CS101 Lecture 7:
Internetworking:
Internet Protocol, IP Addresses, Routing, DNS

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Some images courtesy Wikimedia Commons
What You’ll Learn Today

– What does Internet Protocol actually do?
– What is an IP address?
– How do packets get where they need to go?
– How is an Internet domain name related to an IP address?
– How do applications send messages through the Internet?
Network Protocols

Protocol
A set of rules that defines how data is formatted and processed on a network.

Recall (from video):
- Bob Kahn/BBN had been developing many different packet switching networks in 1970s
- Each network had its own hardware, node-addressing scheme, and protocols (http://en.wikipedia.org/wiki/Packet_switched_network)
Network Protocols

Vint Cerf and Bob Khan created Internet Protocol, to connect different packet switching networks.


Open System
A system which is based on published standards for how protocols should work.

– Interoperability of hardware and software from different vendors
Analogy: Intermodal Transport

What do these have in common?
Internet Protocol

Core ideas in Internet Protocol

– Each node has a logical IP address
– Application data separate from physical transport mechanism
– IP packets can travel across multiple networks
– Packet delivery is not guaranteed
  • “best effort”
Network Addresses

Each node on a network is identified by a unique address.

**IP Address**
A logical address, which uniquely identifies a computer on the Internet; expressed as four one-byte integers.
Example: 128.197.26.35

**Hostname**
A mnemonic for an IP address.
Examples: www.bu.edu corresponds to 128.197.26.35
Network Addresses

Examples:

128.197 is bu.edu network

74.125 is google.com network

The IP Address is made up of 2 components: the Network Number and the Host Number.

Example IP Address: 128.197.26.35

128.197 is the network number

128.197.26 is the sub network (subnet)

35 is the host number on the subnet.
Domain Name System

Domain Name
The part of a hostname that specifies a specific organization or group.
Example: bu.edu

Domain Name System (DNS)
A distributed system for managing hostname resolution – the process of converting a domain name to an IP address.
– Analogous to a “phone book” for Internet hosts.
Routing

Routing directs the forwarding of IP packets from their source to their destination.

Example by analogy:
Suppose you’re flying from Boston, MA to Portland, OR. How do you get there?
Example: BOS to PDX

United Airlines Route map, source: http://www.united.com/page/article/0,6722,1020,00.html
BOS to PDX:
Possible Routes

- BOS to IAD to PDX (2 hops)
- BOS to DEN to PDX (2 hops)
- BOS to SFO to PDX (2 hops)
- BOS to ORD to PDX (2 hops)
- BOS to IAD to SFO to PDX (3 hops)
- BOS to IAD to DFW to DEN to PDX (4 hops)
BOS to PDX: Possible Routes

Suppose you take the first flight to IAD, and then the flight from IAD to PDX was cancelled. Now what?

- IAD to PDX (cancelled)
- IAD to ORD to PDX (2 hops)
- IAD to DEN to PDX (2 hops)
- IAD to LAX to PDX (2 hops)
- IAD to DFW to DEN to PDX (3 hops)
Airline Baggage Routing
IP Packet Header

Each protocol encapsulates some user data along with a packet header. The packet header contains information used for routing and sequencing.
The IP Packet Header is 20 bytes (160 bits) of data:

<table>
<thead>
<tr>
<th>+</th>
<th>Bits 0–3</th>
<th>4–7</th>
<th>8–15</th>
<th>16–18</th>
<th>19–31</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Version</td>
<td>Header length</td>
<td>Type of Service (now DiffServ and ECN)</td>
<td>Total Length</td>
<td></td>
</tr>
<tr>
<td>32</td>
<td>Identification</td>
<td>Flags</td>
<td>Fragment Offset</td>
<td></td>
<td></td>
</tr>
<tr>
<td>64</td>
<td>Time to Live</td>
<td>Protocol</td>
<td>Header Checksum</td>
<td></td>
<td></td>
</tr>
<tr>
<td>96</td>
<td></td>
<td>Source Address</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>128</td>
<td></td>
<td>Destination Address</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>160</td>
<td></td>
<td>Options</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>160 or 192+</td>
<td></td>
<td>Data</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The header specifies 13 fields, including:
- packet length
- source and destination IP addresses
- fragment sequence
- time to live (number of hops remaining).
Internet Protocol Layer Model

A four-layer model of network interaction to facilitate communication standards.

