Computer Networking

COMP 177 | Fall 2020 | University of the Pacific | Jeff Shafer

IPv4 - Part 2

Recap

Past Topics

- Overview of networking and layered architecture
- Wireshark packet sniffer
- Wired LAN and Ethernet
- Wireless LAN and WiFi

Today's Topics

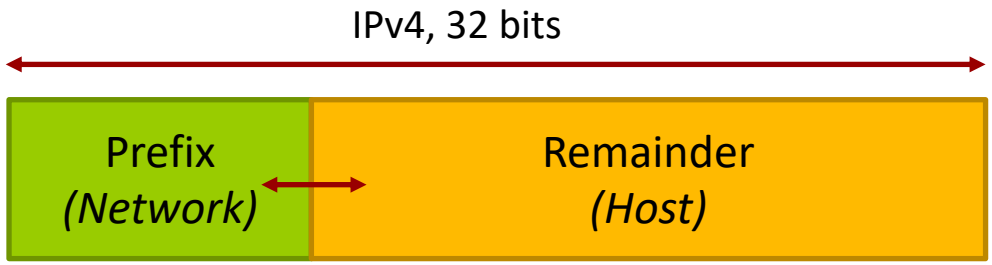
- Internet Protocol v4
  - Fragmentation
  - Special addresses
  - Packet forwarding
  - Subnetting

Internet Protocol (IP)

- IP is the prominent *network layer* protocol
- IP provides for
  - *Universal addressing* of nodes using IP addresses
  - *Routing* packets using *routing protocols*
- IP headers include
  - *Source IP address*: the address of the ultimate sender
  - *Destination IP address*: the address of the ultimate receiver
- Routers use the destination IP address to determine next hop
- Using IP, a packet can be delivered from any arbitrary node to any other as long as the two ends are publicly available

IP Address Format

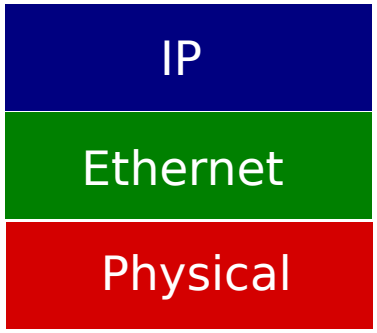
- An IP address consists of two parts:
  - *Network* part (prefix)
  - *Host* (interface) part (remainder)

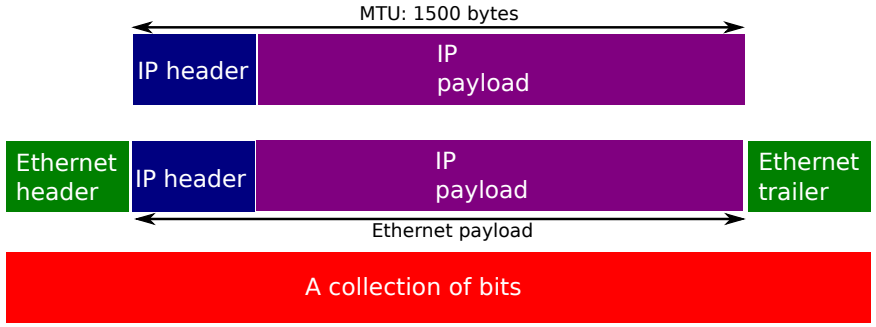


- *Classless Inter-Domain Routing (CIDR)*
  - The size of the prefix can vary!
  - Allows more adaptable network sizes

