15-441 15-641 Computer Networking

Lecture 7 – IP in Practice

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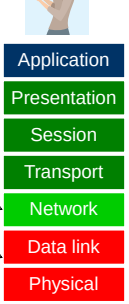
Outline

- The IP protocol
  - IPv4
  - IPv6
- IP in practice
  - Network address translation
  - Address resolution protocol
  - Tunnels

How Do We Identify Hosts?

- Hosts have a
  - host name
  - IP address
  - MAC address
- There is a reason ..
  - Remember?
- But how do we translate?



IP to MAC Address Translation

- How does one find the Ethernet address of a IP host?
- Address Resolution Protocol - ARP
  - Broadcast search for IP address
    - E.g., “who-has 128.2.184.45 tell 128.2.206.138” sent to Ethernet broadcast (all FF address)
  - Destination responds (only to requester using unicast) with appropriate 48-bit Ethernet address
    - E.g, “reply 128.2.184.45 is-at 0:d0:bc:f2:18:58” sent to 0:c0:4f:d:ed:c6

Caching ARP Entries

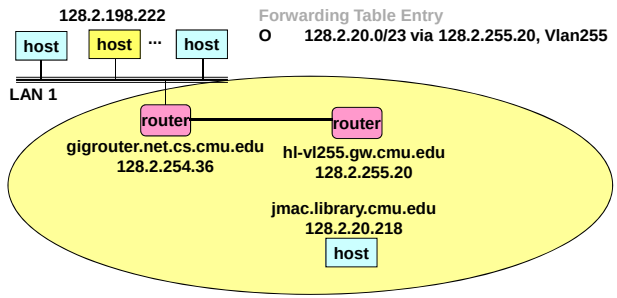
- Efficiency Concern
  - Would be very inefficient to use ARP request/reply every time need to send IP message to machine
- Each Host Maintains Cache of ARP Entries
  - Add entry to cache whenever get ARP response
  - "Soft state": set timeout of ~20 minutes

ARP Cache Example

- Show using command "arp -a"

```
Interface: 128.2.222.198 on Interface 0x1000003
  Internet Address      Physical Address      Type
  128.2.20.218          00-b0-8e-83-df-50     dynamic
  128.2.102.129         00-b0-8e-83-df-50     dynamic
  128.2.194.66          00-02-b3-8a-35-bf     dynamic
  128.2.198.34          00-06-5b-f3-5f-42     dynamic
  128.2.203.3           00-90-27-3c-41-11     dynamic
  128.2.203.61          08-00-20-a6-ba-2b     dynamic
  128.2.205.192         00-60-08-1e-9b-fd     dynamic
  128.2.206.125         00-d0-b7-c5-b3-f3     dynamic
  128.2.206.139         00-a0-c9-98-2c-46     dynamic
  128.2.222.180         08-00-20-a6-ba-c3     dynamic
  128.2.242.182         08-00-20-a7-19-73     dynamic
  128.2.254.36          00-b0-8e-83-df-50     dynamic
```


CMU's Internal Network Structure

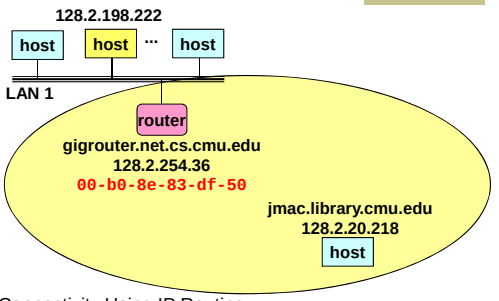


Forwarding Table Entry

O 128.2.20.0/23 via 128.2.255.20, Vlan255

- CMU Uses Routing Internally
  - Maintains forwarding tables using OSPF
  - Most CMU hosts cannot be reached at link layer

Proxy ARP



- Provides Link-Layer Connectivity Using IP Routing
  - Local router (gigrouter) sees ARP request
  - Uses IP addressing to locate host, i.e., which subnet
  - Replies with its own MAC address - becomes "Proxy" for remote host
    - Must then forward packets for that destination
  - Requestor thinks that it is communicating directly with remote host

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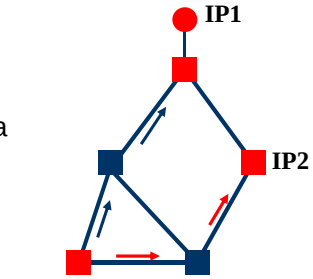
Motivation

There are many cases where not all routers have the same features or consistent state

- An experimental IP feature is only selectively deployed – how do we use this feature e-e?
  - E.g., IP multicast
- A few are using a protocol other than IPv4 – how can they communicate?
  - E.g., incremental deployment of IPv6
- I am traveling with a CMU laptop - how can I can I keep my CMU IP address?
  - E.g., must have CMU address to use services
- How do we make this happen?