Each layer deals with a particular aspect of network communication.

Network protocols are usually specific to one layer of this model.

**IP is a layer 2 protocol.**
Transport Layer Protocols

Break messages into packets, hands them off to the IP software for delivery, and then orders and reassembles the packets at their destination.

**Transmission Control Protocol (TCP)**
A reliable transport protocol:
- TCP guarantees delivery of packets as well as data integrity.

**User Datagram Protocol (UDP)**
An unreliable transport protocol.
- UDP does not guarantee delivery of packets.
Application Layer Protocols

The application layer creates data and communicates to other applications on the same or another host.

<table>
<thead>
<tr>
<th>HTTP</th>
<th>FTP</th>
<th>Telnet</th>
<th>RTP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transmission Control Protocol (TCP)</td>
<td>User Datagram Protocol (UDP)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Internet Protocol (IP)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Layering of key network protocols (diagram showing internet (2), transport (3), and application (4) layers)
# Application-Level Protocols

Some high-level protocols which rely upon Internet Protocol, and the ports they use.

<table>
<thead>
<tr>
<th>Protocol</th>
<th>Port</th>
</tr>
</thead>
<tbody>
<tr>
<td>Echo</td>
<td>7</td>
</tr>
<tr>
<td>File Transfer Protocol (FTP)</td>
<td>21</td>
</tr>
<tr>
<td>Telnet</td>
<td>23</td>
</tr>
<tr>
<td>Simple Mail Transfer Protocol (SMTP)</td>
<td>25</td>
</tr>
<tr>
<td>Domain Name Service (DNS)</td>
<td>53</td>
</tr>
<tr>
<td>Gopher</td>
<td>70</td>
</tr>
<tr>
<td>Finger</td>
<td>79</td>
</tr>
<tr>
<td>Hypertext Transfer Protocol (HTTP)</td>
<td>80</td>
</tr>
<tr>
<td>Post Office Protocol (POP3)</td>
<td>110</td>
</tr>
<tr>
<td>Network News Transfer Protocol (NNTP)</td>
<td>119</td>
</tr>
<tr>
<td>Internet Relay Chat (IRC)</td>
<td>6667</td>
</tr>
</tbody>
</table>

Port
A numeric designation that corresponds to a particular high-level protocol.
What You Learned Today

– Internet Protocol
– Hostnames and IP Addresses
– Domain Name System
– Routing
– TCP/UDP

Combine these ingredients to get the Internet (use only as directed; results may vary).
Announcements and To Do List

– Readings:
  - Reed ch 3, pp. 53-57 (today)
  - http://www.webpagesthatsuck.com (for next week)
  - HTML Tutorial http://www.w3schools.com/HTML/ (next week)

– HW03 (networking) due WED 2/9
Domain Name System

DNS administrators makes changes manually
  – It takes several hours for changes to propagate throughout the network.

When DNS servers fail, users get a “host not found” type of error
  – DNS update errors have caused large “outages.”
  – DNS servers are prime targets of denial of service attacks.
Domain Name System

Domain Name Server
Attempts to translate a hostname into an IP address.
– In practice, a hostname resolution might require queries to several DNS servers, each one with more detailed information than the previous one.

Client programs such as web browsers send requests to a DNS Resolver (in the operating system), which communicates with the DNS servers.
The DNS Resolver typically maintains a cache to prevent unnecessary queries to the DNS Servers. DNS cache entries have a time to live (TTL) metric which prevents stale information from being used.