Chapter 4: Network Layer

4.1 Introduction

4.2 Virtual circuit and datagram networks

4.3 What’s inside a router

4.4 IP: Internet Protocol
   - Datagram format
   - IPv4 addressing
   - ICMP
   - IPv6

4.5 Routing algorithms
   - Link state
   - Distance Vector
   - Hierarchical routing

4.6 Routing in the Internet
   - RIP
   - OSPF
   - BGP

4.7 Broadcast and multicast routing
ICMP: Internet Control Message Protocol

- used by hosts & routers to communicate network-level information
  - **error reporting**: unreachable host, network, port, protocol
  - echo request/reply (used by ping)
- network-layer “above” IP:
  - **ICMP msgs carried in IP datagrams**
- **ICMP message**: type, code plus first 8 bytes of IP datagram causing error

<table>
<thead>
<tr>
<th>Type</th>
<th>Code</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>echo reply (ping)</td>
</tr>
<tr>
<td>3</td>
<td>0</td>
<td>dest. network unreachable</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>dest host unreachable</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td>dest protocol unreachable</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>dest port unreachable</td>
</tr>
<tr>
<td>3</td>
<td>6</td>
<td>dest network unknown</td>
</tr>
<tr>
<td>3</td>
<td>7</td>
<td>dest host unknown</td>
</tr>
<tr>
<td>4</td>
<td>0</td>
<td>source quench (congestion control - not used)</td>
</tr>
<tr>
<td>8</td>
<td>0</td>
<td>echo request (ping)</td>
</tr>
<tr>
<td>9</td>
<td>0</td>
<td>route advertisement</td>
</tr>
<tr>
<td>10</td>
<td>0</td>
<td>router discovery</td>
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<td>11</td>
<td>0</td>
<td>TTL expired</td>
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<tr>
<td>12</td>
<td>0</td>
<td>bad IP header</td>
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</table>
Traceroute and ICMP

- Source sends series of UDP segments to dest
  - first has TTL = 1
  - second has TTL = 2, etc.
  - unlikely port number
- When nth datagram arrives to nth router:
  - router discards datagram
  - and sends to source an ICMP message (type 11, code 0)
  - ICMP message includes name of router & IP address

- When ICMP message arrives, source calculates RTT
- traceroute does this 3 times

Stopping criterion

- UDP segment eventually arrives at destination host
- destination returns ICMP “port unreachable” packet (type 3, code 3)
- when source gets this ICMP, stops.