Networking

UBNetDef, Fall 2023
Week 2

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Administrivia

Learning Goals

- Learn the basics of how network traffic flows
- Interpret a network topology
- Understand OSI network layers 1-3
- Distinguish between network hardware devices
- Configure static networking

Agenda

- What's a network?
- Computer networks
- Understanding the network layer
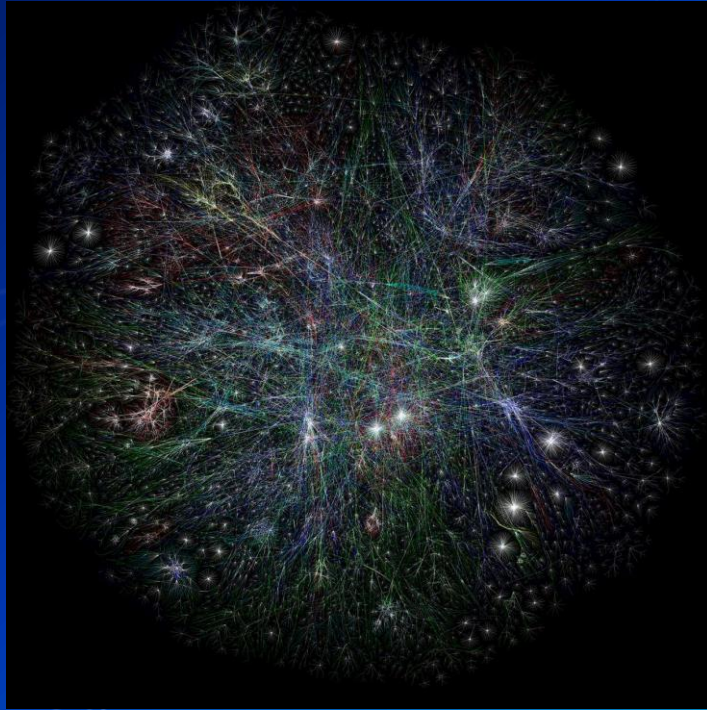- Topologies and IP assignments

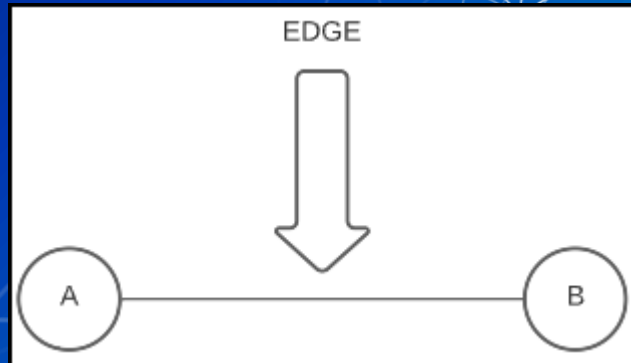Picture 1

Picture 2

Picture 3

What do all of these have in Common?

- These are all Networks
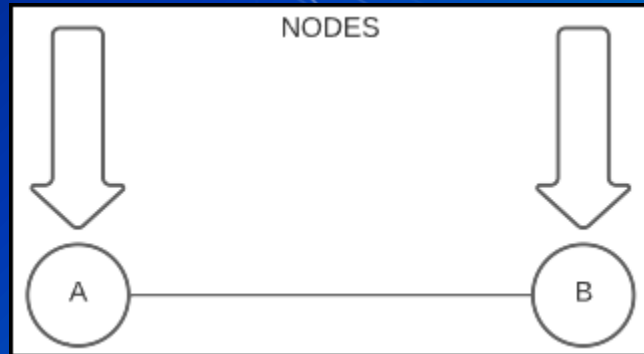
- Each one has a Node and a Edge

Edges

- The connections
  - Roadways between cities
  - Neural pathways

Nodes

- The connection points
  - Cities
  - Neurons

Examples we might see in Class

- Nodes
  - Your physical computer
  - vCenter servers
  - Routers
- Edges
  - Ethernet wires
  - Wireless signals to eduroam
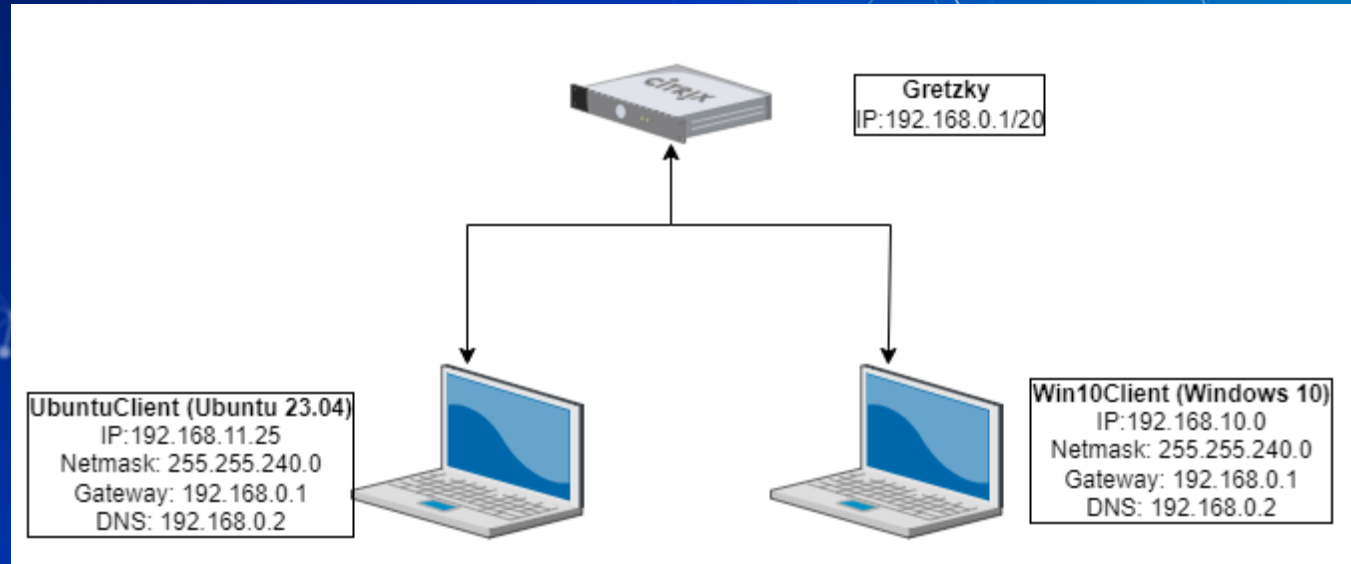
Agenda

