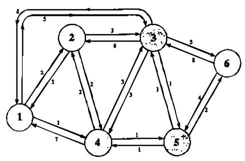
Interior Gateway Protocols: RIP & OSPF



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- **Routing Tables & static routing**
- **Dynamic routing (inter- and intra-domain)**
- **Distance vector vs Link state routing**
- **RIP, RIPv2**
- **OSPF**
- **Refs: Chap 9, 10.**
- **Books: “Routing in Internet” by Huitema, “Interconnections” by Perlman**

Routing vs Forwarding

- **Fig 9.1**
- **Routing table used by IP forwarding. Can display routing table using command “netstat -rn”**
- **Route Table setup by:**
  - **a) ‘route’ command**
  - **b) routing daemon (eg: ‘routed’)**
  - **c) ICMP redirect message.**

Routing Table structure

- Fields: ***destination, gateway, flags, ...***
- *Destination*: **can be a host address or a network address. If the 'H' flag is set, it is the host address.**
- *Gateway:* **router/next hop IP address. The 'G' flag says whether the destination is directly or indirectly connected.**
- **U flag: Is route up ?**
- **G flag: router (indirect vs direct)**
- **H flag: host (dest field: host or n/w address?)**

Static Routing

- **Upon booting, default routes initialized from files. Eg: /etc/rc.net in AIX, /etc/netstart in BSD, /etc/rc.local in SUN/Solaris**
- **Use 'route' command to add new routes eg: route add default sun 1**
- **ICMP redirect: sent to host by router when a "better" router exists on the same subnet.**
- **Alt: router discovery ICMP messages**
  - **Router solicitation request from host**
  - **Router advertisement messages from routers**

Dynamic routing

- **Internet organized as "autonomous systems" (AS).**
- **Interior Gateway Protocols (IGPs) within AS. Eg: RIP, OSPF, HELLO**
- **Exterior Gateway Protocols (EGPs) for AS to AS routing. Eg: EGP, BGP-4**
- **Reality: most of internet uses default routes (which is allowed within dynamic routing). Serious dynamic routing starts near core of AS and from one AS to another.**

Dynamic routing methods

- Source-based: chart route at source.
- Link state routing: Get map of network (in terms of link states) and calculate best route (but specify only a signpost: I.e. the next-hop)
- Distance vector: Set up signposts to destinations looking at neighbors' signposts.
- Key: to make it a "distributed" algorithm ?

Distance Vector routing

- "Vector" of distances (signposts) to each possible destination at each router.
- How to find distances ?
  - Distance to local network is 0.
  - Look in neighbors' distance vectors, and add link cost to reach the neighbor
  - Find which direction yields minimum distance to to particular destination. Turn signpost that way.
  - Keep checking if neighbors change their signposts and modify local vector if necessary.
  - And that's it !
    - Called the "Bellman-Ford algorithm"

Routing Information Protocol

- Uses hop count as metric
- Tables (vectors) "advertised" to neighbors every 30 s.
  - Robustness: Entries reinitialized (as 16 or infinity) if no refresh for 180 s.
  - Efficiency: Triggered updates used to inform neighbors when table changes.
- Protocol details:
  - Runs over UDP.
  - Init: send request message asking for vectors
  - Format can carry upto 25 routes (within 512 bytes)
  - RIPv1 does not carry subnet masks => many networks use default of 255.255.255.0

RIP problems

- Counting-to-infinity problem:
  - Simple configuration A->B->C. If C fails, B needs to update and thinks there is a route through A. A needs to update and thinks there is a route thru B.
  - No clear solution, except to set "infinity" to be small (eg 16 in RIP)
  - Split-horizon: If A's route to C is thru B, then A advertises C's route (only to B) as infinity.
- Slow convergence after topology change:
  - Due to count to infinity problem
  - Also information cannot propagate thru node until it recalculates routing info.

