Internet Protocol

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These slides are available on-line at:
http://www.cse.wustl.edu/~jain/cse473-05/
Overview

- Internetworking Terms
- IP Header
- Fragmentation and Re-assembly
- IP Addressing, Subnetting, Private Addresses
- Address Resolution Protocol (ARP)
- Internet Control Message Protocol (ICMP)
TCP/IP Protocols

- Network access layer: Ethernet, Token Ring
- Internet layer: IP
- Host-host layer: TCP, UDP
- Process/application layer: FTP, Telnet, Mail (SMTP)

Diagram:
- BGP
- FTP
- HTTP
- SMTP
- TELNET
- SNMP
- TCP
- UDP
- ICMP

IP
Internetworking Terms

- End-system: Host
- Network: Provides data transfer between end-systems
- Internet: A collection of networks
- Subnetwork: Each component of an internet
- Intermediate System: Connects two subnetworks
Conclusion

We have looked at the Internet and how it is connected. The Internet is a collection of networks, and any computer can talk to any other computer within this collection. This is made possible through the routing of data packets across these networks.
Internet Protocol (IP)

- Layer 3 protocol that *forwards* datagrams across internet
- Uses routing tables prepared by routing protocols, e.g., Open Shortest Path First (OSPF), Routing Information Protocol (RIP)
- Connectionless service
  vs connection-oriented (circuits)
### IP Header

<p>| | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>4b</td>
<td>4b</td>
<td>8b</td>
<td>16b</td>
<td></td>
</tr>
<tr>
<td>Ver</td>
<td>IHL</td>
<td>ToS</td>
<td>Total Length</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Id</td>
<td>Flags</td>
<td>Fragment Offset</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TTL</td>
<td>Protocol</td>
<td>Header Checksum</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Source Address</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Destination Address</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Options + Padding</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Fig 16.7
IP Header (Cont)

- Version (4 bits)
- Internet header length (4 bits): in 32-bit words. Min header is 5 words or 20 bytes.
- Type of service (8 bits): Reliability, precedence, delay, and throughput
- Total length (16 bits): header+data in bytes
- Identifier (16 bits): Helps uniquely identify the datagram during its life for a given source, destination address
IP Header (Cont)

- Flags (3 bits):
  - More flag - used for fragmentation
  - No-fragmentation
  - Reserved
- Fragment offset (13 bits): In units of 8 bytes
- Time to live (8 bits): Specified in router hops
- Protocol (8 bits): Next level protocol to receive the data
- Header checksum (16 bits): 1’s complement sum of all 16-bit words in the header
IP Header (Cont)

- Source Address (32 bits)
- Destination Address (32 bits)
- Options (variable): Security, source route, record route, stream id (used for voice) for reserved resources, timestamp recording
- Padding (variable):
  Makes header length a multiple of 4
- Data (variable): Data + header ≤ 65,535 bytes
Fragmentation and Re-assembly

- When to re-assemble?
  - At destination: Results in packets getting smaller as data traverses internet
  - Intermediate re-assembly
    - Need large buffers at routers
    - Buffers may fill with fragments
    - All fragments must go through same router
      - Inhibits dynamic routing
  - IP re-assembles at destination only
IP Fragmentation Fields

- Data Unit Identifier (ID)
  - Identifies end system originated datagram
    - Source and destination address
    - Protocol layer generating data (e.g. TCP)
    - Identification supplied by that layer
- Total length: Length of user data plus header in octets
- Data Offset - Position of fragment in original datagram
  - In multiples of 64 bits (8 octets)
- More flag
  - Indicates that this is not the last fragment
Fragmentation Example

Original datagram
Data length = 404 B
Segment Offset = 0
More = 1

First Fragment
Data length = 208 B
Segment Offset = 0
More = 0

Second Fragment
Data length = 196 B
Segment Offset = 26 (64-bit units) = 208 B
More = 0
### IP Address

- **Class A:**
  - | Network | Local |
  - | 0 | 7 bits |
  - | 1 | 24 bits |

- **Class B:**
  - | Network | Local |
  - | 10 | 8 bits |
  - | 2 | 16 bits |

- **Class C:**
  - | Network | Local |
  - | 110 | 8 bits |
  - | 3 | 21 bits |

- **Class D:**
  - | Host Group (Multicast) |
  - | 1110 | 28 bits |

- **Class E:**
  - | Future use |
  - | 11110 | 27 bits |

- **Local = Subnet + Host (Variable length)**
  - | | Local |
  - | 5 | 27 bits |
IP Addressing

- All IP hosts have a 32-bit address: 128.10.0.1 = 1000 0000 0000 1010 0000 0000 0000 0001
- All hosts on a network have the same network prefix
Subnetting

- All hosts on a subnetwork have the same prefix. Position of the prefix is indicated by a “subnet mask”
- Example: First 23 bits = subnet
  Address: 10010100 10101000 00010000 11110001
  Mask: 11111111 11111111 11111110 00000000
  .AND. 10010100 10101000 00010000 00000000

