Global Internet

Outline
- Subnetting
- Supernetting

How to Make Routing Scale

- Flat versus Hierarchical Addresses
- Inefficient use of Hierarchical Address Space
  - class C with 2 hosts \(2/255 = 0.78\%\) efficient
  - class B with 256 hosts \(256/65535 = 0.39\%\) efficient
- Still Too Many Networks
  - routing tables do not scale
  - route propagation protocols do not scale
Internet Structure

Recent Past

Today
Subnetting

- Add another level to address/routing hierarchy: subnet
- Subnet masks define variable partition of host part
- Subnets visible only within site

<table>
<thead>
<tr>
<th>Network number</th>
<th>Host number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class B address</td>
<td></td>
</tr>
<tr>
<td>11111111111111111111110000000000</td>
<td></td>
</tr>
<tr>
<td>Subnet mask (255.255.255.0)</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Network number</th>
<th>Subnet ID</th>
<th>Host ID</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subnetted address</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Subnet Example

Forwarding table at router R1

<table>
<thead>
<tr>
<th>Subnet Number</th>
<th>Subnet Mask</th>
<th>Next Hop</th>
</tr>
</thead>
<tbody>
<tr>
<td>128.96.34.0</td>
<td>255.255.255.128</td>
<td>Interface 0</td>
</tr>
<tr>
<td>128.96.34.128</td>
<td>255.255.255.128</td>
<td>Interface 1</td>
</tr>
<tr>
<td>128.96.33.0</td>
<td>255.255.255.0</td>
<td>R2</td>
</tr>
</tbody>
</table>
**Forwarding Algorithm**

D = destination IP address

for each entry (SubnetNum, SubnetMask, NextHop)

  D1 = SubnetMask & D

  if D1 = SubnetNum
    if NextHop is an interface
      deliver datagram directly to D
    else
      deliver datagram to NextHop

- Use a default router if nothing matches
- Not necessary for all 1s in subnet mask to be contiguous
- Can put multiple subnets on one physical network
- Subnets not visible from the rest of the Internet

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**Supernetting**

- Assign block of contiguous network numbers to nearby networks
- Called CIDR: Classless Inter-Domain Routing
- Represent blocks with a single pair

  (first_network_address, count)

- Restrict block sizes to powers of 2
- Use a bit mask (CIDR mask) to identify block size
- All routers must understand CIDR addressing
CIDR

Route Propagation

- Know a smarter router
  - hosts know local router
  - local routers know site routers
  - site routers know core router
  - core routers know everything

- Autonomous System (AS)
  - corresponds to an administrative domain
  - examples: University, company, backbone network
  - assign each AS a 16-bit number

- Two-level route propagation hierarchy
  - interior gateway protocol (each AS selects its own)
  - exterior gateway protocol (Internet-wide standard)
Popular Interior Gateway Protocols

- **RIP: Route Information Protocol**
  - developed for XNS
  - distributed with Unix
  - distance-vector algorithm
  - based on hop-count
- **OSPF: Open Shortest Path First**
  - recent Internet standard
  - uses link-state algorithm
  - supports load balancing
  - supports authentication
**EGP: Exterior Gateway Protocol**

- **Overview**
  - designed for tree-structured Internet
  - concerned with *reachability*, not optimal routes

- **Protocol messages**
  - neighbor acquisition: one router requests that another be its peer; peers exchange reachability information
  - neighbor reachability: one router periodically tests if the another is still reachable; exchange HELLO/ACK messages; uses a k-out-of-n rule
  - routing updates: peers periodically exchange their routing tables (distance-vector)

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**BGP-4: Border Gateway Protocol**

- **AS Types**
  - stub AS: has a single connection to one other AS
    - carries local traffic only
  - multihomed AS: has connections to more than one AS
    - refuses to carry transit traffic
  - transit AS: has connections to more than one AS
    - carries both transit and local traffic

- **Each AS has:**
  - one or more border routers
  - one BGP *speaker* that advertises:
    - local networks
    - other reachable networks (transit AS only)
    - gives path information
Multi-Backbone Internet

BGP Example

- Speaker for AS2 advertises reachability to P and Q
  - network 128.96, 192.4.153, 192.4.32, and 192.4.3, can be reached directly from AS2

- Speaker for backbone advertises
  - networks 128.96, 192.4.153, 192.4.32, and 192.4.3 can be reached along the path (AS1, AS2).

- Speaker can cancel previously advertised paths
IP Version 6

• Features
  – 128-bit addresses (classless)
  – multicast
  – real-time service
  – authentication and security
  – autoconfiguration
  – end-to-end fragmentation
  – protocol extensions

• Header
  – 40-byte “base” header
  – extension headers (fixed order, mostly fixed length)
    • fragmentation
    • source routing
    • authentication and security
    • other options

Addresses

<table>
<thead>
<tr>
<th>3</th>
<th>m</th>
<th>n</th>
<th>o</th>
<th>p</th>
<th>125- m- n- o- p</th>
</tr>
</thead>
<tbody>
<tr>
<td>010</td>
<td>RegistryID</td>
<td>ProviderID</td>
<td>SubscriberID</td>
<td>SubnetID</td>
<td>InterfaceID</td>
</tr>
</tbody>
</table>

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