Announcement

• HW1 due on 9/14.
• All HW should be electronic, submitted through Moodle, handwritten assignments not accepted
• Form HW and project groups soon
Naming

• Name must scale to a large number of nodes

• IPv4 Address
  – Classes (A,B,C)
  – Subnets
  – Classless
    • More flexible boundaries

http://en.wikipedia.org/wiki/IP_address
Classless Inter-Domain Routing

• Contiguous addresses can be aggregated
  – Why aggregate?

• Two prefixes
  • 239.109.104.0/22: 11101111:01101101:011010xx:xxxxxxxxxx
  • 239.109.108.0/22: 11101111:01101101:011011xx:xxxxxxxxxx

• Aggregate
  • 239.109.104.0/21: 11101111:01101101:01101xxx:xxxxxxxxxx

• Advertise reachable prefix with the routing algorithms

http://en.wikipedia.org/wiki/Classless_Inter-Domain_Routing
Forwarding with CIDR

- Longest Prefix Match

<table>
<thead>
<tr>
<th>Prefix</th>
<th>Nexthop</th>
</tr>
</thead>
<tbody>
<tr>
<td>a.b.0.0/23</td>
<td>A</td>
</tr>
<tr>
<td>a.b.1.0/24</td>
<td>C</td>
</tr>
</tbody>
</table>

Where to forward these packets?
- dst: a.b.0.5
- dst: a.b.1.6
Routing Across the Internet

Abstract View of the Internet Backbone

Autonomous System (AS)
Scaling Routing

• How many routers in the Internet?

• Use hierarchy to scale
  – What is the tradeoff?

• How do we design a hierarchy of routers?
  – Autonomous systems
Inter-domain Routing

• Shortest path not necessarily desirable
• Forwarding packets cost money
  – Money to be made forwarding packets
• Routing should reflect business interests and relations
  – Policies
• Internet scale
Internet Service Providers

- Most have providers and customers
- Provide connectivity to the Internet
- Want full control over internal routing and topology
Example of Policies

• Want to use ISP2 only as backup
• Prefer ISP1 over ISP2 for x.x.x.x/12 but prefer ISP2 over ISP1 for y.y.y.y/14
• Never want to forward packets from ISP3 to ISP2
ISP Tiers

• Size, connectivity, geographical reach
• Tier 1, 2, 3, ...
• Tier 1
  – Can reach most/all networks without transit
  – Global reach

http://en.wikipedia.org/wiki/Tier_1_network
Transit

• Provider / Customer relation

• Customer pays the provider for access

http://en.wikipedia.org/wiki/Internet_transit
Peering

- Public or Private
- Could lower cost
- Could make network efficient
- Traffic ratios

http://en.wikipedia.org/wiki/Peering
http://en.wikipedia.org/wiki/Internet_exchange_point
Transit vs Peering

• Transit or peer with?
  – Competitor
  – Larger ISP
  – Smaller ISP
Hot Potato Routing

- Incentive to turn the packets over quickly

BGP

- Exchange inter-AS connectivity
- Runs between routers across AS
- Advertise reachable networks
- Path Vector

BGP Announcements

• Announce
  – reachable network
  – Attributes (NEXTTHOP, AS PATH, MED, …)
  – Withdrawn routes

• Keepalive

• Over TCP so no periodic route advertisement
MED

• Often multiple paths into an AS
• Assign preference to inbound paths
• Not always honored
Route Selection

• Roughly
  – Weight
  – Local preference
  – MED
  – ...

What Routes to Advertise?

• Minimize use of providers
• Maximize use of customers and peers

• Announce one’s customers to
  – Peers, providers and customers?
• Announce one’s providers to
  – Peers, providers and customers?
Routing with CIDR

• Aggregate desired paths and announce a.b.0.0/24, a.b.0.0/23, a.b.0.5, a.b.0.6, a.b.1.0/24, a.b.1.6, a.b.1.7
Routing within an AS

- Need consistent view of reachability from a given AS
- Multiple border synchronize the paths they have learnt using i-BGP
- Full-mesh topology

- The routers also need to learn the best path to each other
  - OSPF etc.