How Data is Forwarded?

- To create an illusion of large uniform network software works with IP addresses. It puts data into packet and specifies the IP address of the destination.
- TCP/IP software in each host (or router) looks into the destination address and decides the next-hop. This next-hop is also an IP address.
- Unfortunately, IP addresses are virtual and cannot be used to reach the next-hop across a physical network.
- A frame sent across a physical network must have a physical address.

Address Resolution

- Translation from IP address to hosts physical address is known as address resolution.
- Address resolution is always local to a physical network.

AR by Table Lookup

Address binding table:

- IP Address: 197.15.3.2
- Node Address: 0A:67:4B:12:02:38
- IP Address: 197.15.3.3
- Node Address: 0A:67:26:71:02:08
- IP Address: 197.15.3.5
- Node Address: 0A:67:43:08:01:07
- IP Address: 197.15.3.6
- Node Address: 0A:67:43:08:13:02
- IP Address: 197.15.3.7
- Node Address: 0A:77:91:0E:32:FA

AR with Message Exchange

- Send a request for physical address.
  - Broadcast to all
  - Send to designated server.
  - Broadcast to designated servers.
- Receive message with physical address.
  - The actual owner of the IP address replies
  - or a server replies.
**ARP Message Delivery**

- ARP requests are Broadcast.
- ARP replies are not Broadcast.

**ARP Message Format**

- ARP protocol is general and can handle any-to-any translation.

**TCP/IP to Ethernet ARP message format**

- 0800 FOR IP
- 1 FOR ETHERNET
- 1 for REQ
- 2 for RES

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**Sending ARP Message**

- Encapsulation (in Ethernet Frame)

  - How do the computers know if the Ethernet data is ARP?
    - Type 0x806!
  - How do the computers know if it is a request or a response?
    - Need to open packet and check OPERATION field.

**Flashback: Ethernet**

- Preamble 64 (8 octates) '10101010..' synchronizes hardware.
- 48 bits static destination and source address.
- 16 bit frame type describe content forms:
  - 0800 IP Version 4
  - 806 Internet ARP
- 46-1500 byte data.
- 32 bit CRC.

**Caching ARP Address**

- 1 communication ~ 3 messages (2 ARPs)

  - Caching is done:
    - but only in memory.
    - ARP maintains a small memory
    - Entries are deleted if not used for more than 20 min.
    - For new address oldest is removed.

**Processing ARP Message**

- ARP specifies the following actions for the receiver of ARP messages:
  - Extract senders address binding. Update own cache only if it is there.
  - Check the OPERATION field. Request or response?
  - If response, (the receiver must be the target), add the entry.
  - If request, check TARGET PAADR, if this is the target send ARP response.
  - Reverse sender & target fields. Insert own physical address in SENDER HADDR.
  - After sending, if the receiver is target, add the senders binding in own cache.
IP and Hardware Address Boundaries

- Applications
- Higher layers of protocol software
- Address resolution device driver
- Hardware addresses used

IP Packets

- Physical Networks differ in the format, size, transmission mechanism of packets. If applications have to be aware of these diversities than application developed for one physical network technology will not work for other.
- IP therefore creates a definition of virtual packets which all applications can use. IP software takes the responsibility of adapting to specific underlying network technology.
- IP packets are virtual. They never travel across a network intact.
- IP offers communication mechanism for both connectionless and connection-based services.

IP Datagram

- IP packets are called IP datagram.
- IP datagrams can be of variable size 1-64K octates.
- IP datagram header contains information to route the packet across internet.
- IP datagrams are encapsulated in frames before they are transmitted over any Network.

IP Datagram Header

- VARP=IP version, HLEN=how many 32 bit segments in header
- TOTAL LENGTH=HEADER+DATA octates.
- TIMEOUT=mumaxum allowable hops (0-255)
- HEADER CHECKSUM= 1's complement sum
- IP OPTIONS=optional, without them LEN=HLEN=5
- Padding=0's to meet 32 bit boundary

IP Datagram Forwarding: Concept

- Each router sends forwards it to next router. They maintain a simple table which can also be manipulated by humans.

- IP Datagram Forwarding
  - Encapsulation, Fragmentation & Reassembly
  - Datagram Forwarding
  - Connection startup & shutdown
  - Reliability: ordering, missing data handling

TCP- Transmission Control Protocol

- VARP=Transmission control protocol
- RELIABILITY: ordering, missing data handling
IP Datagram Forwarding: Example

- The IP tables are a little complicated. It uses Masks.

<table>
<thead>
<tr>
<th>Destination</th>
<th>Mask</th>
<th>Next Hop</th>
</tr>
</thead>
<tbody>
<tr>
<td>30.0.0.0</td>
<td>30.0.0.0</td>
<td>40.0.0.0</td>
</tr>
<tr>
<td>40.0.0.0</td>
<td>30.0.0.0</td>
<td>deliver direct</td>
</tr>
<tr>
<td>128.1.0.0</td>
<td>255.255.0.0</td>
<td>deliver direct</td>
</tr>
<tr>
<td>192.4.0.0</td>
<td>255.255.255.0</td>
<td>128.1.0.0</td>
</tr>
</tbody>
</table>

- R2's routing table