CSE 461: Introduction to Computer Communications Networks
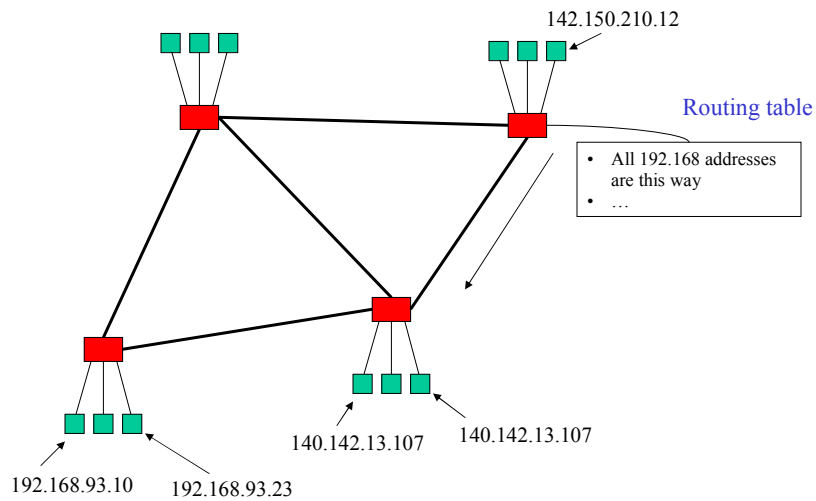## Autumn 2006

Module 6
IP Addressing

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Last Time: Addresses Imply Location

142.150.210.12

Routing table

- All 192.168 addresses are this way
- …

140.142.13.107   140.142.13.107

192.168.93.10   192.168.93.23

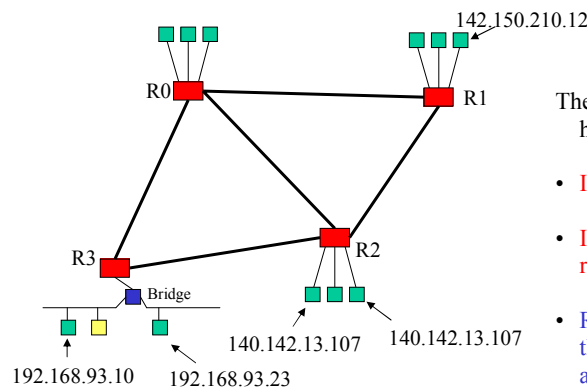10/9/2006   CSE461 06au

1

This Lecture

- IP Addressing
  - Allocation and discovery (DHCP, ARP, NAT)
  - Hierarchy (prefixes, class A, B, C, subnets)

Application
Presentation
Session
Transport
Network
Data Link
Physical

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Address Allocation and Discovery

142.150.210.12

R0

R1

R3

Bridge

R2

192.168.93.10   192.168.93.23   140.142.13.107   140.142.13.107

The yellow node boots. It has a MAC address.

- It needs an IP address.

- It needs to know to use router R3.

- R3 needs to discover the new host's MAC address.

DHCP is used.
ARP is used.

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Topic 1: Obtaining an IP address

- Old fashioned way: sysadmin configured each machine
  - E.g., a local file contained the IP address to use
  - Imagine deploying 50 new machines in one of the labs…

- Future fashioned way (IPV6): Stateless Autoconfiguration
  - Addresses are wide / plentiful
  - Form IPv6 address by concatenating "network's address" (prefix) with your own MAC address
  - Learn "network address" portion from router

- Current (IPv4) way: Dynamic Host Configuration Protocol (DHCP)
  - Addresses are narrow (32-bits) / scarce
    - Have to hand them out carefully
  - Use a DHCP server that provides bootstrap info to hosts
    - Host's IP address, gateway address, …
  - An immediate problem: how does a host without an IP address communicate with the DHCP server?

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The DHCP Problem

Host   DHCP Server

- The host doesn't have an IP address
- The host doesn't know the address of the DHCP server
- The host wants to contact the DHCP server
- We want to use IP packets to talk with the server
  - Why? Why not talk using link layer packets?

