Computer Networking

Internet Routing

Intra-AS Routing

- also known as Interior Gateway Protocols (IGP)
- most common Intra-AS routing protocols:
  - RIP: Routing Information Protocol
  - OSPF: Open Shortest Path First
  - IGRP: Interior Gateway Routing Protocol (Cisco proprietary)
RIP (Routing Information Protocol)

- Distance vector algorithm
- Included in BSD-UNIX Distribution in 1982
- Distance metric: # of hops (max = 15 hops)

![Diagram of RIP]

From router A to subnets:

<table>
<thead>
<tr>
<th>Destination</th>
<th>Hops</th>
</tr>
</thead>
<tbody>
<tr>
<td>u</td>
<td>1</td>
</tr>
<tr>
<td>v</td>
<td>2</td>
</tr>
<tr>
<td>w</td>
<td>2</td>
</tr>
<tr>
<td>x</td>
<td>3</td>
</tr>
<tr>
<td>y</td>
<td>3</td>
</tr>
<tr>
<td>z</td>
<td>2</td>
</tr>
</tbody>
</table>

RIP advertisements

- Distance vectors: exchanged among neighbors every 30 sec via Response Message (also called advertisement)
- Each advertisement: list of up to 25 destination subnets within AS
**RIP: Example**

Routing/Forwarding table in D

```
Dest     Next  hops
w        -      1
x        -      1
z        c      4
....     ...    ...
```

Advertisement from A to D

```
Destination Network  Next  Router  Num. of hops to dest.
 w                   A      2
 y                   B      2
 z                   B      7
 x                   --     1
 ....                ...    ...
```

Routing/Forwarding table in D

```
Dest     Next  hops
w        -      1
x        -      1
z        c      4
....     ...    ...
```

Advertisement from A to D
RIP: Link Failure and Recovery

If no advertisement heard after 180 sec -> neighbor/link declared dead
- routes via neighbor invalidated
- new advertisements sent to neighbors
- neighbors in turn send out new advertisements (if tables changed)
- link failure info quickly (?) propagates to entire net
- *poison reverse* used to prevent ping-pong loops (infinite distance = 16 hops)

RIP Table processing

- RIP routing tables managed by *application-level* process called route-d (daemon)
- advertisements sent in UDP packets, periodically repeated
OSPF (Open Shortest Path First)

- “open”: publicly available
- uses Link State algorithm
  - LS packet dissemination
  - topology map at each node
  - route computation using Dijkstra’s algorithm
- OSPF advertisement carries one entry per neighbor router
- advertisements disseminated to entire AS (via flooding)
  - carried in OSPF messages directly over IP (rather than TCP or UDP)

OSPF “advanced” features (not in RIP)

- security: all OSPF messages authenticated (to prevent malicious intrusion)
- multiple same-cost paths allowed (only one path in RIP)
- For each link, multiple cost metrics for different TOS (e.g., satellite link cost set “low” for best effort; high for real time)
- integrated uni- and multicast support:
  - Multicast OSPF (MOSPF) uses same topology data base as OSPF
- hierarchical OSPF in large domains.
Hierarchical OSPF

- **two-level hierarchy**: local area, backbone.
  - Link-state advertisements only in area
  - Each node has detailed area topology; only know direction (shortest path) to nets in other areas.
- **area border routers**: “summarize” distances to nets in own area, advertise to other Area Border routers.
- **backbone routers**: run OSPF routing limited to backbone.
- **boundary routers**: connect to other AS’s.
Internet inter-AS routing: BGP

- BGP (Border Gateway Protocol): the de facto standard
- BGP provides each AS a means to:
  1. Obtain subnet reachability information from neighboring ASs.
  2. Propagate reachability information to all AS-internal routers.
  3. Determine “good” routes to subnets based on reachability information and policy.
- Allows subnet to advertise its existence to rest of Internet: “I am here”

BGP basics

- Pairs of routers (BGP peers) exchange routing info over semi-permanent TCP connections: BGP sessions
  - BGP sessions need not correspond to physical links.
- When AS2 advertises a prefix to AS1:
  - AS2 promises it will forward datagrams towards that prefix.
  - AS2 can aggregate prefixes in its advertisement
**Distributing reachability info**

- using eBGP session between 3a and 1c, AS3 sends prefix reachability info to AS1.
  - 1c can then use iBGP to distribute new prefix info to all routers in AS1.
  - 1b can then re-advertise new reachability info to AS2 over 1b-to-2a eBGP session.
- when router learns of new prefix, it creates entry for prefix in its forwarding table.

**Path attributes & BGP routes**

- advertised prefix includes BGP attributes.
  - prefix + attributes = “route”
- two important attributes:
  - **AS-PATH**: contains ASs through which prefix advertisement has passed: e.g., AS 67, AS 17
  - **NEXT-HOP**: indicates specific internal-AS router to next-hop AS. (may be multiple links from current AS to next-hop-AS)
- when gateway router receives route advertisement, uses **import policy** to accept/decline.
**BGP route selection**

- router may learn about more than 1 route to some prefix. Router must select route.
- elimination rules:
  1. local preference value attribute: policy decision
  2. shortest AS-PATH
  3. closest NEXT-HOP router: hot potato routing
  4. additional criteria

**BGP messages**

- BGP messages exchanged using TCP.
- BGP messages:
  - OPEN: opens TCP connection to peer and authenticates sender
  - UPDATE: advertises new path (or withdraws old)
  - KEEPALIVE keeps connection alive in absence of UPDATES; also ACKs OPEN request
  - NOTIFICATION: reports errors in previous msg; also used to close connection
BGP routing policy

- A, B, C are provider networks
- X, W, Y are customer (of provider networks)
- X is dual-homed: attached to two networks
  - X does not want to route from B via X to C
  - .. so X will not advertise to B a route to C

BGP routing policy (2)

- A advertises path AW to B
- B advertises path BAW to X
- Should B advertise path BAW to C?
  - No way! B gets no “revenue” for routing CBAW since neither W nor C are B’s customers
  - B wants to force C to route to w via A
  - B wants to route only to/from its customers!
Why different Intra- and Inter-AS routing?

Policy:
- Inter-AS: admin wants control over how its traffic routed, who routes through its net.
- Intra-AS: single admin, so no policy decisions needed

Scale:
- hierarchical routing saves table size, reduced update traffic

Performance:
- Intra-AS: can focus on performance
- Inter-AS: policy may dominate over performance