- What's a network?
- Computer networks
- Understanding the network layer
- Topologies and IP assignments

Clients vs. Network Devices

- Clients: process and manipulate data
  - Also referred to as "hosts"
  - Examples: computers, servers, gaming consoles, mobile devices, IoT devices
- Network Devices: distribute connectivity
  - Examples: routers, modems, switches, other gateways

Which are Clients?

Gretzky
IP:192.168.0.1/20

UbuntuClient (Ubuntu 23.04)
IP:192.168.11.25
Netmask: 255.255.240.0
Gateway: 192.168.0.1
DNS: 192.168.0.2

Win10Client (Windows 10)
IP:192.168.10.0
Netmask: 255.255.240.0
Gateway: 192.168.0.1
DNS: 192.168.0.2

Which are network devices?

Gretzky
IP:192.168.0.1/20

UbuntuClient (Ubuntu 23.04)
IP:192.168.11.25
Netmask: 255.255.240.0
Gateway: 192.168.0.1
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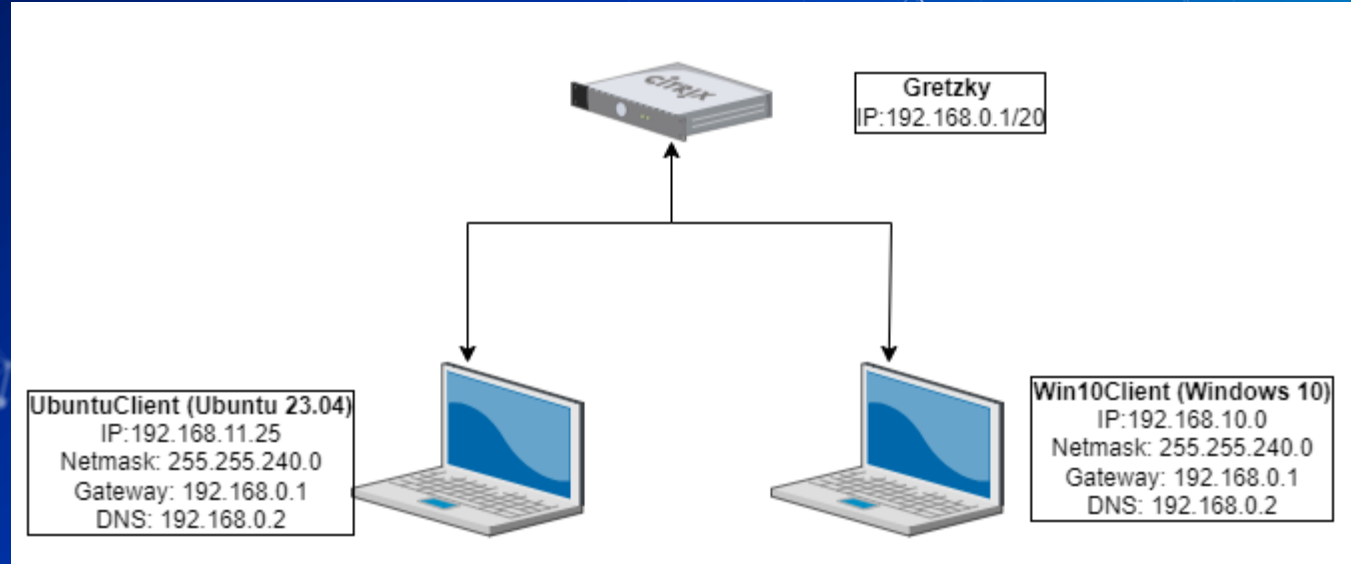
Network Devices

- Gateways
  - Receive incoming messages and send outgoing messages
  - Clients only recognize the gateway immediately connected to them
  - Think Doorway
- Routers
  - Pass messages between networks
  - These work with IP addresses

Network Devices

- Switches
  - Distribute messages within an immediate network
  - These work with MAC Addresses

