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

Target Hardware Addr (bytes 2 - 5)  Target Protocol Addr (bytes 0 - 3)
Source Hardware Addr (bytes 0 - 3)  Source Protocol Addr (bytes 2 - 3)

Hardware type = 1  Protocol type = 0x0800
HLen = 48  PLen = 32

Operation

DHCP

• Dynamic Host Configuration Protocol

Unicast to server

Broadcast

DHCP relay

Other networks

DHCP server

DHCP

Operation  Htype  Hlen  Hops  Xid  ciaddr  yiaddr  siaddr  giaddr  chaddr (16 bytes)  sname (64 bytes)  file (128 bytes)  options
Secs  Flags
timeout
renew
rebind
pad
...
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