Hierarchical Routing

Our routing study thus far -
idealization

=all routers identical

=network “flat”

... not true in practice.

scale: with 200 million destinations:
can’t store all dest’s in routing tables!
routing table exchange would swamp links!

administrative autonomy
internet = network of networks
each network admin may want to control routing in its own network
Hierarchical Routing

aggregate routers into regions, “autonomous systems” (AS)
routers in same AS run same routing protocol

- “intra-AS” routing protocol
routers in different AS can run different intra-AS routing protocol

Gateway router
Direct link to router in another AS
Interconnected ASes

forwarding table configured by both intra- and inter-AS routing algorithm
intra-AS sets entries for internal dests
inter-AS & intra-As sets entries for external dests
suppose router in AS1 receives datagram destined outside of AS1: router should forward packet to gateway router, but which one?

**AS1 must:**
- learn which dests are reachable through AS2, which through AS3
- propagate this reachability info to all routers in AS1

Job of inter-AS routing!
suppose AS1 learns (via inter-AS protocol) that subnet $x$ reachable via AS3 (gateway 1c) but not via AS2. 
inter-AS protocol propagates reachability info to all internal routers. 
router 1d determines from intra-AS routing info that its interface $I$ is on the least cost path to 1c. 
Installs forwarding table entry $(x, I)$
now suppose AS1 learns from inter-AS protocol that subnet \( x \) is reachable from AS3 and from AS2.

to configure forwarding table, router 1d must determine towards which gateway it should forward packets for dest \( x \).
this is also job of inter-AS routing protocol!
Ex: Choosing among multiple ASes

now suppose AS1 learns from inter-AS protocol that subnet $x$ is reachable from AS3 and from AS2.

to configure forwarding table, router 1d must determine towards which gateway it should forward packets for dest $x$.
this is also job of inter-AS routing protocol!
• **hot potato routing**: send packet towards closest of two routers.
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)
distance vector algorithm
included in BSD-UNIX Distribution in 1982
distance metric: # of hops (max = 15 hops)

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

<table>
<thead>
<tr>
<th>Destination Network</th>
<th>Next Router</th>
<th>Num. of hops to dest.</th>
</tr>
</thead>
<tbody>
<tr>
<td>w</td>
<td>A</td>
<td>2</td>
</tr>
<tr>
<td>y</td>
<td>B</td>
<td>2</td>
</tr>
<tr>
<td>z</td>
<td>B</td>
<td>7</td>
</tr>
<tr>
<td>x</td>
<td>--</td>
<td>1</td>
</tr>
<tr>
<td>....</td>
<td>....</td>
<td>....</td>
</tr>
</tbody>
</table>

Routing/Forwarding table in D
**RIP: Example**

**Advertisement from A to D**

<table>
<thead>
<tr>
<th>Dest</th>
<th>Next hops</th>
</tr>
</thead>
<tbody>
<tr>
<td>w</td>
<td>- 1</td>
</tr>
<tr>
<td>x</td>
<td>- 1</td>
</tr>
<tr>
<td>z</td>
<td>C 4</td>
</tr>
</tbody>
</table>

**Routing/Forwarding table in D**

<table>
<thead>
<tr>
<th>Destination Network</th>
<th>Next Router</th>
<th>Num. of hops to dest.</th>
</tr>
</thead>
<tbody>
<tr>
<td>w</td>
<td>A</td>
<td>2</td>
</tr>
<tr>
<td>y</td>
<td>B</td>
<td>2</td>
</tr>
<tr>
<td>z</td>
<td>B A</td>
<td>7 5</td>
</tr>
<tr>
<td>x</td>
<td>--</td>
<td>1</td>
</tr>
</tbody>
</table>

...
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 routing tables managed by **application-level** process called route-d (daemon)
advertisements sent in UDP packets, periodically repeated