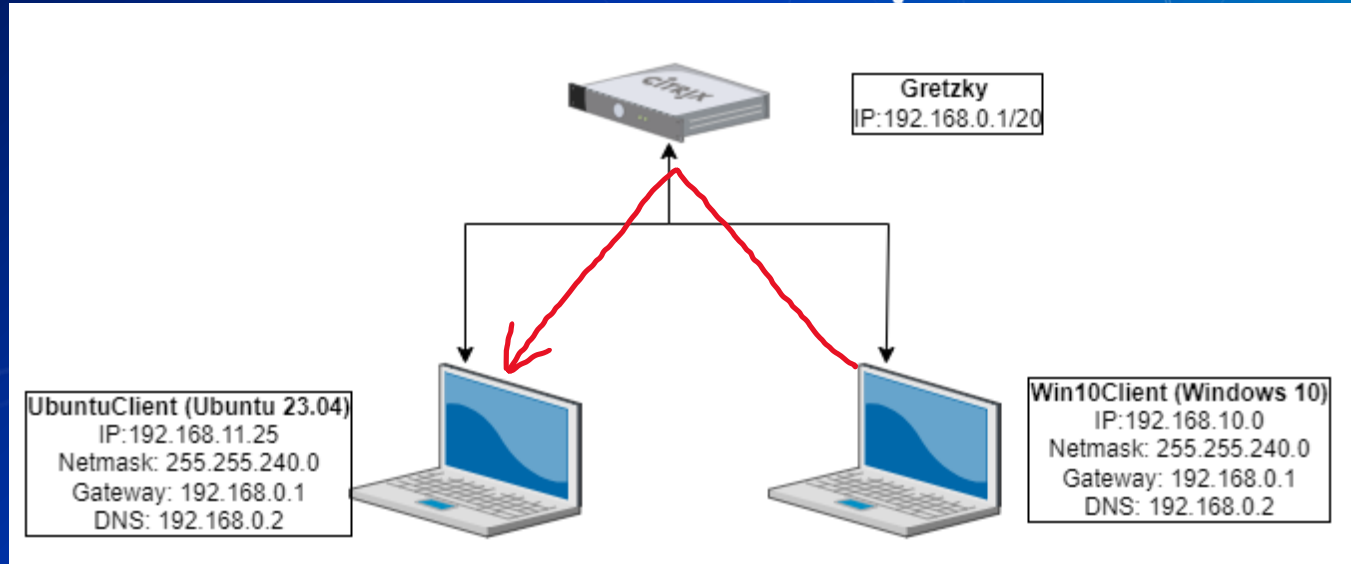- Gateways, routers, switches can be combined into one piece of hardware

Transmitter vs. Receiver

- Transmitter (Tx): Sender of data
- Receiver (Rx): Recipient of data

Transmission methods
  - Unicast: one transmitter, one receiver
  - Multicast: one transmitter, multiple but not all receivers
  - Broadcast: one transmitter, all receivers

Which broadcast method?

Which broadcast method?

Gretzky
IP:192.168.0.1/20

UbuntuClient (Ubuntu 23.04)
IP:192.168.11.25
Netmask: 255.255.240.0
Gateway: 192.168.0.1
DNS: 192.168.0.2

Win10Client (Windows 10)
IP:192.168.10.0
Netmask: 255.255.240.0
Gateway: 192.168.0.1
DNS: 192.168.0.2

How about a multicast?

Gretzky
IP:192.168.0.1/20

UbuntuClient (Ubuntu 23.04)
IP:192.168.11.25
Netmask: 255.255.240.0
Gateway: 192.168.0.1
DNS: 192.168.0.2

Win10Client (Windows 10)
IP:192.168.10.0
Netmask: 255.255.240.0
Gateway: 192.168.0.1
DNS: 192.168.0.2

Clients: Clients vs. Servers

- Clients: primarily request remote services
  - Examples: mobile device, workstation, laptop, computer
  - Behavior: browse the web, receive updates, provide credentials
- Servers: primarily provide remote services
  - Examples: web servers, intrusion detection systems, active directory
  - Behavior: store and provide web pages, distribute updates, verify credentials

Breakdown of Topology

- **IP Address**: Identifies a machine on a network

- **Subnet Mask**: Range of IP addresses allowed on a network

- **Gateway**: A routing device that allows you to connect an external network

- **DNS**: translates domain names (e.g., buffalo.edu) into IP Addresses
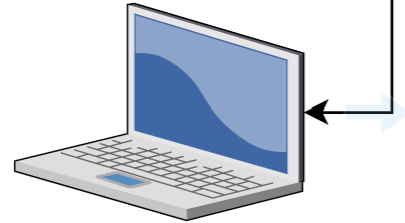
UbuntuClient (Ubuntu 23.04)
IP:192.168.11.25
Netmask: 255.255.240.0
Gateway: 192.168.0.1
DNS:192.168.0.2

LANs

■ Local Area Network
  ○ Devices on the same network share the same
    communication paths (e.g., cables or wireless links)
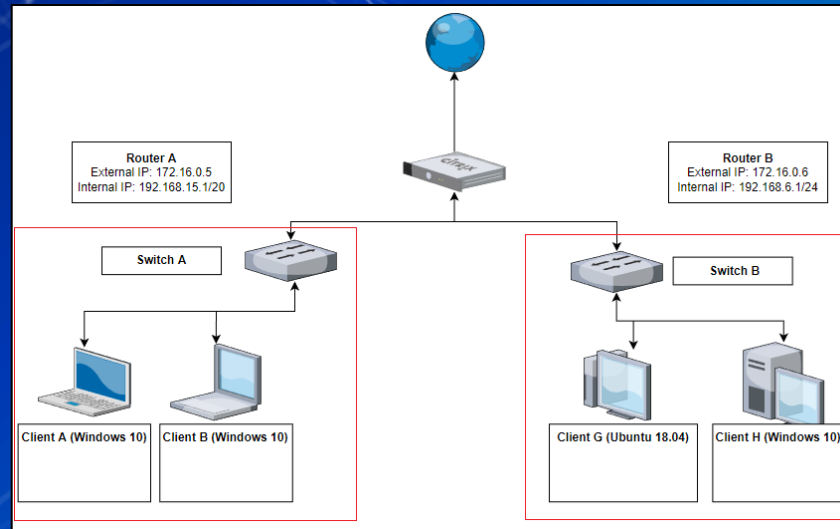
Computer Layering Models

