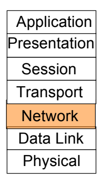
CSE/EE 461

Link State Routing

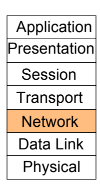
Last Time …

- Routing Algorithms
  - Introduction
  - Distance Vector routing (RIP)



This Lecture

- Routing Algorithms
  - Link State routing (OSPF)



Why have two protocols?

- DV: “Tell your neighbors about the world.”
  - Easy to get confused (“the telephone game”)
  - Simple but limited, costly and slow
    - 15 hops is all you get. (makes it faster to loop to infinity)
    - Periodic broadcasts of large tables
    - Slow convergence due to ripples and hold down
- LS: “Tell the world about your neighbors.”
  - Harder to get confused (“the nightly news”)
  - More complicated
    - As many hops as you want
    - Faster convergence (instantaneous update of link state changes)
    - Able to impose global policies in a globally consistent way
      - Richer cost model, load balancing

#

Link State Routing

- Same assumptions/goals, but different idea than DV:
  - Tell all routers the topology and have each compute best paths
  - Two phases:
    1. Topology dissemination (flooding)
       - New News travels fast.
       - Old News should eventually be forgotten
    2. Shortest-path calculation (Dijkstra’s algorithm)
       - nlogn

#

Flooding

- Each router maintains link state database and periodically sends link state packets (LSPs) to neighbor
  - LSPs contain [router, neighbors, costs]
- Each router forwards LSPs not already in its database on all ports except where received
  - Each LSP will travel over the same link at most once in each direction
- Flooding is fast, and can be made reliable with acknowledgments

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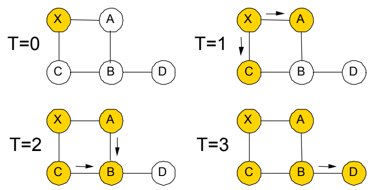
Example

- LSP generated by X at T=0
- Nodes become yellow as they receive it



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Complications

- When link/router fails need to remove old data. How?
  - LSPs carry sequence numbers to determine new data
  - Send a new LSP with cost infinity to signal a link down
- What happens if the network is partitioned and heals?
  - Different LS databases must be synchronized
  - A version number is used!

#

Shortest Paths: Dijkstra's Algorithm

- *N*: Set of all nodes
- *M*: Set of nodes for which we think we have a shortest path
- *s*: The node executing the algorithm
- *L(i,j)*: cost of edge *(i,j)* (inf if no edge connects)
- *C(i)*: Cost of the path from ME to *i*.
- Two phases:
  - Initialize C(n) according to received link states
  - Compute shortest path to all nodes from s
    - As link costs are symmetric, shortest path from A to B is also the shortest path from B to A.

#

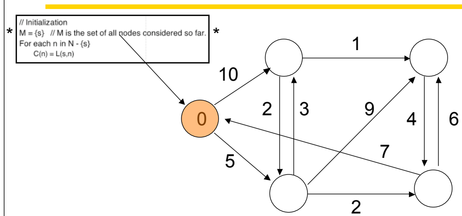
The Algorithm

// Initialization
M = {s} // M is the set of all nodes considered so far.
For each n in N - {s}
    C(n) = L(s,n)

// Find Shortest paths
Forever {
    Unconsidered = N-M
    If *Unconsidered* == {} break
    M = M + {w} such that C(w) is the smallest in *Unconsidered*
    For each n in *Unconsidered*
        C(n) = MIN(C(n), C(w) + L(w,n))
}

#

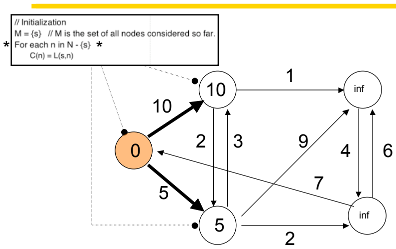
Dijkstra Example – After the flood



The Considered   The Unconsidered.

#

Dijkstra Example – Post Initialization

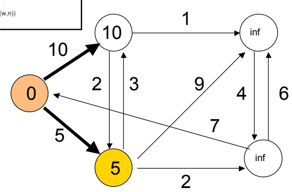


The Considered   The Unconsidered.

