PART VII

INTERNET PROTOCOL: FORWARDING IP DATAGRAMS
Datagram Transmission

- Host delivers datagrams to directly connected machines
- Host sends datagrams that cannot be delivered directly to router
- Routers forward datagrams to other routers
- Final router delivers datagram directly
Question

Does a host need to make forwarding choices?
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Answer: YES!
Example Host That Must Choose How To Forward Datagrams

- Note: host is singly homed!
Two Broad Cases

- Direct delivery
  - Ultimate destination can be reached over one network
  - The ‘last hop’ along a path
  - Also occurs when two communicating hosts both attach to the same physical network
- Indirect delivery
  - Requires intermediary (router)
Important Design Decision

Transmission of an IP datagram between two machines on a single physical network does not involve routers. The sender encapsulates the datagram in a physical frame, binds the destination IP address to a physical hardware address, and sends the resulting frame directly to the destination.
Testing Whether A Destination Lies On The Same Physical Network As The Sender

Because the Internet addresses of all machines on a single network include a common network prefix and extracting that prefix requires only a few machine instructions, testing whether a machine can be reached directly is extremely efficient.
Datagram Forwarding

- General paradigm
  - Source host sends to first router
  - Each router passes datagram to next router
  - Last router along path delivers datagram to destination host
- Only works if routers cooperate
General Concept

Routers in a TCP/IP Internet form a cooperative, interconnected structure. Datagrams pass from router to router until they reach a router that can deliver the datagram directly.
Efficient Forwarding

- Decisions based on table lookup
- Routing tables keep only network portion of addresses (size proportional to number of networks, not number of hosts)
- Extremely efficient
  - Lookup
  - Route update
Important Idea

- Table used to decide how to send datagram known as *routing table* (also called a *forwarding table*).
- Routing table only stores address of next router along the path.
- Scheme is known as *next-hop forwarding* or *next-hop routing*. 
Terminology

- Originally
  - *Routing* used to refer to passing datagram from router to router
- More recently
  - Purists decided to use *forwarding* to refer to the process of looking up a route and sending a datagram
- But...
  - Table is usually called a *routing table*
Conceptual Contents Of Routing Table Found In An IP Router

An example Internet with IP addresses:

<table>
<thead>
<tr>
<th>TO REACH NETWORK</th>
<th>ROUTE TO THIS ADDRESS</th>
</tr>
</thead>
<tbody>
<tr>
<td>10.0.0.0</td>
<td>DIRECT</td>
</tr>
<tr>
<td>20.0.0.0</td>
<td>DIRECT</td>
</tr>
<tr>
<td>30.0.0.0</td>
<td>20.0.0.6</td>
</tr>
<tr>
<td>40.0.0.0</td>
<td>30.0.0.7</td>
</tr>
<tr>
<td>DEFAULT</td>
<td>20.0.0.6</td>
</tr>
</tbody>
</table>

| 10.0.0.0         | 30.0.0.6              |
| 20.0.0.0         | 30.0.0.6              |
| 30.0.0.0         | 20.0.0.6              |
| 40.0.0.0         | 30.0.0.7              |
| DEFAULT          | 40.0.0.8              |
Special Cases

- Default route
- Host-specific route
Default Route

- Special entry in IP routing table
- Matches ‘any’ destination address
- Only one default permitted
- Only selected if no other match in table
Host-Specific Route

- Entry in routing table
- Matches entire 32-bit value
- Can be used to send traffic for a specific host along a specific path (i.e., can differ from the network route)
- More later in the course
Level Of Forwarding Algorithm

- Routing table uses IP addresses, not physical addresses
Summary

- IP uses routing table to forward datagrams
- Routing table
  - Stores pairs of network prefix and next hop
  - Can contain host-specific routes and a default route