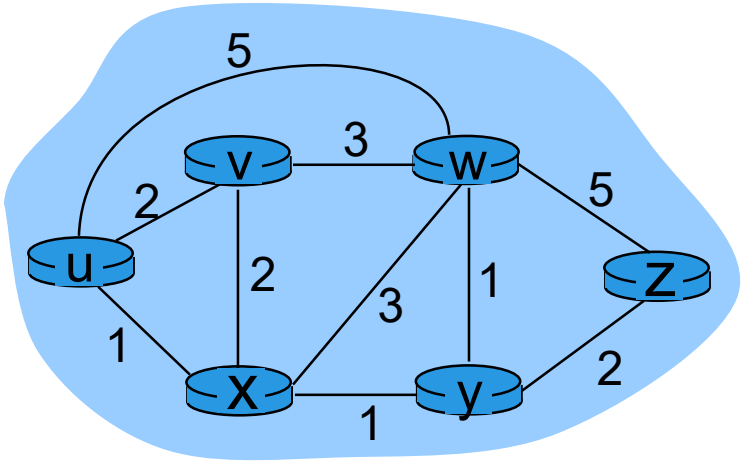
Routing Goal

Routing goal: determine "good" paths (equivalently, routes), from sending hosts to receiving host, through network of routers

path: sequence of routers packets will traverse in going from given initial source host to given final destination host

"good": least "cost", "fastest", "least congested"

Graph abstraction of the network

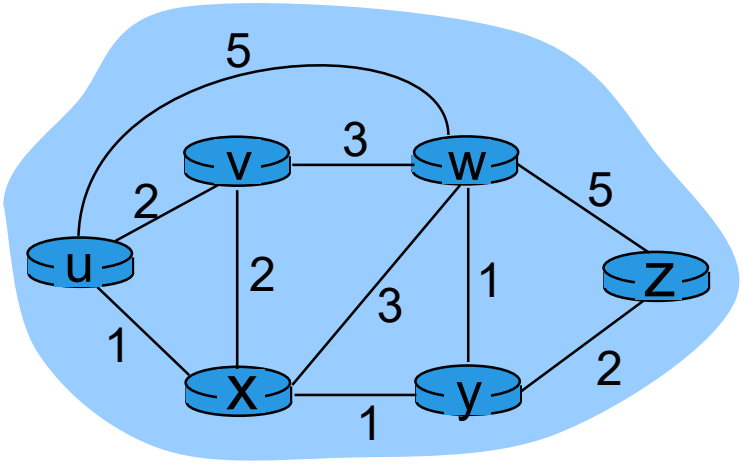


graph: G = (N,E)

N = set of routers = { u, v, w, x, y, z }

E = set of links ={ (u,v), (u,x), (v,x), (v,w), (x,w), (x,y), (w,y), (w,z), (y,z) }

Graph abstraction: costs



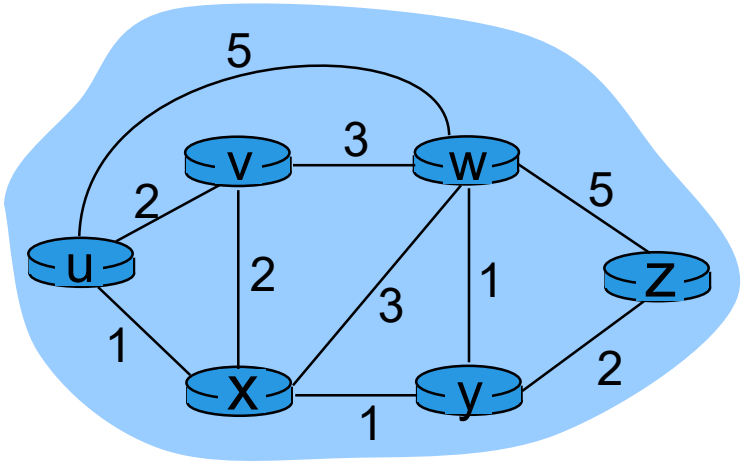
c(x,x') = cost of link (x,x')
e.g., c(w,z) = 5, c(u,v) = 2

cost could always be 1, or
inversely related to bandwidth, or
inversely related to congestion

cost of path $(x_1, x_2, x_3, \ldots, x_p) = c(x_1,x_2) + c(x_2,x_3) + \ldots + c(x_{p-1},x_p)$

Review Question

- What is the least-cost path between u and z?
- How to find that least-cost path?



