2. Link State Routing

- Each node maintains the three lists

H, D, C

- Each node broadcasts its local link state information to all other nodes in the network
  - Often via flooding

Protocol : local info exchanged globally via flooding

Each node has complete information about all link information in the network.

Link State Routing (Algorithm)

- Each node will calculate its shortest paths to all other nodes upon receiving new link state information
  - Dijkstra's Shortest-Path Routing Algorithm
    - An iterative algorithm to find the shortest paths from a source node to all other nodes in the network

Dijkstra's Algorithm

- Notations:
  - s: source node
  - N: the set of nodes whose shortest paths have already been found
- Initialization Step
  - $N = \{s\}$, $D_{sj} = C_{sj}$ and $H_{sj} = j$ for all j

Dijkstra's Algorithm

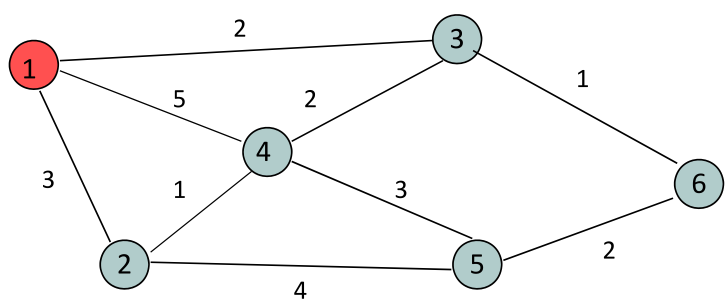
- Notations:
  - s: source node
  - N: the set of nodes whose shortest paths have already been found
- Step A: (Finding the next closest node i)
  - Find node $i \notin N$ such that $D_{si} = \min D_{sj}$ for $j \notin N$
  - Add i to N
  - If N contains all the nodes, Stop

Dijkstra's Algorithm

- Notations:
  - s: source node
  - N: the set of nodes whose shortest paths have already been found
- Step B: (Updating minimum costs after node i is added to N)
  - For each node $j \notin N$
    - if $(D_{si} + C_{ij}) < D_{sj}$, then $D_{sj} = D_{si} + C_{ij}$ and $H_{sj} = H_{si}$
  - Go to Step A

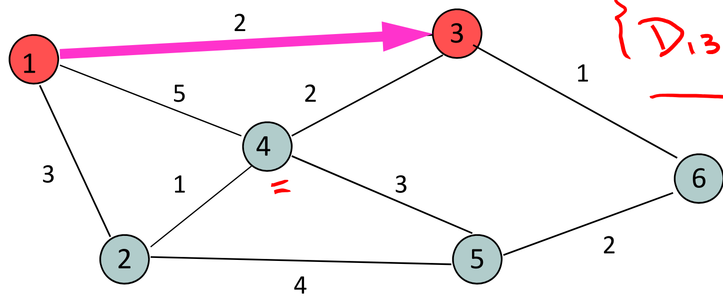
$s \to i \to j$

Example: From Source Node 1



Iteration	N	H_{12}; D_{12}	H_{13}; D_{13}	H_{14}; D_{14}	H_{15}; D_{15}	H_{16}; D_{16}
Initial	{1}	2; 3	3; 2	4; 5	5; ∞	6; ∞

Example: From Source Node 1



$D_{14} = 5$

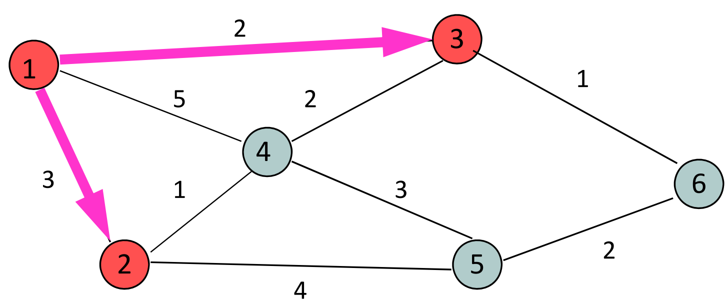
$\left\{ D_{13} + C_{34} = 2 + 2 = 4 \right.$

$\Downarrow$

$D_{14} = 4$

Iteration	N	H_{12}; D_{12}	H_{13}; D_{13}	H_{14}; D_{14}	H_{15}; D_{15}	H_{16}; D_{16}
Initial	{1}	2; 3	3; 2	4; 5	5; ∞	6; ∞
1	{1,3}	2; 3	3; 2	3; 4	5; ∞	3; 3

