Data Forwarding

Every datagram carries the destination IP

The network part of the ID identifies the physical network where the destination belongs to

Every router is connected to at least two physical networks

Check if IP is within the same physical network

If not, consult the forwarding table (at router) or send to router.

Routing Tables

<table>
<thead>
<tr>
<th>Network Number</th>
<th>Next Hop</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (The network part of an IP address)</td>
<td>R3</td>
</tr>
<tr>
<td>2</td>
<td>R2</td>
</tr>
<tr>
<td>3</td>
<td>Interface 1</td>
</tr>
<tr>
<td>4</td>
<td>Interface 0</td>
</tr>
</tbody>
</table>

Still need to map IP addresses to Physical addresses
Address Translation Protocol

IP address → Physical Network Address (e.g., 48-bit Ethernet Address)

Router maintains a matching table that is dynamically updated (remember limited number of hosts per network)

Host broadcast an ARP query with the IP query in question

If target host in the same physical net, it replies with its physical address

Every receiving host updates its ARP table

Host Configuration

IP addresses are network dependent and hence cannot be statically assigned (same host can connect to many nets)

Host needs to know address of the default (gateway) router to other networks

Solution A: manually configure IP address at each network host. This address is now static

Solution B: Dynamically assign IP addresses and to each host for a period of time. Release IP address once host is disconnected

Dynamic vs. Static IP Address

Static IP: IP address does not change over time

Advantages
- You always know where your server is. Remote login, FTP, WWW, Email servers
- You always have an IP address designated to you

Disadvantages
- You need to reconfigure your host, once moved to a different subnet
- You always know where your server is. More prone to attacks
- Not efficient for situations of limited address space
- You usually get charged more

Dynamic IP: Your IP address changes after a period of time

Advantages
- You don’t run out of IP addresses, when IP address space is limited
- Much easier to administer IP assignment, can move from subnet to subnet

Disadvantages
- Cannot run applications that require static IP assignment, unless combined with a dynamic DNS service

Sticky IP: A dynamic IP that does not change. Server always assigns the same IP unless a change is needed.
Dynamic Host Configuration Protocol

A DHCP server is responsible for the IP address assignment

DHCP discovery

Host broadcasts a DHCPDISCOVER message with Dest IP 255.255.255.255
Relay agent unicasts discovery message to DHCP server

DHCP Message Format

<table>
<thead>
<tr>
<th>Operation</th>
<th>HType</th>
<th>HLan</th>
<th>Hops</th>
<th>Xid</th>
<th>Flags</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Assigned IP address

MAC address

Ipconfig on a windows machine

Connection-specific DNS Suffix: .arizona.edu
Description: Intel(R) PRO/Wireless 3945ABG Network Connection
Physical Address: 00-1B-55-A3-6D-02
DHCP Enabled: Yes
Autoconfiguration Enabled: Yes
Link-local IPv6 Address: fe80::98ed:e37f:5000:d6d0%10(Preferred)
IPv4 Address: 192.168.1.148(Preferred)
Subnet Mask: 255.255.224.0
Lease Obtained: Monday, October 10, 2009 11:12:41 AM
Lease Expires: Monday, October 10, 2009 3:12:39 PM
Default Gateway: 192.168.1.1
DHCP Server: 192.168.1.1
DHCPv6 SIA: 18779191
DNS Servers: 128.196.11.234
128.196.11.235
Virtual Networks and Tunnels

A way to create private networks

**Solution 1:** buy lease your own infrastructure that nobody else can use (most of the times too expensive)

**Solution 2:** build virtual circuits on top of shared networks

To build VC, we establish IP tunnels via IP encapsulation

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### IP Tunneling

Routing table at R1

<table>
<thead>
<tr>
<th>Network Number</th>
<th>NextHop</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Interface 0</td>
</tr>
<tr>
<td>2</td>
<td>Virtual Interface 0</td>
</tr>
<tr>
<td>Default</td>
<td>Interface 1</td>
</tr>
</tbody>
</table>

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### IP Tunneling (cont.)

**Advantages**

Combined with encryption, it can realize a confidential private network over public links

May create a virtual network of routers with special capabilities such as multicasting

May be used to transport packets of different protocols over IP networks

**Disadvantages**

 Longer packets in the tunnel, waste of bandwidth, extra fragmentation and reassembly

More overhead at the routers

Extra management for setting up tunnels