  Solution: link and IP layer multicast

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The DHCP Problem Solution

Host

Ethernet	Src: host's MAC address Dst: FF:FF:FF:FF:FF:FF
IP	Src: 00:00:00:00 Dst: FF:FF:FF:FF
UPD	Src port: 68 Dst port: 67
DHCP	RN32 Hi. Startup info please…

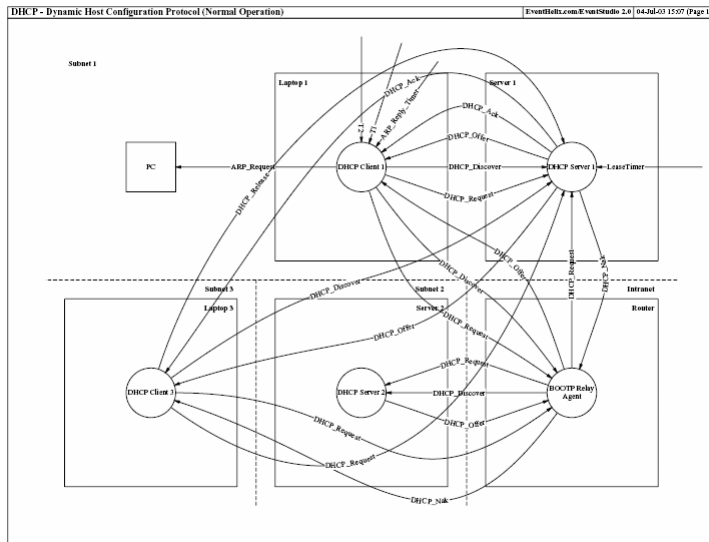**DHCP Server**

Ethernet	Src: server's MAC address Dst: FF:FF:FF:FF:FF:FF
IP	Src: server's IP address Dst: FF:FF:FF:FF
UPD	Src port: 67 Dst port: 68
DHCP	RN32 Your IP is… Your gateway's IP is… …

(As always, the actual protocol is richer than what is shown here.)

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DHCP - Dynamic Host Configuration Protocol (Normal Operation)

- Client is responsible for all retransmissions. (Why?)
- What dangers are there for losing IP addresses?
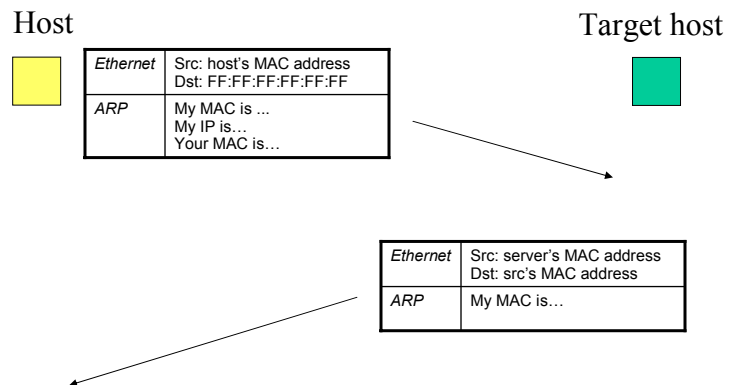
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Topic 2: Discovering MAC's from IP's

- Host has an IP (e.g., for the gateway). It needs a MAC address to send a frame to it.

- Solution: Address Resolution Protocol (ARP)

- Exploits the physical multicast of Ethernet

The DHCP Problem Solution

Host   Target host

| Ethernet | Src: host's MAC address
Dst: FF:FF:FF:FF:FF:FF |
| ARP | My MAC is ...
My IP is…
Your MAC is… |

| Ethernet | Src: server's MAC address
Dst: src's MAC address |
| ARP | My MAC is… |

(As always, the actual protocol is richer than what is shown here.)
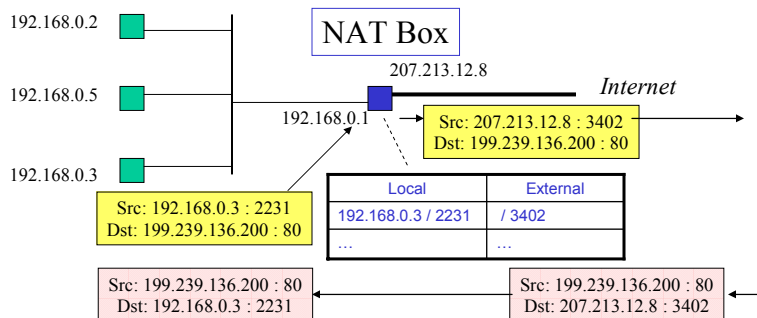
Topic 3: Network Address Translation (NAT)

- Turns out that there aren't all that many 32-bit strings (i.e., IP addresses)
  - The world needs more…
  - An individual network needs more…
  - You need more…
    - Your ISP will give you only one (using DHCP), but you want to connect five machines to the Internet

- NAT exploits *non-routable addresses* to let you build your own private network "behind the NAT box"
  - Non-routable addresses are, well, never routed
  - do not have to be globally unique (just locally unique)