IP Packet Fragmentation

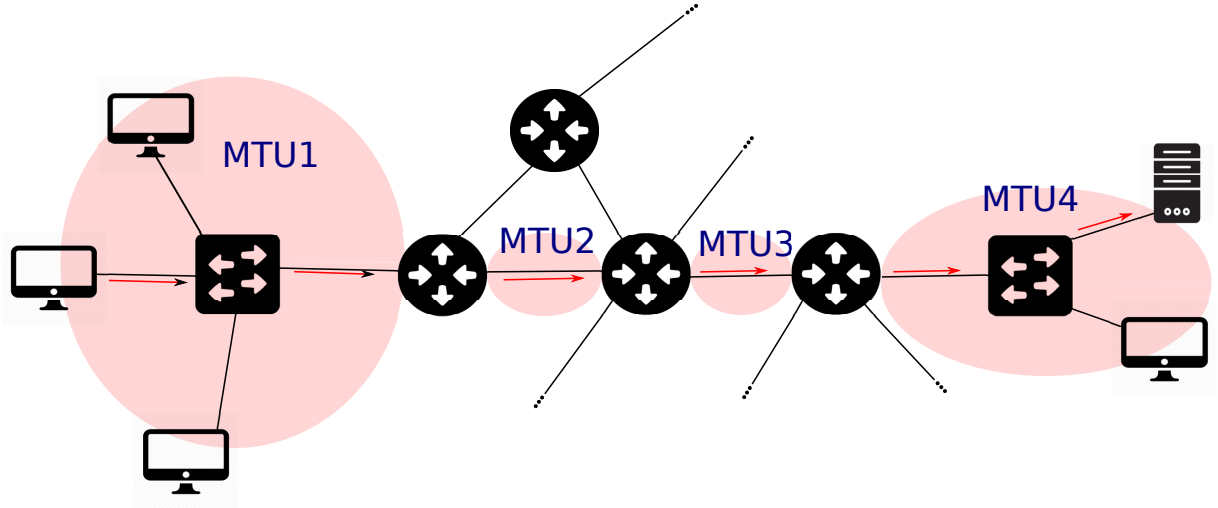
- Data link layer limits the packets to a maximum size
  - The *payload* of a data link layer packet cannot exceed a certain size
  - This entails a maximum size for an IP datagram (IP header + IP payload)
  - This is called the *maximum transmission unit* (MTU)
    - Maximum size of the network layer packet
- Different link layer technologies impose different MTUs
  - Ethernet: 1500 bytes
  - WiFi: 2304 bytes
  - Token ring: 4 KB





Fragmentation

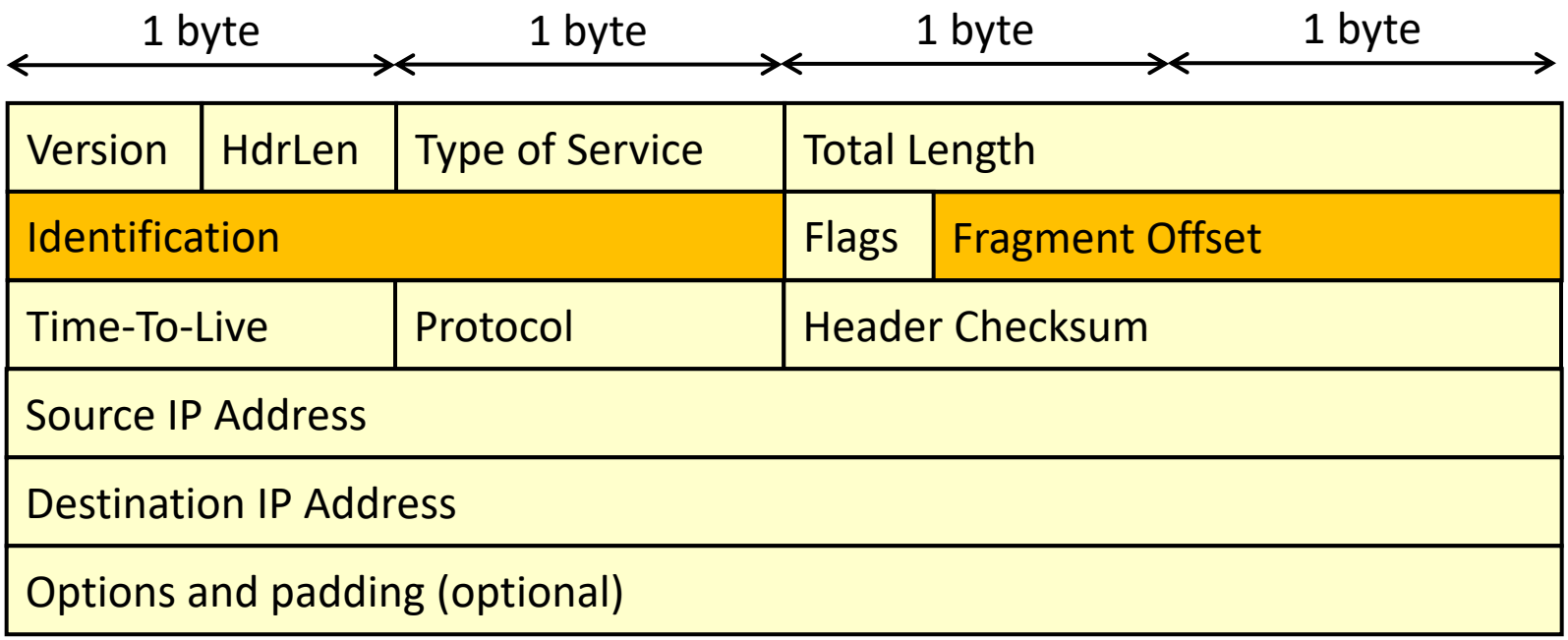
- What if the IP payload is large enough that the whole IP packet size exceeds MTU?
  - IP service needs to divide the payload into smaller chunks, such that
    - Each chunk + IP header is at max 1500 bytes
  - This process is called IP *fragmentation*
  - Each smaller packet is called a *fragment*
- Potentially any network layer entity (host or router) that resides in the path can perform fragmentation according to the MTU on the forwarding link