#

Considering a Node

```
// Find Shortest paths
Forever {
    Unconsidered = N-M
    If Unconsidered == {} break
    M = M + {w} such that C(w) is the smallest in Unconsidered
    For each n in Unconsidered
        C(n) = MIN(C(n), C(w) + L(w,n))
}
```

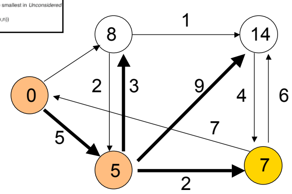


Cost updates of 8,14, and 7

The Considered The Unconsidered. The Under Consideration (*w*). #

Pushing out the horizon

```
// Find Shortest paths
Forever {
    Unconsidered = N-M
    If Unconsidered == {} break
    M = M + {w} such that C(w) is the smallest in Unconsidered
    For each n in Unconsidered
        C(n) = MIN(C(n), C(w) + L(w,n))
}
```

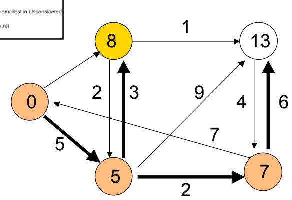


Cost updates of 13

The Considered The Unconsidered. The Under Consideration (*w*). #

Next Phase

```
// Find Shortest paths
Forever {
    Unconsidered = N-M
    If Unconsidered == {} break
    M = M + {w} such that C(w) is the smallest in Unconsidered
    For each n in Unconsidered
        C(n) = MIN(C(n), C(w) + L(w,n))
}
```

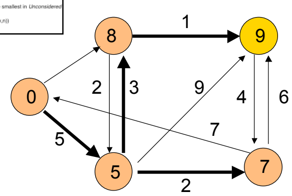


Cost updates of 9

The Considered The Unconsidered. The Under Consideration (*w*). #

Considering the last node

```
// Find Shortest paths
Forever {
    Unconsidered = N-M
    If Unconsidered == {} break
    M = M + {w} such that C(w) is the smallest in Unconsidered
    For each n in Unconsidered
        C(n) = MIN(C(n), C(w) + L(w,n))
}
```



The Considered The Unconsidered. The Under Consideration (*w*).

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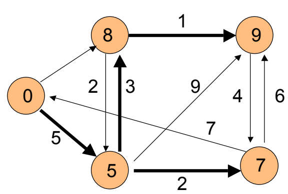
Dijkstra Example – Done



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Open Shortest Path First (OSPF)

- Most widely-used Link State protocol today
- Basic link state algorithms plus many features:
  - Authentication of routing messages
  - Extra hierarchy: partition into routing areas
    - Only bordering routers send link state information to another area
      - Reduces chatter.
      - Border router "summarizes" network costs within an area by making it appear as though it is directly connected to all interior routers
    - Load balancing

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Cost Metrics

- How should we choose cost?
  - To get high bandwidth, low delay or low loss?
  - Do they depend on the load?
- Static Metrics
  - Hopcount is easy but treats OC3 (155 Mbps) and T1 (1.5 Mbps)
  - Can tweak result with manually assigned costs
- Dynamic Metrics
  - Depend on load; try to avoid hotspots (congestion)
  - But can lead to oscillations (damping needed)

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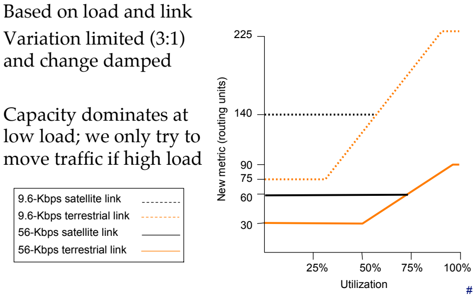
Revised ARPANET Cost Metric

- Based on load and link
- Variation limited (3:1) and change damped
- Capacity dominates at low load; we only try to move traffic if high load



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Key Concepts

- Routing uses global knowledge; forwarding is local
- Many different algorithms address the routing problem
  - We have looked at two classes: DV (RIP) and LS (OSPF)
- Challenges:
  - Handling failures/changes
  - Defining "best" paths
  - Scaling to millions of users

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