The least-cost path between u and z is 4.

Routing Algorithms are used to find that least-cost path.

Network Routing: Algorithms & Protocols

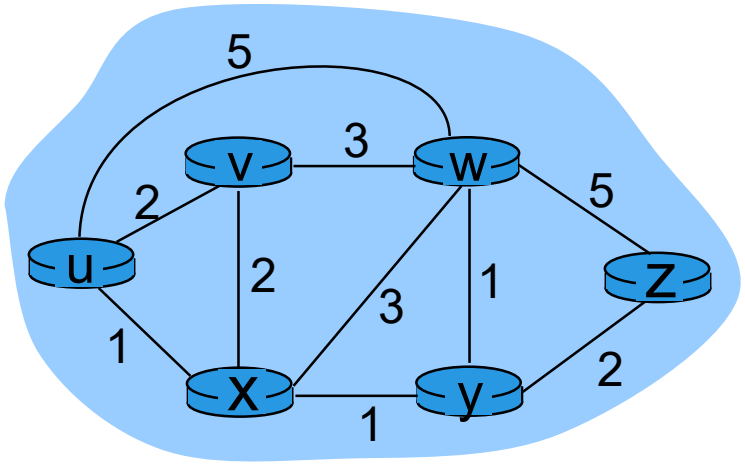
Routing Algorithms

Link-State (Dijkstra)

- each router knows complete topology & link cost information
- Run routing algorithm to calculate shortest path to each destination

Distance-Vector (Bellman-Ford)

- Each router knows direct neighbors & link costs to neighbors
- Calculate the shortest path to each destination through an *iterative* process *based on the neighbors distances* to each destination



Routing Protocols

- define the format of routing information exchanges
- define the computation upon receiving routing updates
- network topology changes over time, routing protocol must continuously update the routers with latest changes

Link-State Routing Algorithm

Dijkstra's Algorithm

net topology, link costs known to all nodes

- accomplished via "link state broadcast"
- all nodes have same info

computes least cost paths from one node ('Source') to all other nodes

- Creates *forwarding table* for that node

iterative: after k iterations, source knows least cost path to k destinations

notation:

c(x,y): link cost from node x to y; (∞ if not direct neighbors)

D(v): current value of cost of path from source to

destination v

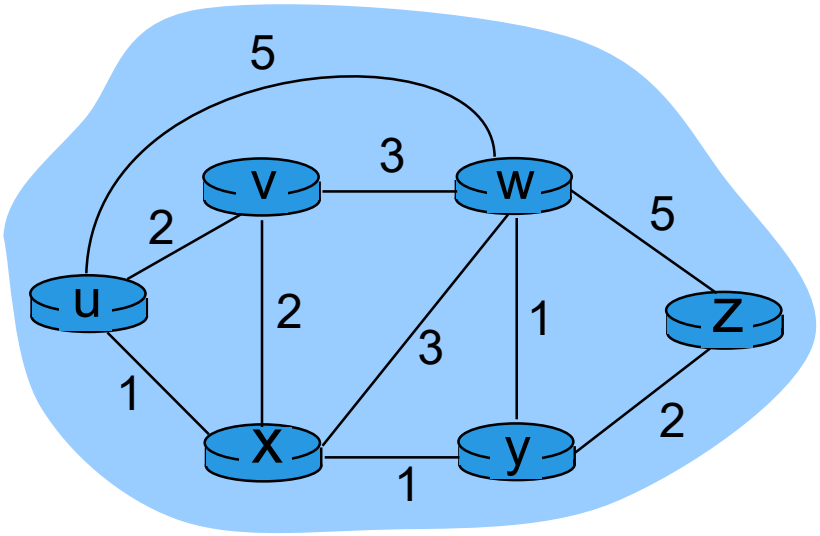
p(v): predecessor node along path from source to v (neighbor of v)

