Internet Packets

- Packets at the network layer level are called datagrams.
- They are encapsulated in frames for delivery across physical networks.
  - “Frames” are packets at the data link layer.
- Datagrams are formed by header and payload.
- Datagrams can have different sizes:
  - Header is fixed (20 bytes).
  - Data area can contain between 1 byte and 65 KB.

Forwarding Datagrams

- Header contains all information needed to deliver datagrams to destination computer:
  - Destination address.
  - Source address.
  - Identifier.
  - Other delivery information.
- Router examines header of each datagram and forwards datagram along path to destination.
Networks and IP addressing

- **IP address:**
  - Network part + Host part
- **Network:**
  - Any host can physically be reached by any other host without intervening router
  - All hosts in the same network have the same network number

Routing

- **Routing** means finding a suitable path for a packet from sender to destination
Routing (cont’d)

• A router must choose between two or more paths that lead to the destination.
  – Choosing the “shortest” path

• Typically, there are multiple hops to make the journey
  – Unless the hosts are on the same network

• The routing algorithm is the part of a network layer software responsible for deciding which output line a packet should be transmitted on

Routing Table

• Each router stores information about forwarding in a routing table
  – Initialized at system initialization
  – Must be updated as network topology changes

• A routing table contains a list of destination networks and next hop for each destination

• Note that a router has several IP addresses!
  – One IP address per interface
Routing Table (cont’d)

• Each table contains information to deliver a packet to the next hop
• Each table entry has two parts
  – **First part**: Network segment (prefix) of IP address of the packet destination
    • No need for the host segment (suffix)
    • Router only delivers across networks; each network takes care of in-network delivery to host
  – **Second part**: IP address of next router interface
    • Specifies where the packet should go
      – If one more hop is needed, we write here the IP address of the next router interface

Example of Routing Table

<table>
<thead>
<tr>
<th>Dest. Net</th>
<th>next router</th>
<th>Nhops</th>
</tr>
</thead>
<tbody>
<tr>
<td>223.1.1</td>
<td>223.1.1.4</td>
<td>1</td>
</tr>
<tr>
<td>223.1.2</td>
<td>223.1.1.4</td>
<td>2</td>
</tr>
<tr>
<td>223.1.3</td>
<td>223.1.1.4</td>
<td>2</td>
</tr>
</tbody>
</table>

IP datagram:

<table>
<thead>
<tr>
<th>misc fields</th>
<th>source IP addr</th>
<th>dest IP addr</th>
<th>data</th>
</tr>
</thead>
</table>

Datagram remains unchanged, as it travels source to destination
Routing Example 1

IP datagram from A, addressed to B:
- look up net. address of B
- find B is on same net. as A
- link layer will send datagram directly to B inside link-layer frame
  - B and A are directly connected

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<td>2</td>
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</table>

Routing Example 2

IP datagram from A, addressed to E
- look up network address of E
- E on different network
  - A, E not directly attached
  - routing table: next hop router to E is 223.1.1.4
  - link layer sends datagram to router 223.1.1.4 inside link-layer frame
  - datagram arrives at 223.1.1.4
  - continued.....
**Routing Example 2 (cont’d)**

Arriving at 223.1.4, destined for 223.1.2.2
- look up network address of E
- E on same network as router’s interface 223.1.2.9
  - router, E directly attached
- link layer sends datagram to 223.1.2.2 inside link-layer frame via interface 223.1.2.9
- datagram arrives at 223.1.2.2!!! (hooray!)

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**Internet Protocol (IP)**

- **IP** (**Internet Protocol**) is the network layer protocol for the Internet
  - It is responsible for datagram routing
- **Important**: each datagram is routed independently!
  - Two different datagrams in the same connection can take different routes!
  - This can determine different delay for different packets within the same connection
**IP (cont’d)**

- **IP provides a best effort delivery mechanism**
  - Does not guarantee to prevent duplicate datagrams, delayed and out-of-order delivery, corruption of data or datagram loss
- **Reliable delivery is provided by the transport layer, not the network layer (IP)**
- Network layer (IP) can detect and report errors without actually fixing them

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**Datagram Header Format**

![Datagram Header Format Diagram]
Address Resolution

- Remember, once a packet is in a network, the IP address in the packet needs to be translated to a MAC address
  - This is called address resolution
- A host or a router uses address resolution only when it needs to send a packet to another computer (host or router) in the same network
  - A computer never resolves the address of a computer that attaches to a remote network!