OSI Reference Model

	Layer
7	Application
6	Presentation
5	Session
4	Transport
3	Network
2	Data Link
1	Physical

TCP/IP Conceptual Layers

- Application
- Transport
- Network
- Network Interface

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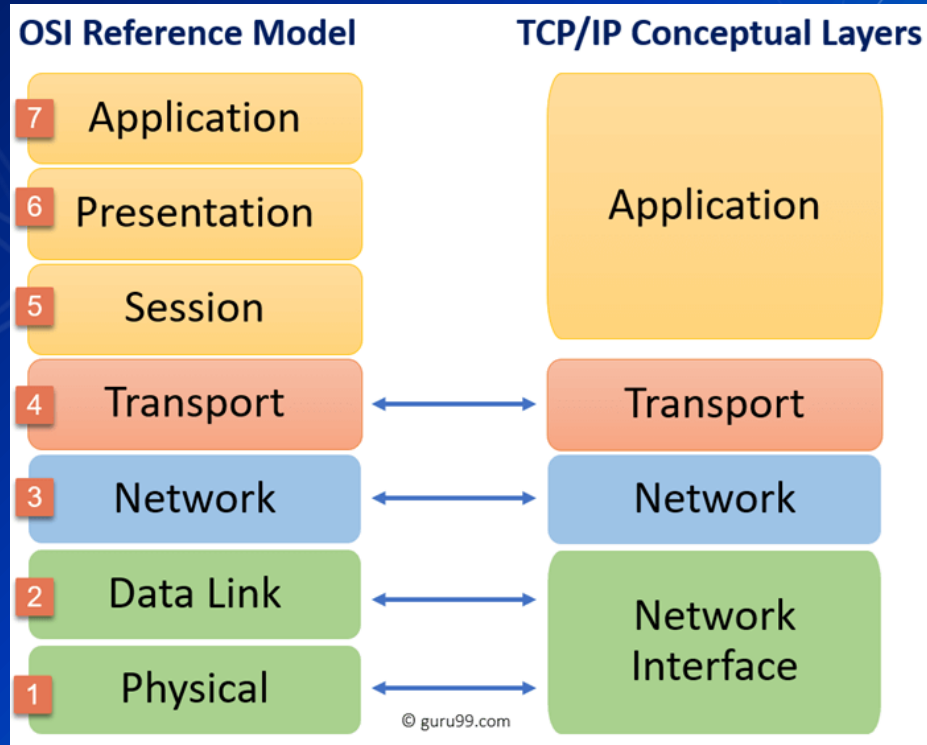
OSI Layer 1: Physical Layer

- Layer 1: Physical Layer
  - Physical connections
    - Mediums

      Examples: Fiber & Radio
    - Signals

      Examples: 1s & 0s

OSI Layer 2: Datalink Layer

- Layer 2: Datalink Layer
  - Receives bits and delivers them to a processor
  - Physical receivers are identified by MAC Addresses
    - On Your Network Interface Card (NIC)
    - Only seen within the Local Area Network

Agenda

- What's a network?
- Computer networks
- Understanding the network layer
- Topologies and IP assignments

OSI Layer 3: Network Layer

- Layer 3: Network Layer
  - Interconnects networks
  - IP Addresses
    - Public and private
    - Requires a network connection to exist
    - 2 different versions of IP addresses
      - IPv4: 10.1.42.15
      - IPv6: 2001:0db8:85a3:0000:0000:8a2e:0370:7334

In Class Activity

Packet Polo

Packet Polo

- Step 1: Local ARPs
- Step 2: Ping

Break slide

Please return in 10 minutes

IPv4 Addresses: Private Address

- Class A: 10.0.0.0 to 10.255.255.255
- Class B: 172.16.0.0 to 172.31.255.255
- Class C: 192.168.0.0 to 192.168.255.255

IPv4 Addresses

- Decimal-octal form (Base 8 bits)
- Separated by octets in range 0-255
  - [octet 1].[octet 2].[octet 3]. [octet 4]
  - Octet 1 - leftmost
  - Octet 4 - rightmost
- For every IP address: 192.168.12.10
- Some characters represent a network.
  - Some characters represent the individual device.

IPv6 Addresses

- Hexadecimal form (Base 16 bits)
- Split into two components; a network and host
- Example: `2001:db8:3333:4444:0000:0000:0007:8888`
  - Shortened: `2001:db8:3333:4444::7:8888`
- Some characters represent a network
  - Some characters represent the subnet
- Some characters represent the individual device

IPv4 Addresses: NAT

- Network Address Translation
    - We would run out of IPv4 address, can only have ~4.3 Billion IPv4 address.
    - Estimated that there was 12.3 Billion IOT devices in 2021
    - How do we save room?

IPv4 Addresses: NAT

- Network Address Translation
    - We have external and internal IPs
  - External, your Public IP, what the internet sees you as
  - Internal, Private IP, what people on your network see you as
  - Router makes the translation

IPv4 Addresses: NAT

Internet

External (Public IP): `128.107.6.121`
Internal (Private IP): `10.8.25.96/16`

Layer 2 Switch

IP Address: `10.8.32.254`
Subnet Mask: `255.255.0.0`
Default Gateway: `10.8.25.96`