N': set of nodes whose least cost path already known

Dijkstra's Algorithm: Example

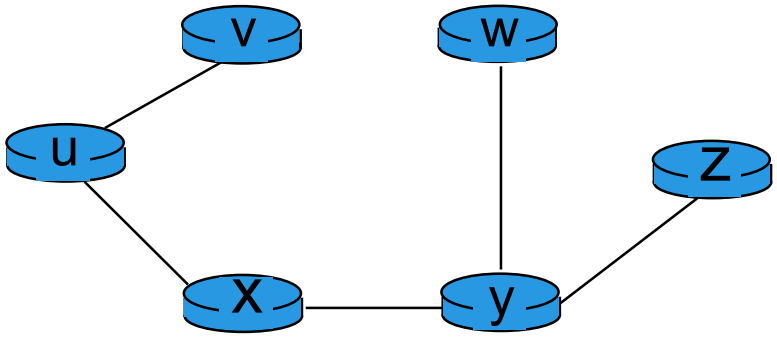
Computer the short-path from u to all network nodes using Dijkstra's Algorithm

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	∞	∞
1	ux	2,u	4,x		2,x	∞
2	uxy	2,u	3,y			4,y
3	uxyv		3,y			4,y
4	uxyvw					4,y
5	uxyvwz					



Dijkstra's Algorithm: Example

resulting shortest-path tree from u:



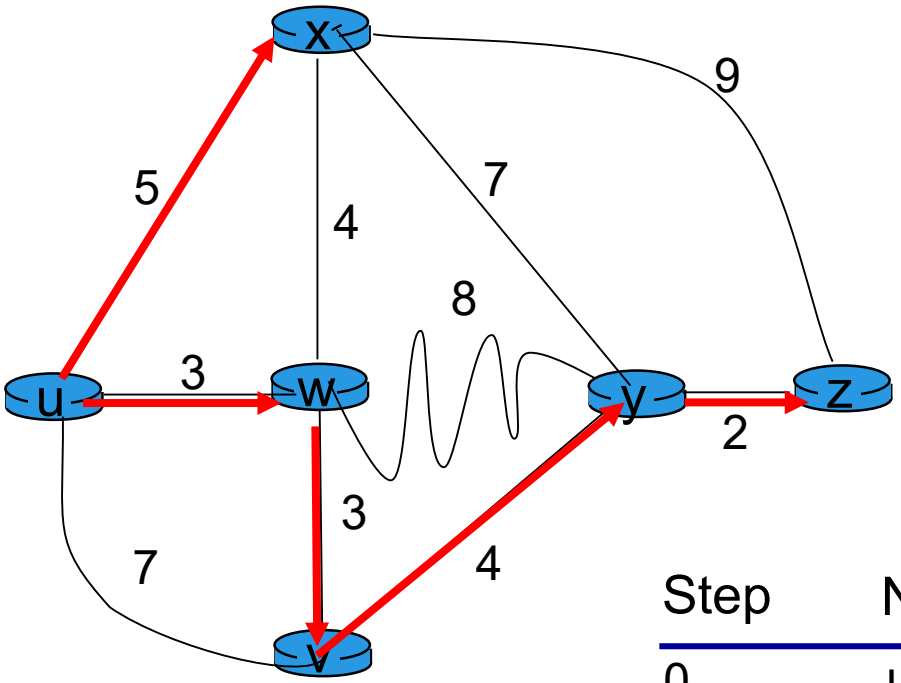
resulting forwarding table at u:

destination	link
v	(u,v)
x	(u,x)
y	(u,x)
w	(u,x)
z	(u,x)

Dijkstra's Algorithm, Discussion

- Algorithm complexity: n nodes
- each iteration: need to check all nodes, w, not in N
- n(n+1)/2 comparisons:
- more efficient implementations possible, Distance-Vector Algorithm