Example: From Source Node 1



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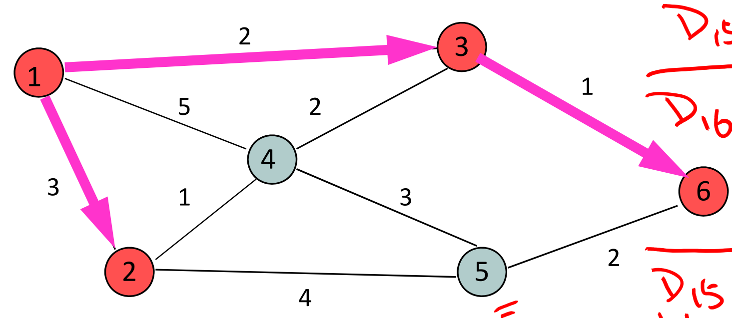
Initial	{1}	2; 3	3; 2	4; 5	5; ∞	6; ∞
1	{1,3}	2; 3	3; 2	3; 4	5; ∞	3; 3
2	{1,2,3}	2; 3	3; 2	3; 4	2; 7	3; 3

Example: From Source Node 1



$H_{15} = 2$

$D_{15} = 7$

$D_{16} + C_{65}$

$= 3 + 2$

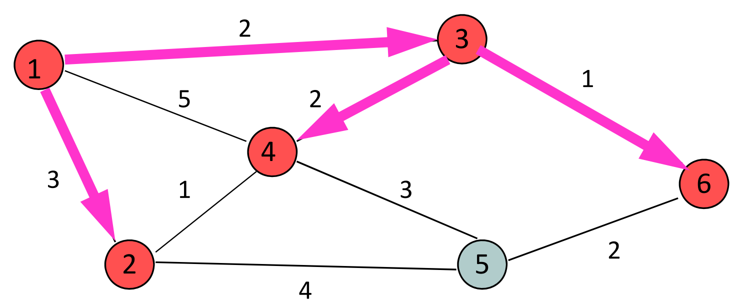
$= 5 < 7$

$D_{15} = 5$

$H_{15} = H_{16} = 3$

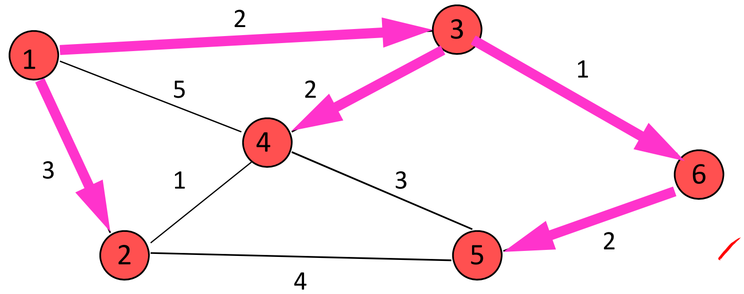
Iteration	N	H_{12}; D_{12}	H_{13}; D_{13}	H_{14}; D_{14}	H_{15}; D_{15}	H_{16}; D_{16}
Initial	{1}	2; 3	3; 2	4; 5	5; ∞	6; ∞
1	{1,3}	2; 3	3; 2	3; 4	5; ∞	3; 3
2	{1,2,3}	2; 3	3; 2	3; 4	2; 7	3; 3
3	{1,2,3,6}	2; 3	3; 2	3; 4	3; 5	3; 3

Example: From Source Node 1



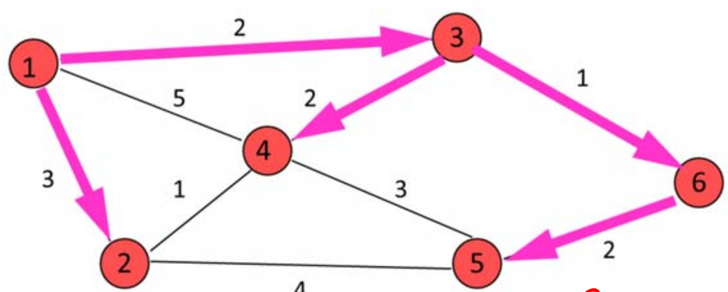
Iteration	N	H_{12}; D_{12}	H_{13}; D_{13}	H_{14}; D_{14}	H_{15}; D_{15}	H_{16}; D_{16}
Initial	{1}	2; 3	3; 2	4; 5	5; ∞	6; ∞
1	{1,3}	2; 3	3; 2	3; 4	5; ∞	3; 3
2	{1,2,3}	2; 3	3; 2	3; 4	2; 7	3; 3
3	{1,2,3,6}	2; 3	3; 2	3; 4	3; 5	3; 3
4	{1,2,3,4,6}	2; 3	3; 2	3; 4	3; 5	3; 3