Reassembly

- *Reassembly* is the process of collecting all fragments of an original packet together in order to reconstruct the original large packet
- The fragments need to be reassembled at some point in the path between the two ends
- This entails two types of fragmentation/reassembly:
  - *Per link fragmentation*: Reassembly takes place at the opposite end of the link, e.g., in ATM networks
  - *Per path fragmentation*: Reassembly takes place at the opposite end of the path, e.g., in IPv4
- What information does a network layer service need to reassemble the fragments into the original packets?
  - Whether a fragment belongs to a specific original packet
  - Where in the original packet the belonging fragment should be placed

IPv4 Header Format



- Identification: Whether a fragment belongs to a specific original packet
- Fragmentation Offset: Where in the original packet the current fragment should be placed

Loopback Addresses

- *Loopback addresses* are assigned to loopback interfaces in the hosts
  - *Loopback interfaces* are virtual interfaces that simulate communication in the network, without emitting packets through the network
  - Useful for running/testing network applications locally
- The subnet for loopback addresses is `127.0.0.0/8`
  - The most well-known loopback address is `127.0.0.1`

Private Addresses

- 32-bit address space for IPv4 is not enough for today's Internet ($2^{32} \simeq$ 4billion addresses)
- Many of the IP addresses are for internal / private use
  - The address for a corporate file server
  - The address of each interfaces of an internal router
  - The address of the PCs and laptops handed to employees
- Private IP addresses can be used *arbitrary number of times* in different networks
- **Public routers (e.g., ISP's) cannot forward packets with a destination address in the private ranges**
- Private IP address blocks
  - 10.0.0.0/8 (Used by PacificNet)
  - 172.16.0.0/12
  - 192.168.0.0/16

Special IP Addresses

http://xkcd.com/742/

Broadcast Addresses

- Broadcast addresses are used to send an IP packet to all interfaces within a network
- Two types of broadcast addresses:
  - Local broadcast: Broadcasting an IP packet within the same LAN that the sender is.
    - The address is `255.255.255.255`
  - Remote broadcast: Broadcasting an IP packet within a (remote) network with a specific prefix
    - The address would include the prefix of the (remote) network + bits of 1 in the place of remainder
    - Example: Suppose you want to broadcast IP packets within a network with prefix `214.153.62.0/24`. The broadcast address would be `214.153.62.255`

Broadcast Addresses

- Network layer (IP) broadcasting needs data link layer broadcasting to function.
  - Local broadcasting: At the sender, when the link layer service receives the IP packet with destination address `255.255.255.255`, it sets the destination MAC address to `FF:FF:FF:FF:FF:FF`
  - Remote broadcasting: At the last router in the path, when the link layer service receives the IP packet with destination address set as the remote broadcast address, it sets the destination MAC address to FF:FF:FF:FF:FF:FF
    - Remote broadcasting is often *filtered* by a router in the path

