Internetworking

Outline

Best Effort Service Model
Global Addressing Scheme
IP Internet

• Concatenation of Networks

• Protocol Stack
Service Model

- Connectionless (datagram-based)
- Best-effort delivery (unreliable service)
  - packets are lost
  - packets are delivered out of order
  - duplicate copies of a packet are delivered
  - packets can be delayed for a long time
- Datagram format
Fragmentation and Reassembly

- Each network has some MTU
- Design decisions
  - fragment when necessary (MTU < Datagram)
  - try to avoid fragmentation at source host
  - re-fragmentation is possible
  - fragments are self-contained datagrams
  - use CS-PDU (not cells) for ATM
  - delay reassembly until destination host
  - do not recover from lost fragments
Example
Global Addresses

- **Properties**
  - globally unique
  - hierarchical: network + host

- **Dot Notation**
  - 10.3.2.4
  - 128.96.33.81
  - 192.12.69.77
Datagram Forwarding

• Strategy
  – every datagram contains destination’s address
  – if connected to destination network, then forward to host
  – if not directly connected, then forward to some router
  – forwarding table maps network number into next hop
  – each host has a default router
  – each router maintains a forwarding table

• Example (R2)

<table>
<thead>
<tr>
<th>Network Number</th>
<th>Next Hop</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>R3</td>
</tr>
<tr>
<td>2</td>
<td>R1</td>
</tr>
<tr>
<td>3</td>
<td>interface 1</td>
</tr>
<tr>
<td>4</td>
<td>interface 0</td>
</tr>
</tbody>
</table>
Address Translation

• Map IP addresses into physical addresses
  – destination host
  – next hop router

• Techniques
  – encode physical address in host part of IP address
  – table-based

• ARP
  – table of IP to physical address bindings
  – broadcast request if IP address not in table
  – target machine responds with its physical address
  – table entries are discarded if not refreshed
ARP Details

• Request Format
  – HardwareType: type of physical network (e.g., Ethernet)
  – ProtocolType: type of higher layer protocol (e.g., IP)
  – HLEN & PLEN: length of physical and protocol addresses
  – Operation: request or response
  – Source/Target-Physical/Protocol addresses

• Notes
  – table entries timeout in about 15 minutes
  – update table with source when you are the target
  – update table if already have an entry
  – do not refresh table entries upon reference
### ARP Packet Format

<table>
<thead>
<tr>
<th>0</th>
<th>8</th>
<th>16</th>
<th>31</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hardware type = 1</td>
<td>ProtocolType = 0x0800</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HLen = 48</td>
<td>PLen = 32</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Operation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SourceHardwareAddr (bytes 0–3)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SourceHardwareAddr (bytes 4–5)</td>
<td>SourceProtocolAddr (bytes 0–1)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SourceProtocolAddr (bytes 2–3)</td>
<td>TargetHardwareAddr (bytes 0–1)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TargetHardwareAddr (bytes 2–5)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TargetProtocolAddr (bytes 0–3)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
DHCP

- Dynamic Host Configuration Protocol
## DHCP

### Fields

<table>
<thead>
<tr>
<th>Operation</th>
<th>HType</th>
<th>HLen</th>
<th>Hops</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **Xid**
- **Secs**
- **Flags**

- **ciaddr**
- **yiaddr**
- **siaddr**
- **giaddr**

- **chaddr** (16 bytes)
- **sname** (64 bytes)

- **file** (128 bytes)

- **options**
Internet Control Message Protocol (ICMP)

- Echo (ping)
- Redirect (from router to source host)
- Destination unreachable (protocol, port, or host)
- TTL exceeded (so datagrams don’t cycle forever)
- Checksum failed
- Reassembly failed
- Cannot fragment