

Lecture (10)

Routing in Switched Networks

(III)

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Agenda

- Routing protocols
 - Fixed
 - Flooding
 - Random
 - Adaptive
- ARPANET Routing Strategies
- Least cost algorithms
 - Dijkstra's algorithm
 - Bellman-Ford algorithm

Least cost algorithms

- Virtually all packet-switching networks and all internets base their routing decision on some form of least-cost criterion.

Cost can be calculated based on:

1. if the criterion is to minimize the number of hops, each link has a value of 1.
 2. the link value is inversely proportional to the link capacity, proportional to the current load on the link, or some combination.
- It doesn't matter how we calculate cost, these link or hop costs are used as input to a least-cost routing algorithm,

Link cost and node cost

- “Given a network of nodes connected by bidirectional links, where each link has a cost associated with it in each direction, define the cost of a path between two nodes as the sum of the costs of the links traversed.
- For each pair of nodes, find a path with the least cost.”
- Link cost may differ in its two directions.
- This would be true, for example, if the cost of a link equaled the length of the queue of packets awaiting transmission from each of the two nodes on the link.

Common used least cost algorithms

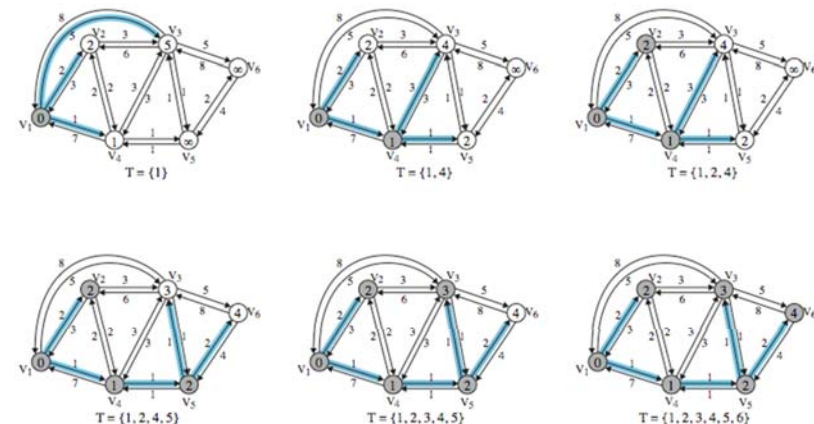
Dijkstra's algorithm

Bellman-Ford algorithm

Dijkstra's algorithm

- finds shortest paths from given source node s to all other nodes
- by developing paths in order of increasing path length
- algorithm runs in stages (next slide)
 - each time adding node with next shortest path
- algorithm terminates when all nodes processed by algorithm (in set T)

- Step 1 [Initialization]
 - $T = \{s\}$ Set of nodes so far incorporated
 - $L(n) = w(s, n)$ for $n \neq s$
 - initial path costs to neighboring nodes are simply link costs
- Step 2 [Get Next Node]
 - find neighboring node not in T with least-cost path from s
 - incorporate node into T
 - also incorporate the edge that is incident on that node and a node in T that contributes to the path
- Step 3 [Update Least-Cost Paths]
 - $L(n) = \min[L(n), L(x) + w(x, n)]$ for all $n \notin T$
 - if latter term is minimum, path from s to n is path from s to x concatenated with edge from x to n



Bellman-Ford Algorithm

- find shortest paths from given node subject to constraint that paths contain at most one link
- find the shortest paths with a constraint of paths of at most two links and so on

Iter	T	L(2)	Path	L(3)	Path	L(4)	Path	L(5)	Path	L(6)	Path
1	{1}	2	1-2	5	1-3	1	1-4	∞	-	∞	-
2	{1,4}	2	1-2	4	1-4-3	1	1-4	2	1-4-5	∞	-
3	{1, 2, 4}	2	1-2	4	1-4-3	1	1-4	2	1-4-5	∞	-
4	{1, 2, 4, 5}	2	1-2	3	1-4-5-3	1	1-4	2	1-4-5	4	1-4-5-6
5	{1, 2, 3, 4, 5}	2	1-2	3	1-4-5-3	1	1-4	2	1-4-5	4	1-4-5-6
6	{1, 2, 3, 4, 5, 6}	2	1-2	3	1-4-5-3	1	1-4	2	1-4-5	4	1-4-5-6

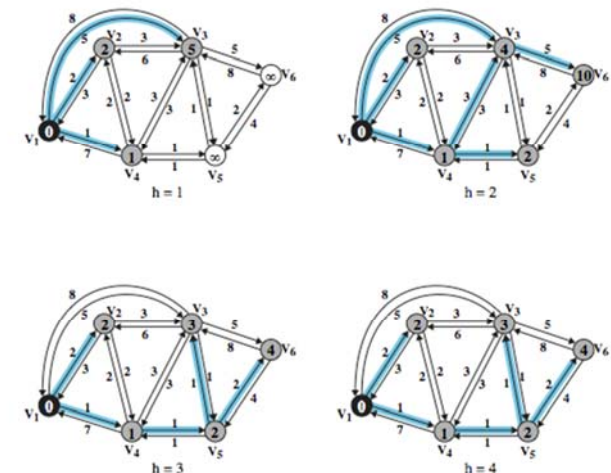
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step 1 [Initialization]

- $L_0(n) = \infty$, for all $n \neq s$
- $L_h(s) = 0$, for all h

step 2 [Update]

- for each successive $h \geq 0$
 - for each $n \neq s$, compute: $L_{h+1}(n) = \min_j [L_h(j) + w(j, n)]$
- connect n with predecessor node j that gives min
- eliminate any connection of n with different predecessor node formed during an earlier iteration
- path from s to n terminates with link from j to n



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h	$L_h(2)$	Path	$L_h(3)$	Path	$L_h(4)$	Path	$L_h(5)$	Path	$L_h(6)$	Path
0	∞	-	∞	-	∞	-	∞	-	∞	-
1	2	1-2	5	1-3	1	1-4	∞	-	∞	-
2	2	1-2	4	1-4-3	1	1-4	2	1-4-5	10	1-3-6
3	2	1-2	3	1-4-5-3	1	1-4	2	1-4-5	4	1-4-5-6
4	2	1-2	3	1-4-5-3	1	1-4	2	1-4-5	4	1-4-5-6

Comparison

Bellman-Ford algorithm

- the calculation for node n involves knowledge of the link cost to all neighboring nodes to node $[n]$ i.e., $w(j, n)$ plus the total path cost to each of those neighboring nodes from a particular source node s [i.e., $L_h(j)$].
- Each node can maintain a set of costs and associated paths for every other node in the network and exchange this information with its direct neighbors from time to time.
- Each node can therefore use the expression in step 2 of the Bellman-Ford algorithm, based only on information from its neighbors and knowledge of its link costs, to update its costs and paths.

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Dijkstra's algorithm

- Step 3 appears to require that each node must have complete topological information about the network.
- That is, each node must know the link costs of all links in the network.
- Thus, for this algorithm, information must be exchanged with all other nodes.

Evaluation

- In general, evaluation of the relative merits of the two algorithms should consider the
 - processing time of the algorithms and
 - the amount of information that must be collected from other nodes in the network or internet.
- The evaluation will depend on the implementation approach and the specific implementation.

A final point:

- Both algorithms are known to converge under static conditions of topology, link costs and will converge to the same solution.
- If the link costs change over time, the algorithm will attempt to catch up with these changes.
- However, if the link cost depends on traffic, which in turn depends on the routes chosen, then a feedback condition exists, and instabilities may result.

Thanks,...