Multicast Addresses

- *Multicast IP addresses* are used to send a packet to all interfaces within the *multicast group*
- Multicasting in network layer allows having interfaces from different networks to be in a multicast group
- A specific class of IP addresses are used as multicast addresses, called *Class D*
  - The high four bits of the first byte in the address is `1110`
- Multicast in IP needs router support
  - Routers need to keep track of the multicast groups
  - Only used in special situations

Number of IP Addresses Within a Network

- Consider the network with prefix `214.153.62.0/24`
- Class C network with 8 bits for remainder
  - 2^8 = 256 different addresses
- However, 2 of the addresses are unavailable:
  - `214.153.62.0` : 0's in remainder (subnet addr)
  - `214.153.62.255` : 1's in remainder (broadcast addr)
- Thus, 256 − 2 = **254** addresses are available to be used by devices in the network

ARIN WHOIS Database Search

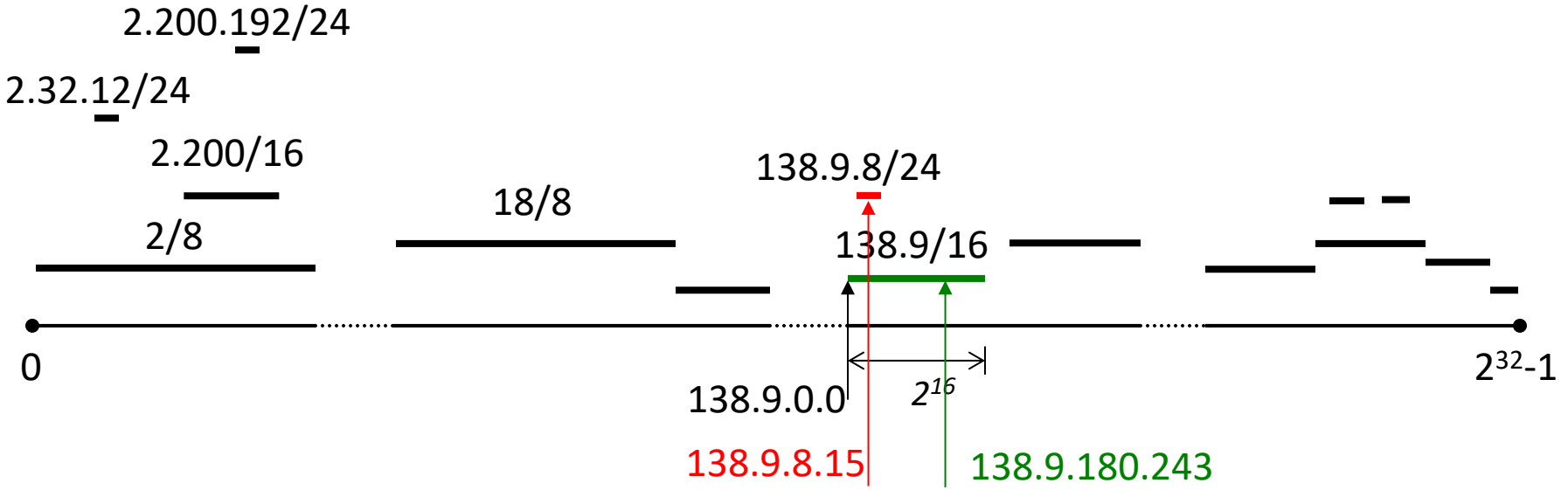
Relevant Links: ARIN Home Page ARIN Site Map Training: *Querying ARIN's WHOIS*

Search ARIN WHOIS for: 138.9.1.21

Submit

```
OrgName:    University of the Pacific
OrgID:      UNIVER-95
Address:    3601 Pacific Ave.
City:       Stockton
StateProv:  CA
PostalCode: 95211
Country:    US

NetRange:   138.9.0.0 - 138.9.255.255
CIDR:       138.9.0.0/16
NetName:    UOP
NetHandle:  NET-138-9-0-0-1
Parent:     NET-138-0-0-0-0
NetType:    Direct Assignment
NameServer: NS1.PACIFIC.EDU
NameServer: NS2.PACIFIC.EDU
Comment:
RegDate:    1990-01-17
Updated:    2007-09-07

RAbuseHandle: DAVEA-ARIN
RAbuseName:   Lundy, Dave A.
RAbusePhone:  +1-209-946-3951
RAbuseEmail:  dlundy@pacific.edu

RTechHandle: EES7-ARIN
RTechName:   Escalante, Edgar
RTechPhone:  +1-209-946-3190
RTechEmail:  eescalante@pacific.edu

OrgTechHandle: DAVEA-ARIN
OrgTechName:   Lundy, Dave A.
OrgTechPhone:  +1-209-946-3951
OrgTechEmail:  dlundy@pacific.edu
```