- The NAT box substitutes its own IP address for outgoing packets, and the local address of the actual destination for incoming packets

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NAT Overview

- Recall that IP addresses are 32-bits (e.g., 192.168.10.3)
- Recall that TCP addresses are IP addresses plus a port number
- These IP address ranges are "non-routable":
  - 10.0.0.0 - 10.255.255.255
  - 172.16.0.0 - 172.31.255.255
  - 192.168.0.0 - 192.168.255.255

192.168.0.2

192.168.0.5

192.168.0.3

NAT Box

207.213.12.8

192.168.0.1

Internet

Src: 207.213.12.8 : 3402
Dst: 199.239.136.200 : 80

Src: 192.168.0.3 : 2231
Dst: 199.239.136.200 : 80

Local	External
192.168.0.3 / 2231	/ 3402
…	…

Src: 199.239.136.200 : 80
Dst: 192.168.0.3 : 2231

Src: 199.239.136.200 : 80
Dst: 207.213.12.8 : 3402

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6

Topic 4: IP Addresses

- Routing burden grows with size of an internetwork
  - Size of routing tables
  - Volume of routing messages
  - Amount of routing computation

- To scale to the size of the Internet, apply:
  - Hierarchical addressing
  - Use of structural hierarchy
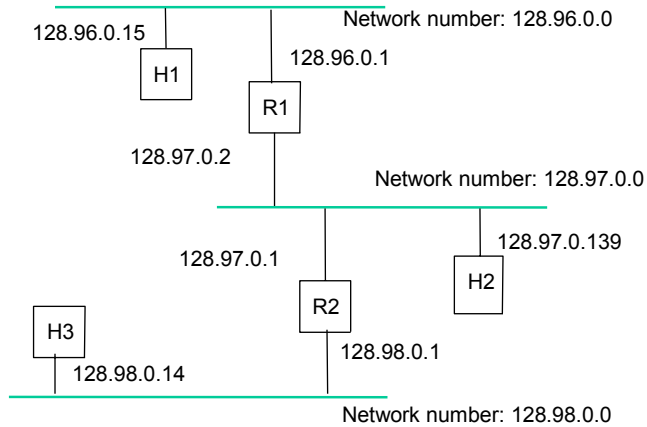 - Route aggregation

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IP Addresses: Hierarchy

- Hierarchy is used for routing
  - IP addresses reflect some properties of location in topology
    - Interfaces on the same network share prefix
    - Local delivery in a single network doesn't involve router
    - Routers advertise prefixes to each other
  - Unlike "flat" Ethernet addresses
  - Like hierarchical file names (e.g., `/homes/zahorjan/cse461/06au/m6.ppt`). What are the similarities / differences?

- Hierarchy is used for network management
  - Prefix administratively assigned (IANA or ISP)
    - Addresses globally unique
  - Full host IP assigned locally
    - Distributes burden over users

IPv4 Address Formats

		7	24	
Class A	0	Network	Host	126 networks / 16M hosts each

			14	16	
Class B	1	0	Network	Host	16K networks / 64K hosts each

				21	8	
Class C	1	1	0	Network	Host	2M networks / 255 hosts each

- 32 bits written in "dotted quad" notation, e.g., 18.31.0.135
- Given an IP address, it's easy to determine the network number

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IPv6 Address Format

3	5			
001	RegistryID	ProviderID	SubscriberID	SubnetID	InterfaceID

- 128 bits written in 16 bit hexadecimal chunks
- Still hierarchical, just more levels – roughly
  - World owner of this address range (e.g., IANA)
  - Backbone provider
  - ISP
  - End-client organization
  - Interface (host)

IPv4 Network Example

Network number: 128.96.0.0

128.96.0.15

H1

128.96.0.1

R1

128.97.0.2

Network number: 128.97.0.0

128.97.0.139

128.97.0.1

H2

H3

R2

128.98.0.14

128.98.0.1

Network number: 128.98.0.0

Internet Router Forwarding Routine: Take 1

- With bridging, it used to be "look up destination address to determine next hop"

- Now addresses have network and host portions:
  - Host: if destination network is the same as the host network, then deliver locally (without router). Otherwise send to the router

  - Router: look up destination network in routing table to find next hop and send to next router. If destination network is directly attached then deliver locally.