IP Address: `10.8.55.1`
Subnet Mask: `255.255.0.0`
Default Gateway: `10.8.25.96`

IP Address: `10.8.0.33`
Subnet Mask: `255.255.0.0`
Default Gateway: `10.8.25.96`
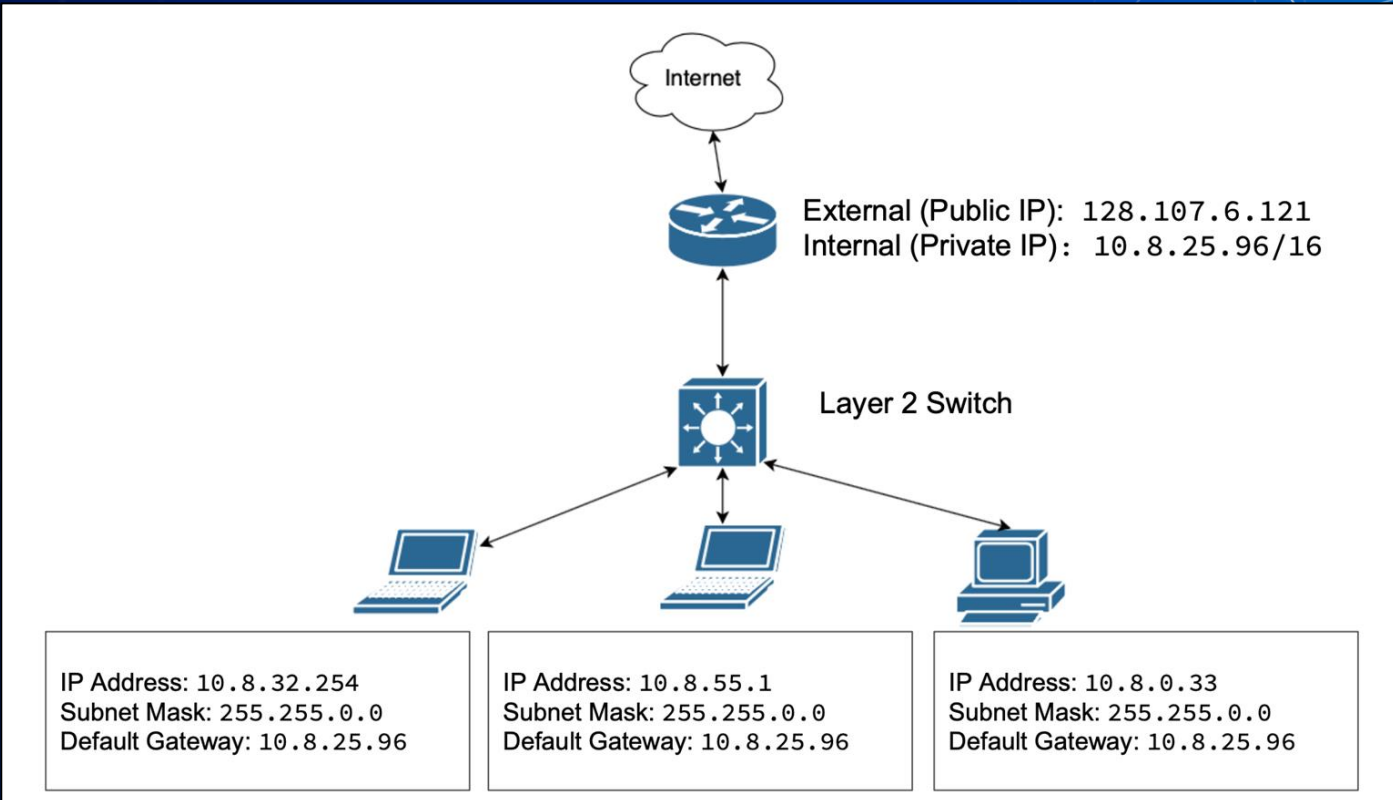
In Class Activity

Network Address Translation

Subnet Masks

- The Subnet indicates how many clients we can have on a network
  - Really neat*
  - Subnets can be written as "255.255.255.0" (decimal-octal) or Classless Inter-Domain Routing (CIDR) notation (e.g., 192.168.12.0/24)
  - /24 gives us 254 different address. No 0 (Network Identifier) or 255 (Broadcast Address)

Subnet Masks

- The smaller the subnet mask, the more possible addresses
- We can use a calculator to help us
  https://www.calculator.net/ip-subnet-calculator.html

	Addresses	Hosts	Netmask
/30	4	2	255.255.255.252
/29	8	6	255.255.255.248
/28	16	14	255.255.255.240
/27	32	30	255.255.255.224
/26	64	62	255.255.255.192
/25	128	126	255.255.255.128
/24	256	254	255.255.255.0
/23	512	510	255.255.254.0
/22	1024	1022	255.255.252.0
/21	2048	2046	255.255.248.0
/20	4096	4094	255.255.240.0
/19	8192	8190	255.255.224.0
/18	16384	16382	255.255.192.0
/17	32768	32766	255.255.128.0
/16	65536	65534	255.255.0.0