IP Prefixes



- IP address space can be viewed as a number line
  - Each segment represents an aggregated route
  - Segments can overlap
- Look for smallest segment that matches the destination address : **Longest Prefix Match**

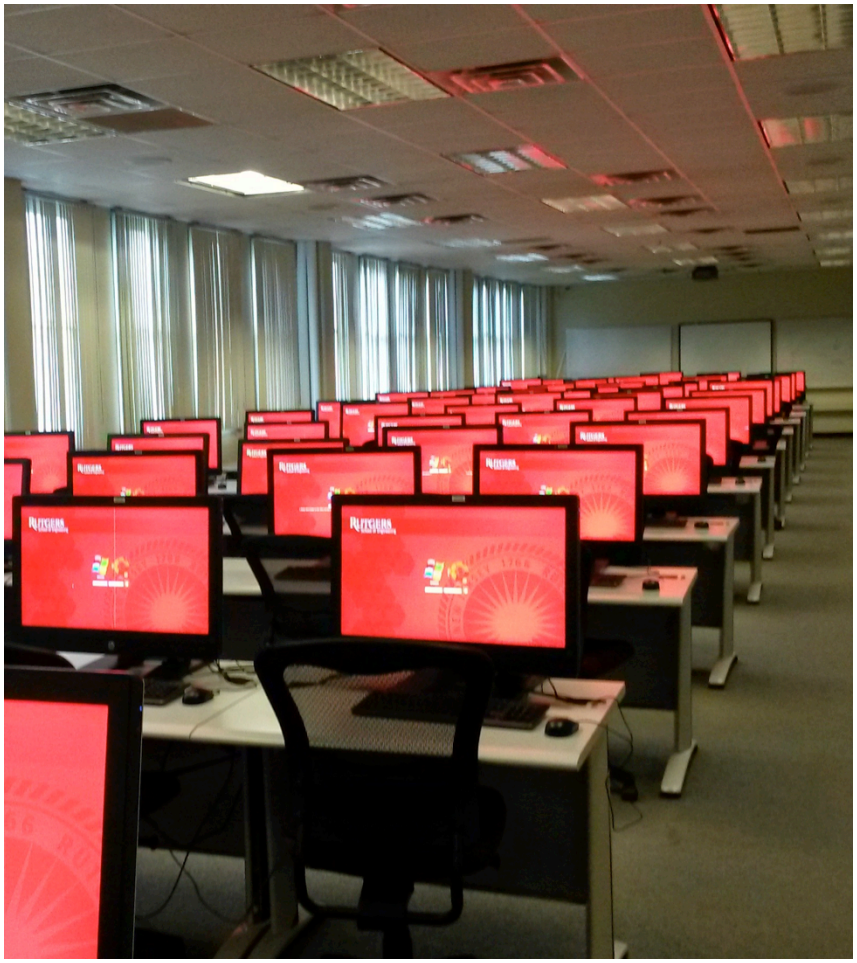
Longest Prefix Match

- Allow more specific entries to supersede more general ones
  - 138.9.8/24
    - Route this traffic to Sacramento
  - 138.9/16
    - Route this traffic to Stockton
    - Except for addresses that match a route with a longer prefix (i.e., 138.9.8/24)
- Allows significantly more route aggregation
- Simplifies things if companies move (physically or to another ISP) their block of IP addresses