RIP problems (contd)

- Black-holes:
  - If one node goes broke and advertises route of zero to several key networks, all nodes immediately point to it.
- How to install a fix in a distributed manner ??
  - Require protocol to be "self-stabilizing" I.e even if some nodes are faulty, once they are isolated, the system should quickly return to normal operation
- Broadcasts consume non-router resources
- Does not support subnet masks (VLSMs)
- No authentication

RIPv2

- Why ? Installed base of RIP routers
- Provides:
  - VLSM support
  - Authentication
  - Multicasting
  - "Wire-sharing" by multiple routing domains,
  - Tags to support EGP/BGP routes.
- Uses reserved fields in RIPv1 header.
- First route entry replaced by authentication info.

Link State protocols

- Create a network "map" at each node.
  - For a map, we need inks and attributes (link states), not of destinations and metrics (distance vector)
- 1. Node collects the state of its connected links and forms a "Link State Packet" (LSP)
- 2. Broadcast LSP => reaches every other node in the network.
- 3. Given map, run Dijkstra's shortest path algorithm => get paths to all destinations
- 4. Routing table = next hops of these paths.

Dijkstra's algorithm

- A.k.a "Shortest Path First" (SPF) algorithm.
- Idea: compute shortest path from a "root" node to every other node."Greedy method":
  - P is a set of nodes for which shortest path has already been found.
  - For every node "o" outside P, find shortest one-hop path from some node in P.
  - Add that node "o" which has the shortest of these paths to P. Record the path found.
  - Continue till we add all nodes (&paths) to P

Dijkstra's algorithm

- P: (ID, path-cost, next-hop) triples.
  - ID: node id.
  - Path-cost: cost of path from root to node
  - Next-hop: ID of next-hop on shortest path from the root to reach that node
  - P: Set of nodes for which the best path cost (and next-hop from root) have been found.
- T: (ID, path-cost, next-hop):
  - Set of candidate nodes at a one-hop distance from some node in P.
  - Note: there is only one entry per node. In the interim, some nodes may not lie in P or T.
- R=Routing table: (ID, next-hop) to be created

Dijkstra's algorithm

- 1. Put root I.e., (myID, 0, 0) in P & (myID,0) to R.
- 2. If node ***N*** is just put into P, look at N's links (I.e. its LSP).
  - 2a. For each link to neighbor ***M***, add cost of the root-to-N-path to the cost of the N-to-M-link (from LSP) to determine a new cost: ***C***.
  - 2b. The "next-hop" corresponds to the next-hop ID in N's tuple (or N if M is the root itself): ***h***
  - 2c. If M not in T (or P) with better path cost, add (M, C, h) to T.
- 3. If T = empty, terminate. Else, move the min-cost triple from T to P, and add (M, h) to R. Go to step 2.

Topology dissemination

- aka LSP distribution
- 1. Flood LSPs on links except incoming link
  - Require at most 2E transfers for n/w with E edges
- 2. Sequence numbers to detect duplicates
  - Why? Routers/links may go down/up
  - Problem: wrap-around => have large seq # space
- 3. Age field (similar to TTL)
  - Periodically decremented after acceptance
  - Zero => discard LSP & request everyone to do so
  - Router awakens => knows that all its old LSPs would have been purged and can choose a new initial sequence number

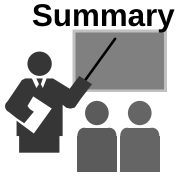
Link state vs Distance vector

- Advantages:
  - More stable (aka fewer routing loops)
  - Faster convergence than distance vector
  - Easier to discover network topology, troubleshoot network.
  - Can do better source-routing with link-state
  - Type & Quality-of-service routing (multiple route tables) possible
- Caveat: With path-vector-type distance vector routing, these arguments don't hold

OSPF

- OSPF runs directly on top of IP (not over UDP)
- It can calculate a separate set of routes for each IP type of service (=> multiple routing entries)
- Dimensionless cost (eg: based on throughput, delay)
- Load balancing: distributing traffic equally among routes
- Supports VLSMs: subnet mask field in header
- Supports multicasting, authentication, unnumbered networks (point-to-point).

Summary



- Route Tables
- Distance vector, RIP, RIPv2
- Link state, OSPF.