Domain Name System or DNS

- A Domain is used to identify a system on the Internet
  - Example@buffalo.edu
  - www.buffalo.edu
  - When we type "dns.google.com", DNS translates to "8.8.8.8"
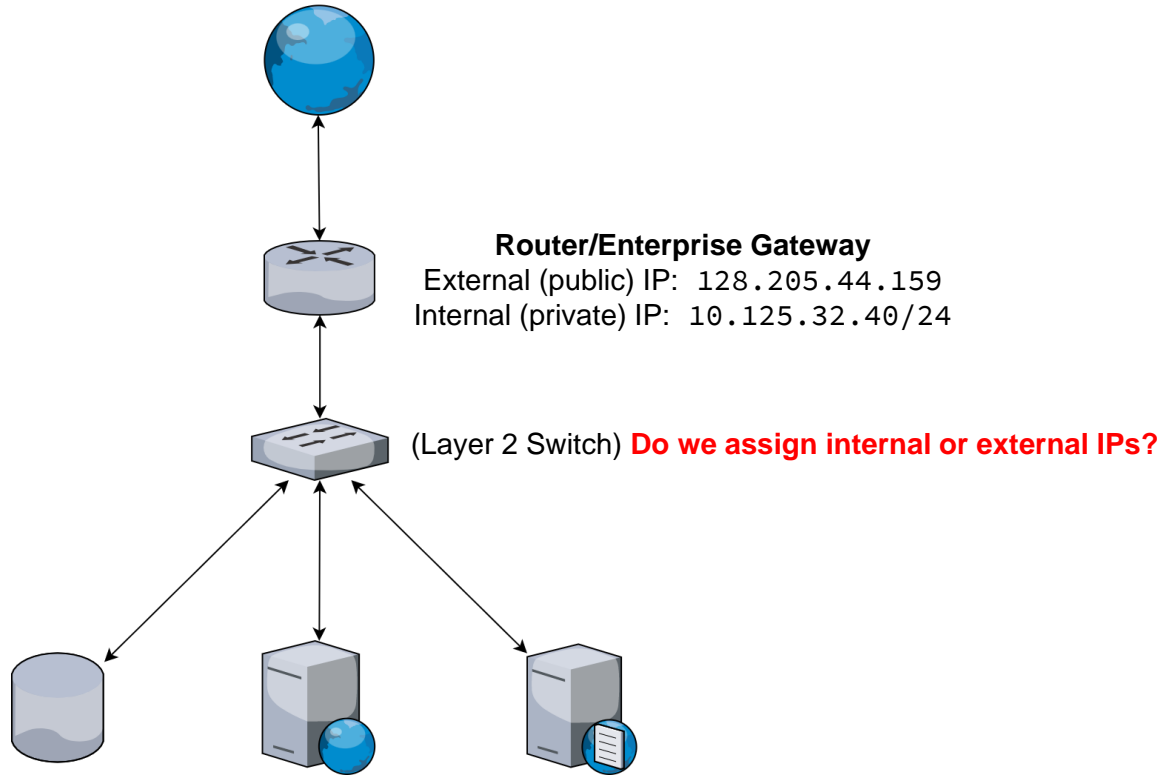
Questions?

Agenda

- What's a network?
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- Topologies and IP assignments

In Class Activity

IP Assignment Walkthrough

Example 1

Router/Enterprise Gateway
External (public) IP: `128.205.44.159`
Internal (private) IP: `10.125.32.40/24`
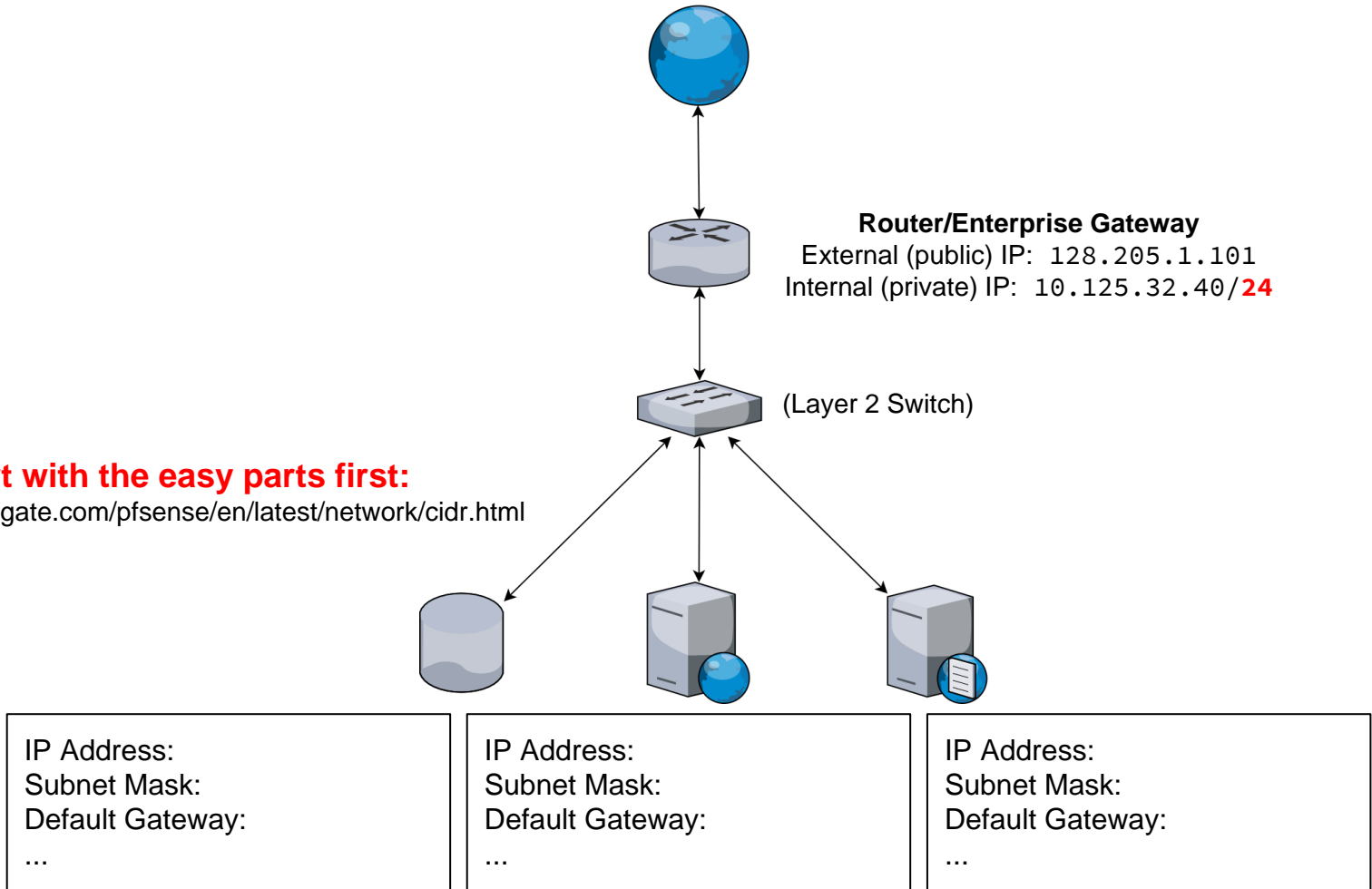
(Layer 2 Switch) **Do we assign internal or external IPs?**

IP Address:
Subnet Mask:
Default Gateway:
...