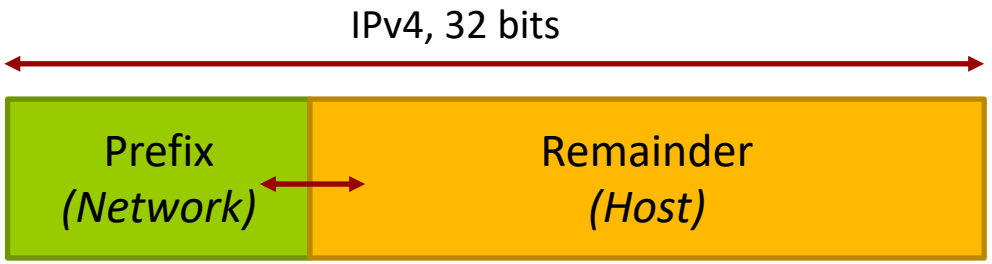
IP Subnets

Subnets

- Imagine we are designing the network for an "engineering building"
- How many hosts (max) will be connected to the building network?
  - Estimate: **800 hosts**
- **How big should our subnet be?**



Subnets



- How big should the host address field be?
  - 8 bits? ($2^8 = 256$)
  - 9 bits? ($2^9 = 512$)
  - 10 bits? ($2^{10} = 1024$)
    - **Sufficiently large for "800 hosts"**

Subnet Naming

- Imagine you could use any IP address range for this network
- **Will `192.168.1.0/24` work?**
  (like we use in lab out of habit?)
  - **Definitely not!**

Subnet Naming

- **Problem 1:**
  - The length of the subnet address is 22 bits, not 24 bits
  - This address should be of the form **`a.b.c.d/22`**

Subnet Naming

- **Problem 2:**
  - The bits don't fit in the fields any more…
  - Decimal: `192.168.1.0/22`
  - Binary:
    `11000000.10101000.000000`**`01`**`.00000000`

You have "prefix address" bits in the host address field…

What addresses would work?

- Host field needs to be all 0's

11000000.10101000.000000**00**.00000000

192.168.0.0/22

11000000.10101000.000001**00**.00000000

192.168.4.0/22

11000000.10101000.000010**00**.00000000

192.168.8.0/22

11000000.10101000.000011**00**.00000000

192.168.12.0/22

...

11000000.10101000.111111**00**.00000000

192.168.252.0/22

Subnet Naming

- Let's choose `192.168.252.0/22`
- **What addresses are available for hosts within the subnet?**

11000000.10101000.111111xx.xxxxxxxx

- 11000000.10101000.111111**00.00000000**
  - **192.168.252.0**
  - All zeros in host field = "**Subnet Name**"
  - Not allowed for host address
- 11000000.10101000.111111**00.00000001**
  - **192.168.252.1** – **Lowest possible** IP address
- . . .
- 11000000.10101000.111111**11.11111110**
  - **192.168.255.254** – **Highest possible** IP address
- 11000000.10101000.111111**11.11111111**
  - **192.168.255.255**
  - All ones in host field = "**Broadcast Address**"
  - Not allowed for host address

Router Naming

- What should the default gateway be for a host in this subnet?
- Any valid IP within the subnet
  - From `192.168.252.1` – `192.168.255.254`
- Convention?
  - Either the lowest address ("`.1`") or highest address ("`.254`") – easier to remember
- The default gateway needs to be **part of the subnet** for hosts to **reach it**!

Subnet -vs- Netmask

- These are equivalent
  - `192.168.252.0/22`
  - `192.168.252.0`, netmask `255.255.252.0`
    - `11111111.11111111.111111`|`00.00000000`

- The netmask merely indicates the size of the subnet
  - `/22` is easier for humans
  - `255.255.252.0` represents computer memory

Subnet Calculator

http://www.tunnelsup.com/subnet-calculator

IP Address and Netmask:

192.168.252.0/22

Calculate | Random IP

IP Address:	192.168.252.0
Netmask:	255.255.252.0
Wildcard Mask:	0.0.3.255
CIDR Notation:	/22
Network Address:	192.168.252.0
Usable Host Range:	192.168.252.1 - 192.168.255.254
Broadcast Address:	192.168.255.255
Binary Netmask:	11111111.11111111.11111100.00000000
Total number of hosts:	1,024
Number of usable hosts:	1,022
IP Class:	C (192.0.0.0 - 223.255.255.255)
Move to adjacent network	Backward Forward

G+1 150

Closing Thoughts

Recap

- Today we discussed
  - Special addresses
    - Loopback addresses
    - Private addresses
    - Broadcast addresses
    - Multicast addresses
  - Subnets

Next Class

- Scapy packet manipulation framework

Class Activity

CA.5 – IP Addresses and Subnets

Due tonight at 11:59pm