Internetworking

Outline
Best Effort Service Model
Global Addressing Scheme

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
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 10 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>Hardware type</th>
<th>ProtocolType</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0x0800</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>HLen</th>
<th>PLen</th>
<th>Operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>48</td>
<td>32</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SourceHardwareAddr (bytes 0 – 3)</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>SourceProtocolAddr (bytes 0 – 1)</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>TargetHardwareAddr (bytes 2 – 5)</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>TargetProtocolAddr (bytes 0 – 3)</th>
</tr>
</thead>
</table>

---

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