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- Link state
- Distance Vector
- Hierarchical routing
II.7 Routing in the Internet
- RIP
**MAC Addresses and ARP**

- **32-bit IPv4 address:**
  - network-layer address
  - used to get datagram to destination IP subnet

- **MAC (or LAN or physical or Ethernet) address:**
  - function: *get frame from one interface to another physically-connected interface (same network)*
  - 48 bit MAC address (for most LANs)
    - burned in NIC ROM, also sometimes software settable

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**LAN Addresses and ARP**

Each adapter on LAN has unique LAN address

Broadcast address = FF-FF-FF-FF-FF-FF

LAN (wired or wireless)

- 1A-2F-88-76-09-AD
- 71-65-F7-28-08-53
- 58-23-D7-FA-20-80
- 0C-C4-11-6F-E3-98

= adapter
**LAN Address (more)**

- MAC address allocation administered by IEEE
- manufacturer buys portion of MAC address space (to assure uniqueness)
- analogy:
  - (a) MAC address: like Social Security Number
  - (b) IP address: like postal address
- MAC flat address ➜ portability
  - can move LAN card from one LAN to another
- IP hierarchical address NOT portable
  - address depends on IP subnet to which node is attached

**ARP: Address Resolution Protocol**

**Question:** how to determine MAC address of B knowing B’s IPv4 address?

- Each IPv4 node (host, router) on LAN has ARP table
- ARP table: IPv4/MAC address mappings for some LAN nodes
  - IPv4 address; MAC address; TTL
  - TTL (Time To Live): time after which address mapping will be forgotten (typically 20 min)
**ARP protocol: Same LAN (network)**

- A: 193.196.7.23;
  B: 193.196.7.78;
  Subnet: 193.196.7.0
- A wants to send a datagram to B, B is in the same IP sub-network as A (as learned in A's routing table), and B's MAC address not in A's ARP table.
- A broadcasts ARP query packet, containing B's IP address
  - dest MAC address = FF-FF-FF-FF-FF-FF
  - all machines on LAN receive ARP query
- B receives ARP packet, replies to A with its (B's) MAC address
  - frame sent to A's MAC address (unicast)
- A caches (saves) IP-to-MAC address pair in its ARP table until information becomes old (times out)
  - soft state: information that times out (goes away) unless refreshed
- ARP is "plug-and-play";
  - nodes create their ARP tables without intervention from net administrator

<table>
<thead>
<tr>
<th>Forwarding table in A:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Network</td>
</tr>
<tr>
<td>193.196.7.0</td>
</tr>
</tbody>
</table>

**Addressing: routing to another LAN**

Walkthrough: send datagram from A to B via R

Assume A knows B's IPv4 address

- two ARP tables in router R, one for each IPv4 network (LAN)
- Forwarding table in A:

<table>
<thead>
<tr>
<th>Network</th>
<th>Mask</th>
<th>Gateway</th>
<th>Interface</th>
</tr>
</thead>
<tbody>
<tr>
<td>111.111.111.0</td>
<td>255.255.255.0</td>
<td>111.111.111.110</td>
<td>111.111.111.111</td>
</tr>
</tbody>
</table>
- A creates IPv4 datagram with source A, destination B
- A uses ARP to get R’s MAC address for 111.111.111.110
- A creates link-layer frame with R’s MAC address as dest, frame contains A-to-B IPv4 datagram
- A’s NIC sends frame
- R’s NIC receives frame
- R removes IPv4 datagram from Ethernet frame, sees its destined to B
- R uses ARP to get B’s MAC address
- R creates frame containing A-to-B IPv4 datagram sends to B

This is a really important example - make sure you understand!