IP Address:
Subnet Mask:
Default Gateway:
...

IP Address:
Subnet Mask:
Default Gateway:
...

Router/Enterprise Gateway
External (public) IP: `128.205.1.101`
Internal (private) IP: `10.125.32.40/`**24**

(Layer 2 Switch)

Start with the easy parts first:
https://docs.netgate.com/pfsense/en/latest/network/cidr.html

IP Address:	IP Address:	IP Address:
Subnet Mask:	Subnet Mask:	Subnet Mask:
Default Gateway:	Default Gateway:	Default Gateway:
...	...	...

Subnet Mask	CIDR Prefix	Total IP Addresses	Usable IP Addresses	Number of /24 net
255.255.255.128	/25	128	126	1 half
255.255.255.0	/24	256	254	1
255.255.254.0	/23	512	510	2
255.255.252.0	/22	1024	1022	4
255.255.248.0	/21	2048	2046	8
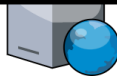
IP Address:
Subnet Mask: 255.255.255.0
Default Gateway:
...

IP Address:
Subnet Mask: 255.255.255.0
Default Gateway:
...

IP Address:
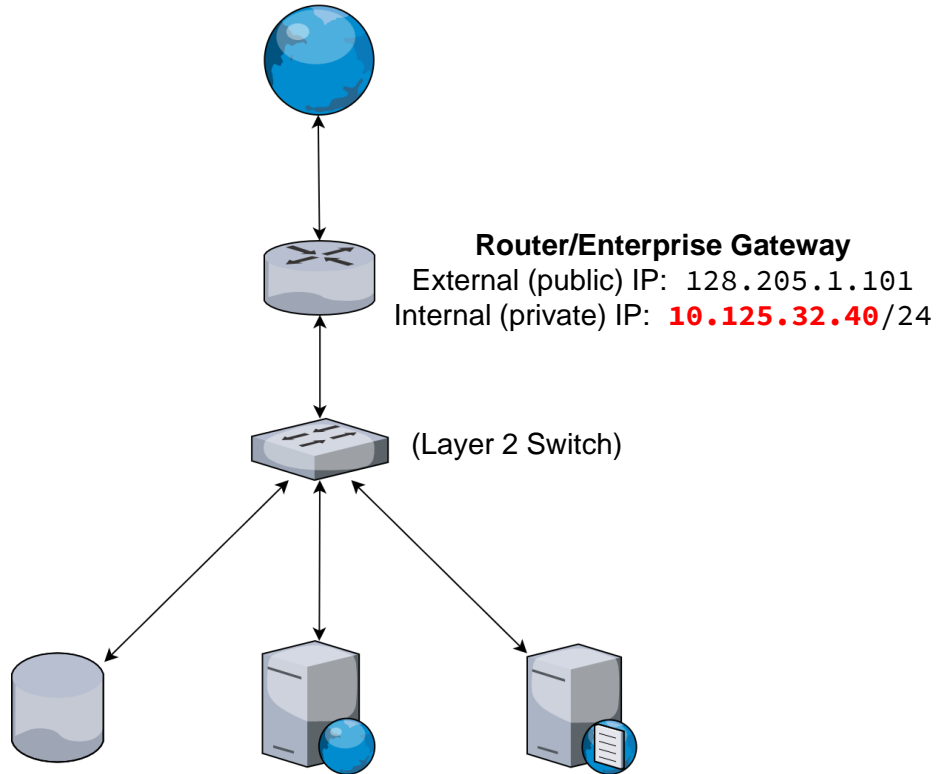Subnet Mask: 255.255.255.0
Default Gateway:
...

Router/Enterprise Gateway
External (public) IP: `128.205.1.101`
Internal (private) IP: **`10.125.32.40`**`/24`

(Layer 2 Switch)

Next easy part:
Default Gateway

IP Address:	IP Address:	IP Address:
Subnet Mask: `255.255.255.0`	Subnet Mask: `255.255.255.0`	Subnet Mask: `255.255.255.0`
Default Gateway:	Default Gateway:	Default Gateway:
...	...	...