Example: From Source Node 1



Iteration	N	H_{12}; D_{12}	H_{13}; D_{13}	H_{14}; D_{14}	H_{15}; D_{15}	H_{16}; D_{16}
Initial	{1}	2; 3	3; 2	4; 5	5; ∞	6; ∞
1	{1,3}	2; 3	3; 2	3; 4	5; ∞	3; 3
2	{1,2,3}	2; 3	3; 2	3; 4	2; 7	3; 3
3	{1,2,3,6}	2; 3	3; 2	3; 4	3; 5	3; 3
4	{1,2,3,4,6}	2; 3	3; 2	3; 4	3; 5	3; 3
5	{1,2,3,4,5,6}	2; 3	3; 2	3; 4	3; 5	3; 3

Example: After Algorithm Terminates, Information at Node 1



dest	H_{ij}	D_{ij}	C_{ij}
1	1	0	0
2	2	3	3
3	3	2	2
4	3	4	5
5	3	5	∞
6	3	3	∞

Reaction to Link Failure

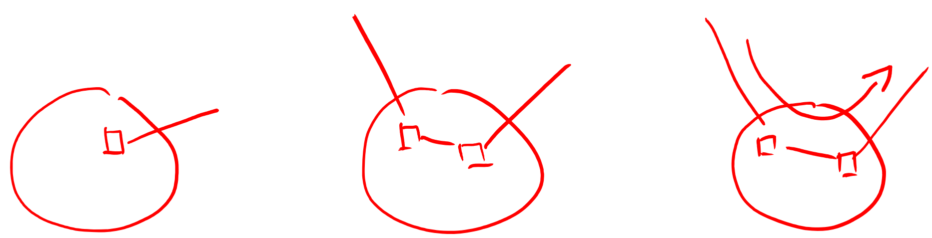
- If a link is broken,
  - Affected nodes set link cost to infinity & flood the network with update packets
  - All nodes immediately update their link database & re-calculate their shortest paths
  - Recovery is very quick

- Link State Routing is NOT loop-free
  - Due to delay in link state information propagation

Internet Routing Protocols

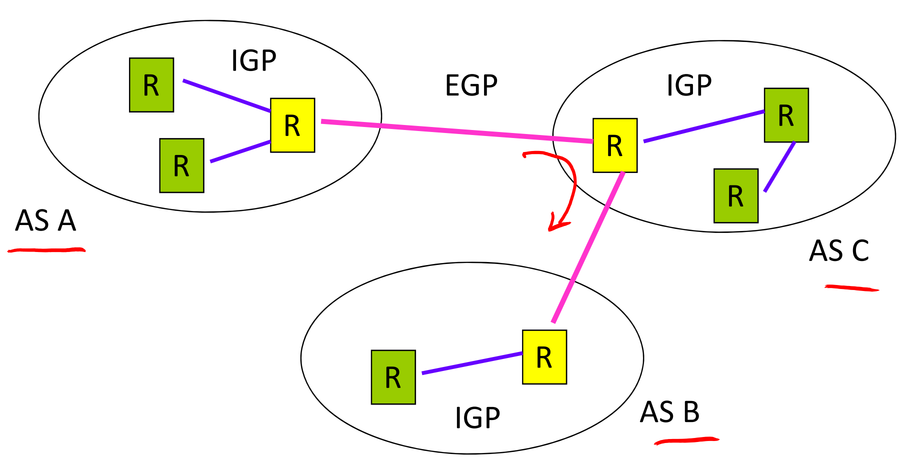
Autonomous Systems

- Autonomous System (AS) is defined as a set of routers or networks administered by a single organization
  - Stub AS: has only a single connection to the outside world
  - Multi-homed AS: has multiple connections to the outside world, but refuses to carry transit traffic
  - Transit AS: has multiple connections to the outside world, and can carry both transit and local traffic



Inter and Intra AS Routing

- IGP (Interior Gateway Protocol): routing within an AS
  - RIP, OSPF
- EGP (Exterior Gateway Protocol): routing between ASs
  - BGPv4



RIP (Routing Information Protocol)

- Distance Vector Routing Protocol
  - Split Horizon with Poisoned Reverse

- Runs on top of UDP, port # 520, **"routed"** BSD Unix program

- Routing Metric: number of hops

- Max number of hops is limited to 15
  - Suitable for small networks (local area environments)
  - 16 is reserved to represent infinity
  - Small number helps to limit the Counting-to-Infinity Problem

Routing Loop

OSPF (Open Shortest Path First)

- Link State Routing Protocol

- OSPF runs directly over IP
  - Value in the protocol field of IP headers: 89

- OSPF typically converges faster than RIP when there is a failure in the network

BGP (Border Gateway Protocol)

- Path Vector Routing Protocol
  - Avoid routing loops

- BGP
  - Is a reachability protocol
  - Uses TCP to send updates
    - Reliable transmission
    - Allow incremental updates
  - Allows for policy routing
    - Path selection by policy rather than path optimality