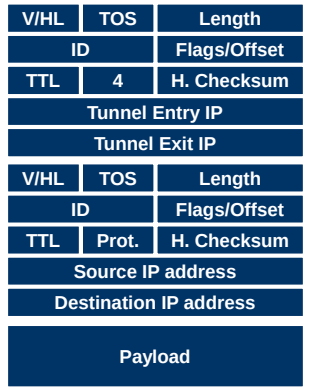
Tunneling

- Force a packet to go to a specific point in the network
  - Cannot rely on routers on regular path, e.g., an IPv6 packet
- Achieved by adding an extra IP header to the packet with a new destination address
  - Similar to putting a letter in another envelope
- Used to deal with new IP features
  - Mobile IP,..
  - Multicast, IPv6, research, ..

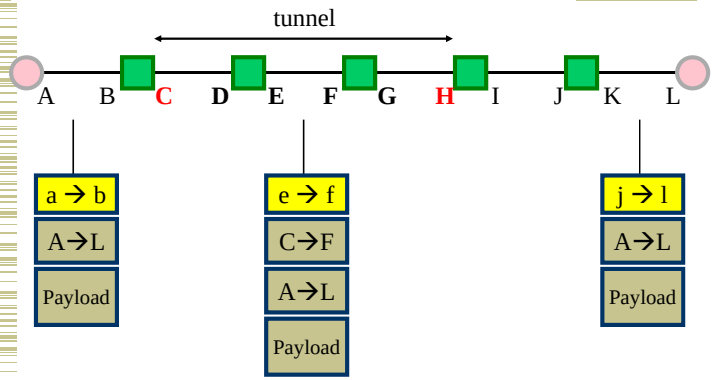


IP-in-IP Tunneling

- Described in RFC 1993.
- IP source and destination address identify tunnel endpoints.
- Protocol id = 4.
  - IP
- Several fields are copies of the inner-IP header.
  - TOS, some flags, ..
- Inner header is not modified, except for decrementing TTL.



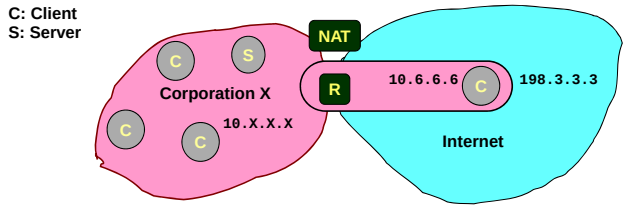
Tunneling Example



Tunneling Applications

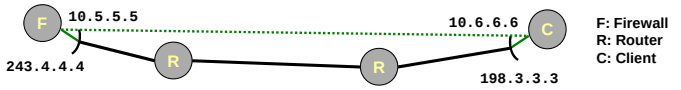
- Virtual private networks.
  - Connect subnets of a corporation using IP tunnels
  - Often combined with IP Sec (later)
- Support for new or unusual protocols.
  - Routers that support the protocols use tunnels to "bypass" routers that do not support it
  - E.g. multicast, IPv6 (!)
- Force packets to follow non-standard routes.
  - Routing is based on outer-header
  - E.g. mobile IP (later)

Extending Private Network



- Supporting Road Warrior
  - Employee working remotely with assigned IP address 198.3.3.3
  - Wants to appear to rest of corporation as if working internally
    - From address 10.6.6.6 – can also be a public address, e.g., 128.2.6.6
    - Gives access to internal services (e.g., ability to send mail)
- Virtual Private Network (VPN)
  - Overlays private network on top of regular Internet

Supporting VPN by Tunneling



- Idea: client sets up tunnel to company's firewall
- Example: client wants to send packet to internal node 10.1.1.1
- Entering Tunnel
  - Add extra IP header directed to firewall (243.4.4.4)
  - Original header becomes part of payload
  - Possible to encrypt it
- Exiting Tunnel
  - Firewall receives packet
  - Strips off header
  - Sends through internal network to destination