Announcements

- Reading: Chapter 16
- Project #6 Due on next Tuesday
- Midterm #2 re-grade requests due today
- Project #5 style grading is done
Sending Data

- **Data is split into packets**
  - limited size units of sending information
  - can be
    - fixed sized (ATM)
    - variable size (Ethernet)

- **Need to provide a destination for the packet**
  - need to identify two levels of information
    - machine to send data to
    - comm abstraction (e.g. process) to get data
  - address may be:
    - a globally unique destination
      - for example every host has a unique id
    - may unique between hops
      - unique id between two switches
TCP/IP Protocol

- **Name for a family of Network and Transport layers**
  - can run over many link layers:
    - Arpanet, Ethernet, Token Ring, SLIP/PPP, T1/T3, etc.

- **IP - Internet Protocol**
  - network level packet oriented protocol
  - 32 bit host addresses (dotted quad 128.8.128.84)
  - 8 bit protocol field (e.g. TCP, UDP, ICMP)

- **TCP - Transmission Control Protocol**
  - transport protocol
  - end-to-end reliable byte streams
  - provides ports for application specific end-points

- **UDP - user datagram protocol**
  - transport protocol
  - unreliable packet service
  - provides ports for application specific end-points
TCP/IP History

- **Arpanet was the origin of today’s Internet**
  - started in 1969 to connect universities and DoD sites
  - early example of packet switched network
  - original links were 64kbps and 9.6kbps

- **TCP/IP v4**
  - started in use Jan 1, 1983
  - This was a *flag day*
    - all systems had to change to the new protocol at once
    - with the modern Internet this would be **hard** to do

- **TCP/IP v6**
  - Moves to 128 bit addresses
  - Simplified packet header
Subnet Addressing

- Single site which has many physical networks
  - Only local routers know about all the physical nets
  - Site chooses part of address that distinguishes between physical networks
- Subnet mask: splits the IP address into two parts
- Common Class B site mask 255.255.255.0
  - Use 3rd byte to represent physical net
  - Use 4th byte to represent host

Internet Part  Local Part

vanilla scheme

Internet Part  Physical network  Host

subnet scheme
Encapsulation

How do we send higher layer packets over lower layers?

- Higher level info is opaque to lower layers
  - it’s just data to be moved from one point to another

- Higher levels may support larger sizes than lower
  - could need to *fragment* a higher level packet
    - split into several lower level packets
    - need to re-assemble at the end
  - examples:
    - ATM cells are 48 bytes, but IP packets can be 64K
    - IP packets are 64K, but files are megabytes
Ethernet

- 10 Mbps (to 10 Gbps)
- mili-second latency
- limited to several kilometers in distance
- variable sized units of transmission
- Conceptually a bus based protocol
  - requests to use the network can collide
- addresses are 48 bits
  - unique to each interface
Switched Ethernet

- Logically it is still a bus
- Physically, it is a star configuration
  - the hub is at the center of the network
- Switches provide:
  - better control of hosts
    • possible to restrict traffic to only the desired target
    • can shutdown a host’s connection at the hub if its Ethernet device is misbehaving
  - easier wiring
    • can use twisted pair wiring
- 100 Mbps/1Gbps Ethernet
  - is only available with switches
- 10Gbps Ethernet
  - Requires cat-6 (to 100 feet) or cat-7 wiring (to 100 meters)
Ethernet Collisions

- If one host is sending, other hosts must wait
  - called Carrier Sense with Multiple Access (CSMA)
- Possible for two hosts to try to send at once
  - each host can detect this event (cd- Collision Detection)
  - both hosts must re-send information
    - if they both try immediately, will collide again
    - instead each waits a random interval then tries again
- Only provides statistical guarantee of transmission
  - however, the probability of success if higher than the probability of hardware failures and other events
Routing

- How does a packet find its destination?
  - problem is called routing
- Several options:
  - source routing
    - end points know how to get everywhere
    - each packet is given a list of hops before it is sent
  - hop-by-hop
    - each host knows for each destination how to get one more hop in the right direction
- Can route packets:
  - per session
    - each packet in a connection takes same path
  - per packet
    - packets may take different routes
    - possible to have out of order delivery
Routing IP Datagrams

- **Direct Delivery:**
  - A machine on a physical network can send a physical frame directly to another.
  - Transmission of an IP datagram between two machines on a single physical network does not involve routers.
    - Sender encapsulates datagram into a physical frame, maps destination IP address to a physical address and sends frame directly to destination.
  - Sender knows that a machine is on a directly connected network.
    - Compare network portion of destination ID with own ID - if these match, the datagram can be sent directly.
  - Direct delivery can be viewed as the final step in any datagram transmission.
Routing Datagrams (cont.)

- **Indirect Delivery**
  - sender must identify a router to which a datagram can be sent
  - sending processor can reach a router on the sending processor’s physical network (otherwise the network is isolated!)
  - when frame reaches router, router extracts encapsulated datagram and IP software selects the next router
    - datagram is placed in a frame and sent off to the next router
Table Driven Routing

- Routing tables on each machine store information about possible destinations and how to reach them.
- Routing tables only need to contain network prefixes, not full IP addresses.
  - No need to include information about specific hosts.
- Each entry in a routing table points to a router that can be reached across a single network.
- Hosts and routers decide:
  - Can packet be directly sent?
  - Which router should be responsible for a packet (if there is more than one on physical net).

<table>
<thead>
<tr>
<th>Network</th>
<th>Route to this address</th>
</tr>
</thead>
<tbody>
<tr>
<td>20.0.0.0</td>
<td>&lt;DIRECT&gt;</td>
</tr>
<tr>
<td>30.0.0.0</td>
<td>&lt;DIRECT&gt;</td>
</tr>
<tr>
<td>10.0.0.0</td>
<td>20.0.0.5</td>
</tr>
<tr>
<td>40.0.0.0</td>
<td>30.0.0.7</td>
</tr>
</tbody>
</table>
Algorithm: RouteDatagram (Datagram, RoutingTable)

Extract destination IP address, D, from datagram and compute network prefix N

If N matches any directly connected network address

   [Direct delivery]

Else if the table contains a host-specific route for D

   [send datagram to next-hop specified in table]

Else if the table contains a route for network N

   [send datagram to next-hop specified in table]

Else if the table contains a default route

   [send the datagram to the default route]

Else declare a routing error
Routing (w/ subnets)

Consider a datagram destined for address 192.4.10.3 and the datagram arrives at router R.

Extract destination IP address, D from datagram and compute network prefix N:

- 255.0.0.0 & 192.4.10.3 is not equal to 30.0.0.0
- 255.255.255.0 & 192.4.10.3 = 192.4.10.0

Send to 128.1.0.9

Mask field is used to extract the network part of an address during lookup.

If((Mask[i] & D) == Destination[i]) forward to nextHop[i]