Intra-AS and Inter-AS Routing

Gateways:
- perform inter-AS routing amongst themselves
- perform intra-AS routers with other routers in their AS
Intra-AS and Inter-AS Routing

Gateways:
- perform inter-AS routing amongst themselves
- perform intra-AS routers with other routers in their AS

inter-AS, intra-AS routing in gateway A.c

network layer
link layer
physical layer
We have already talked about two intra-AS routing algorithms:

- Link state routing
- Distance vector routing
Link State vs Distance Vector

- Tells everyone about neighbors
- Controlled flooding to exchange link state
- Dijkstra’s algorithm
- Each router computes its own table
- May have oscillations

- Tells neighbors about everyone
- Exchanges distance vectors with neighbors
- Bellman-Ford algorithm
- Each router’s table is used by others
- May have routing loops
RIP

- RIP == Routing Information Protocol
- RIP is a distance vector implementation

Instead of advertising costs to the next router, RIP advertises the cost to the next network.

```
(network_address, distance) pairs
```

```
+----------------+-------+-----------------+-----------------+
<table>
<thead>
<tr>
<th>Command</th>
<th>Version</th>
<th>Must be zero</th>
</tr>
</thead>
<tbody>
<tr>
<td>Family of net 1</td>
<td>Address of net 1</td>
<td></td>
</tr>
<tr>
<td>Address of net 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Distance to net 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Family of net 2</td>
<td>Address of net 2</td>
<td></td>
</tr>
<tr>
<td>Address of net 2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Distance to net 2</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
```
Large Routing

- OSPF
- BGP
One of the most widely-used link-state routing protocols is **Open Shortest Path First**

- Open, nonproprietary standard created by the Internet Engineering Task Force
- **Shortest Path First** is an alternative name for link-state routing

Hierarchical – can divide the system into “areas.”
**OSPF Roles**

- *Internal router*: a level 1 router.
- *Backbone router*: a level 2 router.
- *Area border router (ABR)*: a backbone router that attaches to more than one area.
- *AS border router*: (an interdomain router), namely, a router that attaches to routers from other ASs across AS boundaries.
**OSPF advertisement**

<table>
<thead>
<tr>
<th>LS Age</th>
<th>Options</th>
<th>Type=1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Link-state ID</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Advertising router</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LS sequence number</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LS checksum</td>
<td>Length</td>
<td></td>
</tr>
<tr>
<td>0 Flags</td>
<td>0</td>
<td>Number of links</td>
</tr>
<tr>
<td>Link ID</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Link data</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Link type</td>
<td>Num_TOS</td>
<td>Metric</td>
</tr>
<tr>
<td>Optional TOS information</td>
<td></td>
<td></td>
</tr>
<tr>
<td>More links</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Indicates LSA type

Indicates link cost
OSPF LSA types

- Router link advertisement [Hello message]
- Network link advertisement
- Network summary link advertisement
- AS border router’s summary link advertisement
- AS external link advertisement
Border Gateway Protocol and Autonomous Systems

- Assumes the Internet is an arbitrarily interconnected set of AS's.

- Define local traffic as traffic that originates at or terminates on nodes within an AS, and transit traffic as traffic that passes through an AS.
Border Gateway Protocol and Autonomous Systems

- We can classify AS's into three types:
  - **Stub AS**: an AS that has only a single connection to one other AS; such an AS will only carry local traffic
Border Gateway Protocol and Autonomous Systems

We can classify AS's into three types:

- **Multihomed AS:** an AS that has connections to more than one other AS, but refuses to carry transit traffic
Border Gateway Protocol and Autonomous Systems

- We can classify AS's into three types:
  - **Transit AS**: an AS that has connections to more than one other AS, and is designed to carry both transit and local traffic (backbone provider)
The goal of Inter-domain routing is to find any path to the intended destination that is loop free

- We are concerned with reachability than optimality
- Finding path anywhere close to optimal is considered to be a great achievement
Scalability: An Internet backbone router must be able to forward any packet destined anywhere in the Internet

Autonomous nature of the domains

Issues of trust
Each AS has:

- One BGP *speaker* that advertises:
  - local networks
  - other reachable networks (transit AS only)
  - gives *path* information

- In addition to the BGP speakers, the AS has one or more border “gateways” which need not be the same as the speakers

- The border gateways are the routers through which packets enter and leave the AS
BGP

- BGP does not belong to either of the two main classes of routing protocols (distance vectors and link-state protocols)

- BGP advertises *complete paths* as an enumerated lists of ASs to reach a particular network
IPv6

- Moving on to IPv6!
- For more information, refer to Section 4.1.3 in your textbooks
Why not IPv4?