Network

Subnet 1  Subnet 2  •••  Subnet n
Forwarding an IP Datagram

- Delivers **datagrams** to destination network (subnet)
- Routers maintain a “routing table” of “next hops”
- Next Hop field does not appear in the datagram

Table at R2:

<table>
<thead>
<tr>
<th>Destination</th>
<th>Next Hop</th>
</tr>
</thead>
<tbody>
<tr>
<td>Net 1</td>
<td>Forward to R1</td>
</tr>
<tr>
<td>Net 2</td>
<td>Deliver Direct</td>
</tr>
<tr>
<td>Net 3</td>
<td>Deliver Direct</td>
</tr>
<tr>
<td>Net 4</td>
<td>Forward to R3</td>
</tr>
</tbody>
</table>
Private Addresses

- Any organization can use these inside their network. Can’t go on the internet. [RFC 1918]
- 10.0.0.0 - 10.255.255.255 (10/8 prefix)
- 172.16.0.0 - 172.31.255.255 (172.16/12 prefix)
- 192.168.0.0 - 192.168.255.255 (192.168/16 prefix)
Address Resolution Protocol

- Problem: Given an IP address find the MAC address
- Solution: Address resolution protocol
- The host broadcasts a request:
  “What is the MAC address of 127.123.115.08?”
- The host whose IP address is 127.123.115.08 replies back:
  “The MAC address for 127.123.115.08 is 8A-5F-3C-23-45-5616”
- A router may act as a proxy for many IP addresses
Internet Control Message Protocol (ICMP)

- Required companion to IP. Provides feedback from the network.
  - Destination unreachable
  - Time exceeded
  - Parameter problem
  - Source quench
  - Redirect
  - Echo
  - Echo reply
  - Timestamp
  - Timestamp reply
  - Information Request
  - Information reply
**Internet Control Message Protocol (ICMP)**

- Required companion to IP. Provides feedback from the network.
- ICMP: Used by IP to send error and control messages.
- ICMP uses IP to send its messages (Not UDP).
- ICMP does not report errors on ICMP messages.
- ICMP reports error only on the first fragment.

<table>
<thead>
<tr>
<th>ICMP Header</th>
<th>ICMP Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>IP Header</td>
<td>IP Data</td>
</tr>
<tr>
<td>Datalink Header</td>
<td>Datalink Data</td>
</tr>
</tbody>
</table>
ICMP Message Format

<table>
<thead>
<tr>
<th>Field</th>
<th>Length</th>
</tr>
</thead>
<tbody>
<tr>
<td>IP Header</td>
<td>8b</td>
</tr>
<tr>
<td>Type of Message</td>
<td>8b</td>
</tr>
<tr>
<td>Error Code</td>
<td>8b</td>
</tr>
<tr>
<td>Checksum</td>
<td>16b</td>
</tr>
<tr>
<td>Parameters, if any</td>
<td>Var</td>
</tr>
<tr>
<td>Information</td>
<td>Var</td>
</tr>
</tbody>
</table>
**ICMP: Message Types**

<table>
<thead>
<tr>
<th>Type</th>
<th>Message</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Echo reply</td>
</tr>
<tr>
<td>3</td>
<td>Destination unreachable</td>
</tr>
<tr>
<td>4</td>
<td>Source quench</td>
</tr>
<tr>
<td>5</td>
<td>Redirect</td>
</tr>
<tr>
<td>8</td>
<td>Echo request</td>
</tr>
<tr>
<td>11</td>
<td>Time exceeded</td>
</tr>
<tr>
<td>12</td>
<td>Parameter unintelligible</td>
</tr>
<tr>
<td>13</td>
<td>Time-stamp request</td>
</tr>
<tr>
<td>14</td>
<td>Time-stamp reply</td>
</tr>
<tr>
<td>15</td>
<td>Information request</td>
</tr>
<tr>
<td>16</td>
<td>Information reply</td>
</tr>
<tr>
<td>17</td>
<td>Address mask request</td>
</tr>
<tr>
<td>18</td>
<td>Address mask reply</td>
</tr>
</tbody>
</table>
ICMP Messages

- Source Quench: Please slow down! I just dropped one of your datagrams.
- Time Exceeded: Time to live field in one of your packets became zero.” or “Reassembly timer expired at the destination.
- Fragmentation Required: Datagram was longer than MTU and “No Fragment bit” was set.
- Address Mask Request/Reply: What is the subnet mask on this net? Replied by “Address mask agent”
Summary

- Hosts, networks, subnetwork, Internet
- IP: header
- Time to Live
- IP Addresses, Class A, B, C, D, Private, Subnet Mask
- Fragmentation
- ARP, ICMP
Reading Assignment

- Read Sections 18.1-18.4 of Stallings’ 7th edition
Submit answer to Exercise 18.5 from Stallings’ 7th edition