Network Essentials
Session 1

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- 7-Layer OSI Model
- Network Layer protocols (Internet Protocol)
- Transport Layer protocols (TCP and UDP)
This presentation has been adapted from presentations available at:

2. Prof. Shivkumar Kalyanaraman (http://www.ecse.rpi.edu/Homepages/shivkuma/)
3. Prof. Sneha Kumar Kasera (http://www.cs.utah.edu/classes/cs5480/)
4. Prof. David Hollinger (http://www.cs.rpi.edu/~hollingd/netprog)
5. South Asian Network Operators Group
Network Models

- Formal models allow us to deal with various aspects of networks abstractly
  - One such model is the OSI reference model

  "Open Systems Interconnection Basic Reference Model"

- The OSI reference model is a \textit{layered} model
  - Divide a task into pieces and then solve each piece independently
  - Establishing a well defined interface between layers

- Major Advantages:
  - Each layer can be implemented independently
  - Adaptability
  - Code Reuse
  - Extensibility
<table>
<thead>
<tr>
<th>Layers</th>
<th>Examples</th>
<th>Functionality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Application</td>
<td>Mail, Web, etc.</td>
<td>Data encryption, compression</td>
</tr>
<tr>
<td>Presentation</td>
<td></td>
<td>Managing sessions</td>
</tr>
<tr>
<td>Session</td>
<td>TCP/UDP</td>
<td>Virtual End-to-end connectivity</td>
</tr>
<tr>
<td>Network</td>
<td>IP</td>
<td>Path selection, Internetworking</td>
</tr>
<tr>
<td>Data Link</td>
<td>Ethernet</td>
<td>Error-free communication links</td>
</tr>
<tr>
<td>Physical</td>
<td></td>
<td>Transmission of raw signal</td>
</tr>
</tbody>
</table>
No session or presentation layers in TCP/IP model
Network Layer
- Packet-switched, connectionless datagram network
- IP is the network layer protocol
  - Acts as a glue
- Hourglass concept
  - All hosts and routers run IP
- Stateless architecture
  - No per flow state inside the network
- Hop-by-hop packet forwarding
  - Header contains all the information
IP - Minimalist Approach

- Dumb network
  - *Connectivity* is the key
  - Network provides minimal functionalities to support connectivity
  - Addressing, forwarding, routing

- Smart end systems
  - Transport layer or application performs more sophisticated functionalities
  - Flow control, error control, congestion control

- Advantages
  - High scalability
  - Works across heterogeneous technologies (Ethernet, modem, satellite, wireless)
  - Supports diverse applications (telnet, ftp, Web, media streaming)
  - Decentralized network administration
### IPv4 Header

<table>
<thead>
<tr>
<th>Field</th>
<th>Length</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version</td>
<td>4</td>
</tr>
<tr>
<td>IHL</td>
<td>4</td>
</tr>
<tr>
<td>Type of Service</td>
<td>8</td>
</tr>
<tr>
<td>Identification</td>
<td>16</td>
</tr>
<tr>
<td>Time to Live</td>
<td>16</td>
</tr>
<tr>
<td>Protocol</td>
<td>16</td>
</tr>
<tr>
<td>Flags</td>
<td>16</td>
</tr>
<tr>
<td>Fragment Offset</td>
<td>16</td>
</tr>
<tr>
<td>Header Checksum</td>
<td>16</td>
</tr>
<tr>
<td>Source Address</td>
<td>32</td>
</tr>
<tr>
<td>Destination Address</td>
<td>32</td>
</tr>
<tr>
<td>Options</td>
<td>32</td>
</tr>
<tr>
<td>Padding</td>
<td>32</td>
</tr>
<tr>
<td>Transport Layer Data</td>
<td>32</td>
</tr>
</tbody>
</table>
IP Address

- IP address: Unique identification of the end-system from a network-layer perspective
- IP address is 32-bits long (version 4)
- Contains a network ID and host ID
  - Use subnet mask to detect the network ID
- Example of IP address:
  - 133.27.162.125

<table>
<thead>
<tr>
<th>Decimal</th>
<th>Binary</th>
<th>HEX</th>
</tr>
</thead>
<tbody>
<tr>
<td>133</td>
<td>10000101</td>
<td>85</td>
</tr>
<tr>
<td>27</td>
<td>00011011</td>
<td>1B</td>
</tr>
<tr>
<td>162</td>
<td>10100010</td>
<td>A2</td>
</tr>
<tr>
<td>125</td>
<td>01111101</td>
<td>7D</td>
</tr>
</tbody>
</table>
Network Mask

- Define which bits are used to describe the network ID

- Different Representations:
  - Decimal dot notation: 255.255.224.0
  - Number of network bits: /19

- Bitwise-AND of 32-bit IP address with 32-bit netmask yields network ID part of the address (truncated appropriately)
Network Mask Examples

137.158.128.0/17  (netmask 255.255.128.0)

```
1111 1111 1111 1111 | 1   000 0000 | 0000 0000
1000 1001 1001 1110 | 1   000 0000 | 0000 0000
```

198.134.0.0/16  (netmask 255.255.0.0)

```
1111 1111 1111 1111 | 0000 0000 | 0000 0000
1100 0110 1000 0110 | 0000 0000 | 0000 0000
```

205.37.193.128/26  (netmask 255.255.255.192)

```
1111 1111 1111 1111 | 1111 1111 | 0000 0000
1100 1101 0010 0101 | 1100 0001 | 10 00 0000
```
Subnets

- All device interfaces having the same network ID are part of the same subnet.

- Devices within a subnet can communicate with each other without an intervening router.
IP router

- A device with more than one link-layer interface
  - Each interface identified by a different IP address (from different subnets)

- Packets arriving at one interface are forwarded out on another interface to get them closer to the destination

- Creates and maintains forwarding tables
  - Tables help in making forwarding decisions
  - Tables created and updated based on routing information exchanged between routers
  - Each router maintains its own forwarding table
Hop by Hop Forwarding
IP Forwarding Rules - I

- Destination is in the same subnet (direct connectivity)
  - Recognize that destination IP address is on same subnet
  - Find the destination’s datalink-layer address
  - IP packet encapsulated and sent directly to the destination’s datalink-layer address

- Destination is in a different subnet (indirect connectivity)
  - Recognize that destination IP address is on different subnet
  - Look up destination IP address in a (L3 forwarding) table to find a match, called the next hop router IP address
  - Find the next hop router’s datalink-layer address
  - IP packet encapsulated and sent directly to the next hop router’s datalink-layer address
IP Forwarding Rules - II

❖ Problem 1: Recognize if destination is on the same subnet
  ❑ Use netmask to compute network ID of the destination and match it with device’s network ID

❖ Problem 2: Find a device’s datalink-layer address
  ❑ Static mapping
  ❑ Dynamic mapping using Address Resolution Protocol (ARP)
    ➢ Sender host broadcasts a request: “What is the Ethernet address of 192.1.1.4?”
    ➢ The device whose IP address is 192.1.1.4 replies back: “The Ethernet address for 192.1.1.4 is 00-0C-F1-4E-2A-E2”
    ➢ ARP responses are cached at the sender
    ➢ Use `arp` command to view/modify the cache
Thank You!