- IPv4 addresses have become relatively scarce.
- NATs help by promoting reuse of address space, but they don’t do enough.
Why not IPv4?

- The public IPv4 address space will eventually be depleted.
- It would be nice to not have to rely on protocols like DHCP to configure addresses.
Why not IPv4?

- Private communication over a public medium like the Internet requires encryption services that protect the data being sent from being viewed or modified in transit.
Why IPv6?

- IPv6 is required to include IPsec.
  - IPsec allows authentication, encryption, and compression of IP traffic.
Why IPv6?

- IPv6 uses a 128-bit address instead of the 32-bit address of IPv4.
- This doesn't give 4 times the addresses of IPv4 but rather the number of IPv4 addresses squared twice.
- A couple of articles out there have stated that this works out to billions of billions of addresses for every square meter on the planet.
IPv6 Addressing

- An IPv6 address is written as hexadecimal values (0-F) in groups of four separated by colons, like:

  A223:BB34:0000:0000:0000:0099:DA78:5679

- Strings of zeros can be dropped and leading zeros in a number group can be dropped, so the example above would shorten to

  A223:BB34::99:DA78:5679.
IPv6 Addressing

- IPv4 isn't left out completely
- IPv4 addresses can be expressed in IPv6 form as follows:
  
  0000:0000:0000:0000:0000:0000:0000:192.168.10.10
  
  –which can be shortened to ::192.168.10.10

- This makes transitioning a bit easier.
IPv6 adds significant extra features that were not possible with IPv4.

- Automatic configuration of hosts (similar and DHCP)
- Extensive multicasting capabilities
- Built-in security using authentication headers and encryption
- Built-in support for QOS and path control
IPv4 and IPv6 Headers

IPv4 Header
- Version
- IHL
- Type of Service
- Total Length
- Identification
- Flags
- Fragment Offset
- Time to Live
- Protocol
- Header Checksum
- Source Address
- Destination Address
- Options
- Padding

IPv6 Header
- Version
- Traffic Class
- Flow Label
- Payload Length
- Next Header
- Hop Limit
- Source Address
- Destination Address

Legend:
- Field's Name Kept from IPv4 to IPv6
- Fields Not Kept in IPv6
- Name and Position Changed in IPv6
- New Field in IPv6
IPV4 and IPV6 Addressing

- Ipv4:
  - 32 bits
  - ~ 4,200,000,000 addresses

- IPV6
  - 128 bits
  - 340,282,366,920,938,463,463,374,607,431,768,211,456 nodes
  - Addresses have "scope"
    - Link Local
    - Unique Local
    - Global
  - Addresses have lifetime
    - Valid and preferred lifetime facets
  - Unicast, Multicast, and Anycast...but no broadcast
IPv6 Addressing

- Same “longest-prefix match” routing as IPv4 CIDR
  - e.g: 2001:db8:12::/40

- Two Different Classes
  - Link-State (i.e., OSPF, ISIS, etc.)
  - Distance-Vector (i.e., RIP, IGRP, etc.)

- Autonomous System / Routing Domain
  - Interior Gateway Protocols (IGPs)
    - i.e., OSPFv3, ISIS for IPv6, RIPng, EIGRP for IPv6
  - Exterior Gateway Protocols (EGPs)
    - Multi-Protocol Extensions for BGP4
The idea behind having fixed-width, 64-bit wide host identifiers is that they aren't assigned manually as in IPv4.

Instead, v6 host addresses are recommended to be built from so-called EUI64 addresses.

EUI64 addresses are 64-bits wide, and derived from MAC addresses of the underlying network interface.

For example, with Ethernet, the 6-byte (48-bit) MAC address is usually filled with the hex bits "fffe" in the middle
What's your address, MAC?

- For example, with Ethernet, the 6-byte (48-bit) MAC address is usually filled with the hex bits "fffe" in the middle -- the MAC address

  01:23:45:67:89:ab

results in the EUI64 address

  01:23:45:ff:fe:67:89:ab

which again gives the host bits for the IPv6 address.

  ::0123:45ff:fe67:89ab
End of Chapters 3-4