Take 2: Subnetting

- Split up one network number into multiple physical networks

- Helps allocation efficiency -- can hand out subnets

- Rest of internet does not see subnet structure
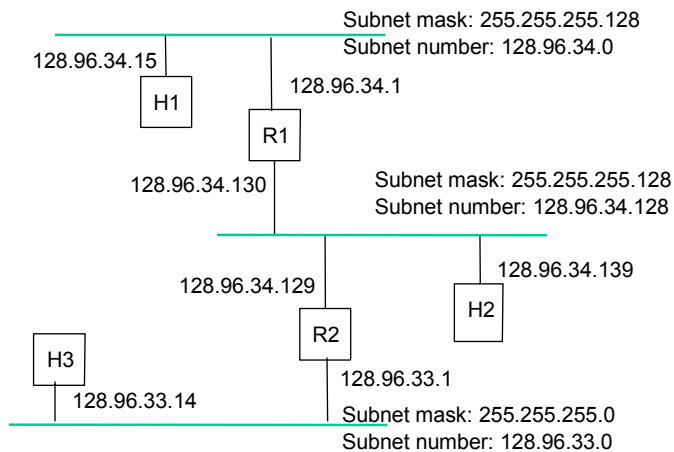 - subnet is purely internal to network
  - aggregates routing info

Network number	Host number

Class B address

111111111111111111111111	00000000

Subnet mask (255.255.255.0)

Network number	Subnet ID	Host ID

Subnetted address

Subnet Example

Subnet mask: 255.255.255.128
Subnet number: 128.96.34.0

128.96.34.15

128.96.34.1

H1

R1

128.96.34.130

Subnet mask: 255.255.255.128
Subnet number: 128.96.34.128

128.96.34.139

128.96.34.129

H2

H3

R2

128.96.33.1

128.96.33.14

Subnet mask: 255.255.255.0
Subnet number: 128.96.33.0

Updated Forwarding Routine

- Used to know network from address (class A, B, C)

- Now need to "search" routing table for right subnet
  - Host: easy, just substitute "subnet" for "network"

  - Router: search routing table for the subnet that the destination belongs to, and use that to forward as before
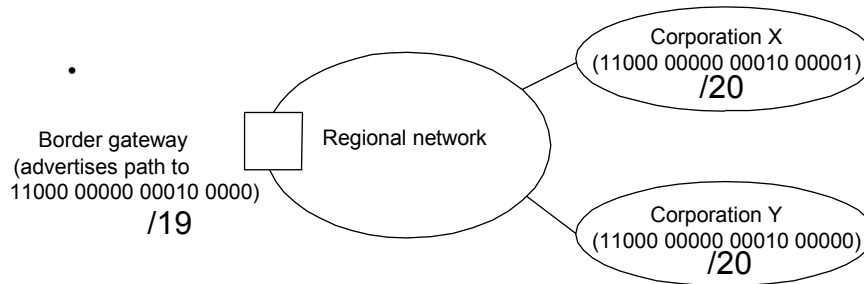

Take 3: CIDR (Supernetting)

- CIDR = Classless Inter-Domain Routing

- Generalize class A, B, C into prefixes of arbitrary length; now must carry prefix length with address

- Aggregate adjacent advertised network routes
  - e.g., ISP has class C addresses 192.4.16 through 192.4.31
  - Really like one larger 20 bit address class …
  - Advertise as such (network number, prefix length)
  - Reduces size of routing tables

- But IP forwarding is more involved
  - Based on Longest Matching Prefix operation

CIDR Example

- X and Y routes can be aggregated because they form a bigger contiguous range.

-

```
Border gateway
(advertises path to
11000 00000 00010 0000)
       /19
```

Regional network

Corporation X
(11000 00000 00010 00001)
/20

Corporation Y
(11000 00000 00010 00000)
/20

- But aggregation isn't always possible. Why?
  - can only aggregate power of 2

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IP Forwarding Revisited

- Routing table now contains routes to "prefixes"
  - IP address and length indicating what bits are fixed

- Now need to "search" routing table for longest matching prefix, only at routers
  - Search routing table for the prefix that the destination belongs to, and use that to forward as before
  - There can be multiple matches; take the longest prefix

- This is the IP forwarding routine used at routers.

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Key Concepts

- Hierarchical address allocation helps routing scale
    - Technical Issues:
        - Addresses are constrained by topology
        - Advertise and compute routes for networks, not each host
        - Separate internet view of networks from local implementation via subnets
        - Keep host simple and let routers worry about routing
    - Network Administration Issue:
        - Distribute workload of assigning IP addresses to clients

- DHCP provides convenient management of host startup information

- ARP learns the mapping from IP to MAC address

- NAT hides local names behind a single global name

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