Implementations of routing protocols

Problems with our ideas of a homogenous Internet

- The scale of the Internet makes it prohibitive to do routing in the ways we’ve discussed
  - Example: LS flooding approach
- Individual organizations want to run and administer their internal networks in any way they wish, and still connect to “outside” networks
Autonomous Systems (AS)

- aka “Routing Domains”
- Large networks are divided into AS’s, usually along administrative boundaries

AS concepts

- Within an AS, all routers run the same routing protocol and share the same information
- Gateway routers (“Boundary routers”):
  - Run their local AS’s protocol and,
  - Run a separate routing protocol to route between the Gateway routers (“Inter-AS Routing protocol”)
Inter-AS routing

Virtual network
Running Inter-AS
protocol

"Links" in the virtual network may correspond to physical links or to multi-hop paths

How routing packets flow over the virtual Inter-AS network

Inside AS1:

R1c

R1a

R1b

R1a receives a routing packet on the Inter-AS net. The next node on the virtual net is R1b. R1a hands the packet over to the AS1 Intra-AS protocols to send it to R1b.

Note that routers outside of AS1 require no knowledge of AS1’s internals
Keeping track of AS’s

• Each AS is identified by a globally-unique AS number assigned by ICANN (RFC 1930*)

Intra-AS protocols
(“Interior Gateway Protocols”)

• Routing Information Protocol (RIP)
• Open Shortest Path First (OSPF)
RIP v1

- Simple DV protocol
- Costs based on hop counts
- Defined in RFC 1058

RIP v1 packets

- Each packet can carry distances for up to 25 destinations
- Packet size (bytes) = 4 + 20*number_destinations
- Packets cannot carry Subnet Masks
- Packets can be:
  - Request type – ask for distances on one or more destinations
  - Response type – provide distances
RIP v2

- RFC 2453
- Adds
  - Subnetting
  - Authentication
  - One router can advertise paths for another
- Packet size (bytes) = 24 + 20*number_destinations

Open Shortest Path First (OSPF)

- Link State protocol
- Designed as a successor to RIP
- RFC 2328
OSPF features

- Link costs can be configured by administrator
- Periodic LS advertisements at least every 30 min
- Rides directly on IP, implements its own reliable communication

More OSPF features

- All messages authenticated
- Can maintain multiple paths to a destination
- Multicast routing support
- Supports hierarchies within an AS
OSPF hierarchy within an AS

- AS’s can be divided into “areas”
- Each area runs a separate OSPF – details of the area’s internals are invisible to other areas
- Each area has “area border routers” to communicate with other areas
- One area is identified as the “backbone” – routes traffic between other areas and contains all area border routers

Inter-AS Routing

- Border Gateway Protocol (BGP)
BGP

- The standard Inter-AS routing protocol for the Internet
- RFC 1771 (+ see 1772, 1773)

BGP protocol

- Based on DV concepts
- A “Path Vector” protocol
  - Routers advertise complete routes to destination AS’s, not costs (normally)
Path vector problems?

- Resolves the Count-to-Infinity problem
  (a router receiving a path vector can check to see if it is on the path)

Choosing between paths

- A BGP router may receive several paths to a single destination, but advertises only one
- Possible selection criteria:
  - Local preferences set by administrator
  - Minimum number of AS’s crossed
  - Random
  - ...
BGP route advertising

- Administrator is free to set own policies for advertising routes
  - For example:
    - Particular AS’s preferred
    - Particular AS’s avoided

BGP message types

- OPEN: establishes link to a BGP peer
- UPDATE: a path advertisement (or withdrawing a previous advertisement)
- KEEPALIVE: ACK or “I’m still alive”
- NOTIFICATION: Error or other BGP control message
Finally!!

• Why different Inter- and Intra-AS protocols?
  – Much more need for local admin control in Inter-AS (because multiple admins involved)
  – For Inter-AS, policy needs may dominate performance concerns – not so Intra