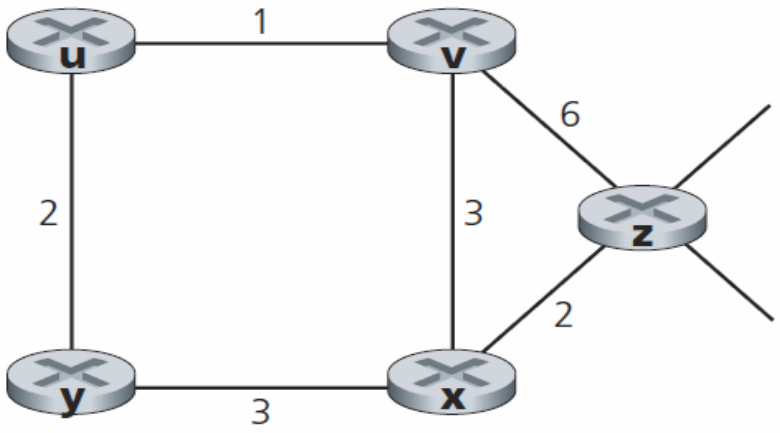
Dijkstra's Algorithm: another example



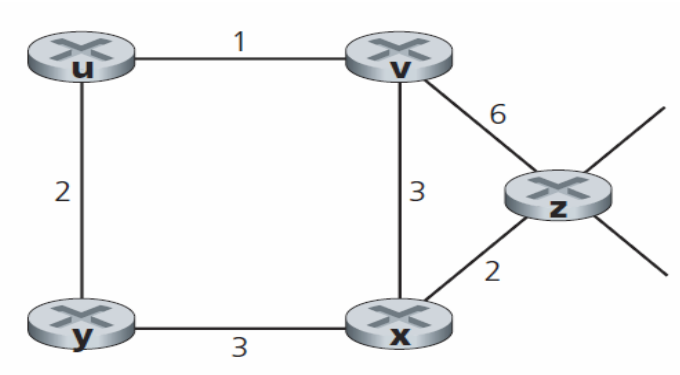
Step	N'	D(**v**) p(v)	D(**w**) p(w)	D(**x**) p(x)	D(**y**) p(y)	D(**z**) p(z)
0	u	7,u	3,u	5,u	∞	∞
1	uw	6,w		5,u	11,w	∞
2	uwx	6,w			11,w	14,x
3	uwxv				10,v	14,x
4	uwxvy					12,y
5	uwxvyz					

Dijkstra's Algorithm, Practice Problem 1

Compute the shortest path from **z** to all network nodes, using Dijkstra Algorithm.

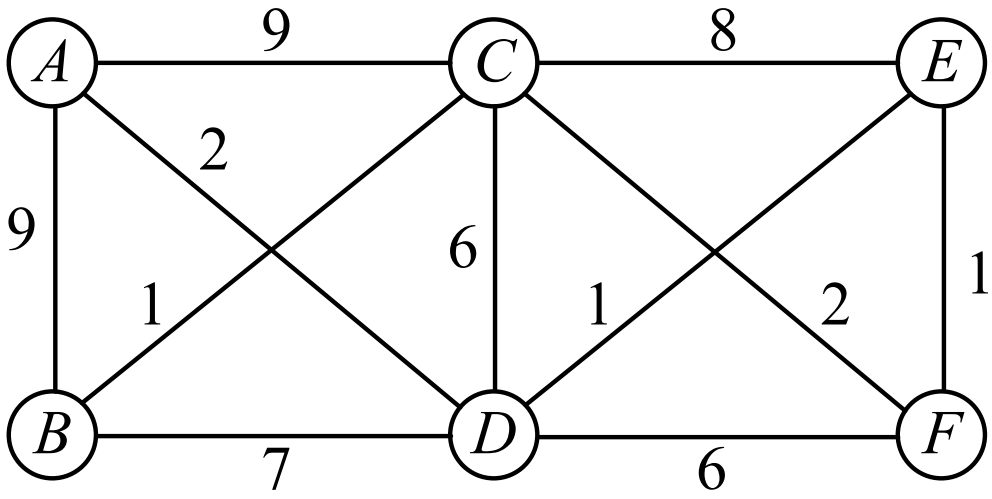


Dijkstra's Algorithm, Practice Problem 1



Dijkstra's Algorithm, Practice Problem 2

Consider the following network. With the indicated link costs, compute the shortest path from A to all network nodes using Dijkstra Algorithm.



Dijkstra's Algorithm, Practice Problem 2