Router/Enterprise Gateway
External (public) IP: `128.205.1.101`
Internal (private) IP: **`10.125.32.40`**`/24`

(Layer 2 Switch)
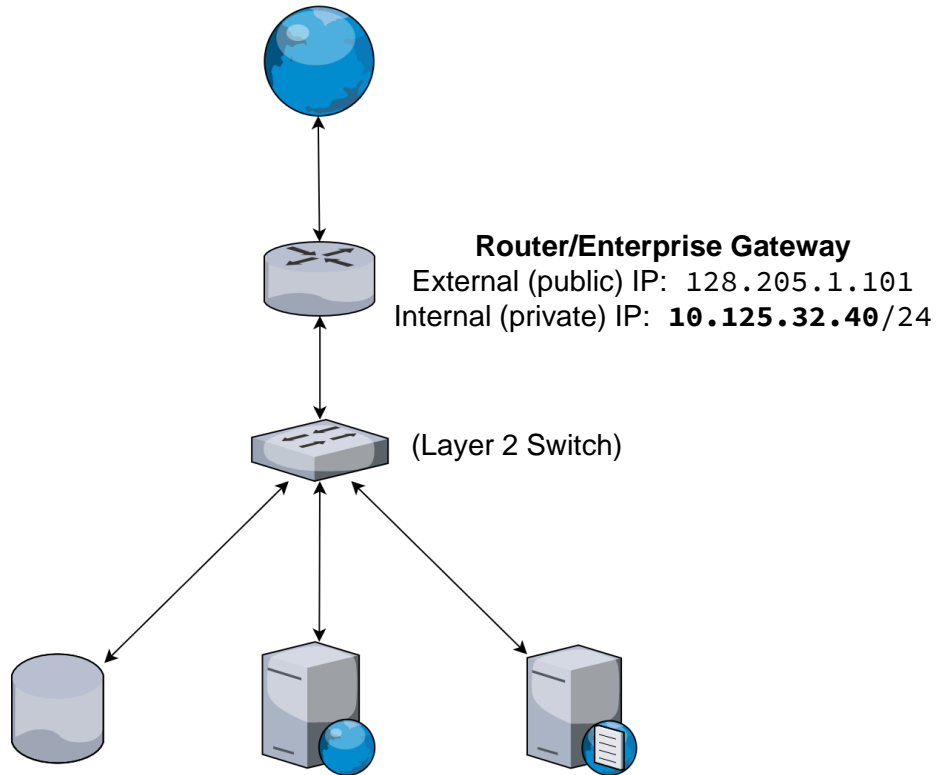
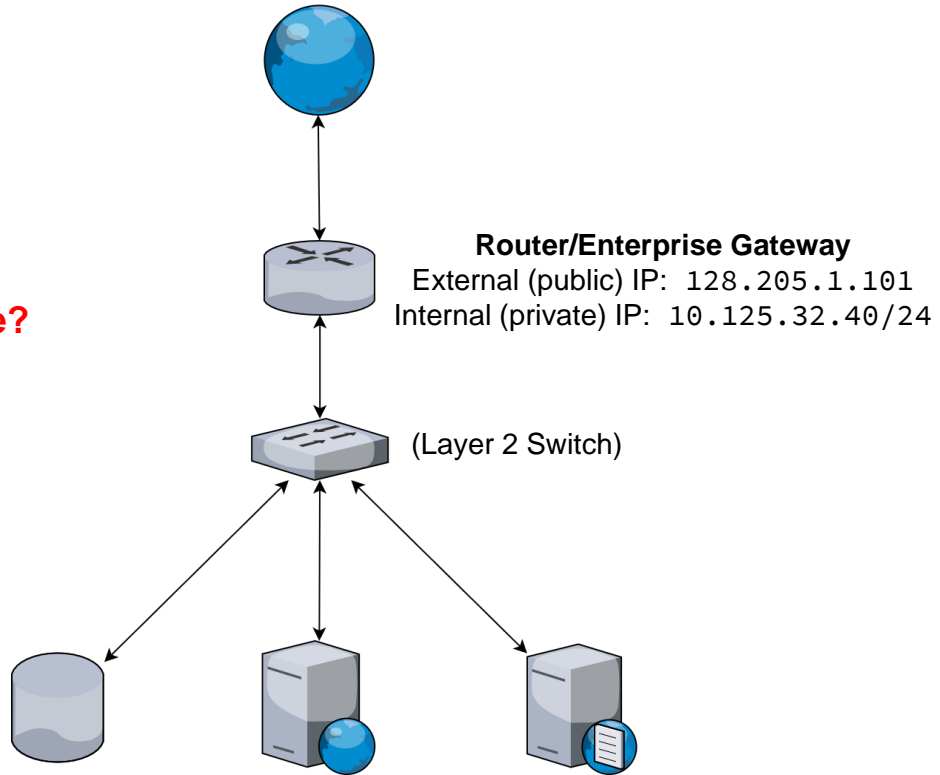**Next easy part:**
Default Gateway = Internal IP

IP Address:
Subnet Mask: `255.255.255.0`
Default Gateway: `10.125.32.40`
...

IP Address:
Subnet Mask: `255.255.255.0`
Default Gateway: `10.125.32.40`
...

IP Address:
Subnet Mask: `255.255.255.0`
Default Gateway: `10.125.32.40`
...

Router/Enterprise Gateway
External (public) IP: `128.205.1.101`
Internal (private) IP: `10.125.32.40/24`

What address space is available?

Consult: https://www.subnet-calculator.com/

(Layer 2 Switch)

IP Address:
Subnet Mask: `255.255.255.0`
Default Gateway: `10.125.32.40`
...

IP Address:
Subnet Mask: `255.255.255.0`
Default Gateway: `10.125.32.40`
...

IP Address:
Subnet Mask: `255.255.255.0`
Default Gateway: `10.125.32.40`
...

What address space is available?

- Subnet ID and Broadcast Address are unusable

Subnet Calculator

Network Class
A ● B ○ C ○

First Octet Range
1 - 126

IP Address
10.125.32.40

Hex IP Address
0A.7D.20.28

Subnet Mask
255.255.255.0

Wildcard Mask
0.0.0.255

Subnet Bits
16

Mask Bits
24

Maximum Subnets
65536

Hosts per Subnet
254

Host Address Range
10.125.32.1 - 10.125.32.254

Subnet ID
10.125.32.0

Broadcast Address
10.125.32.255
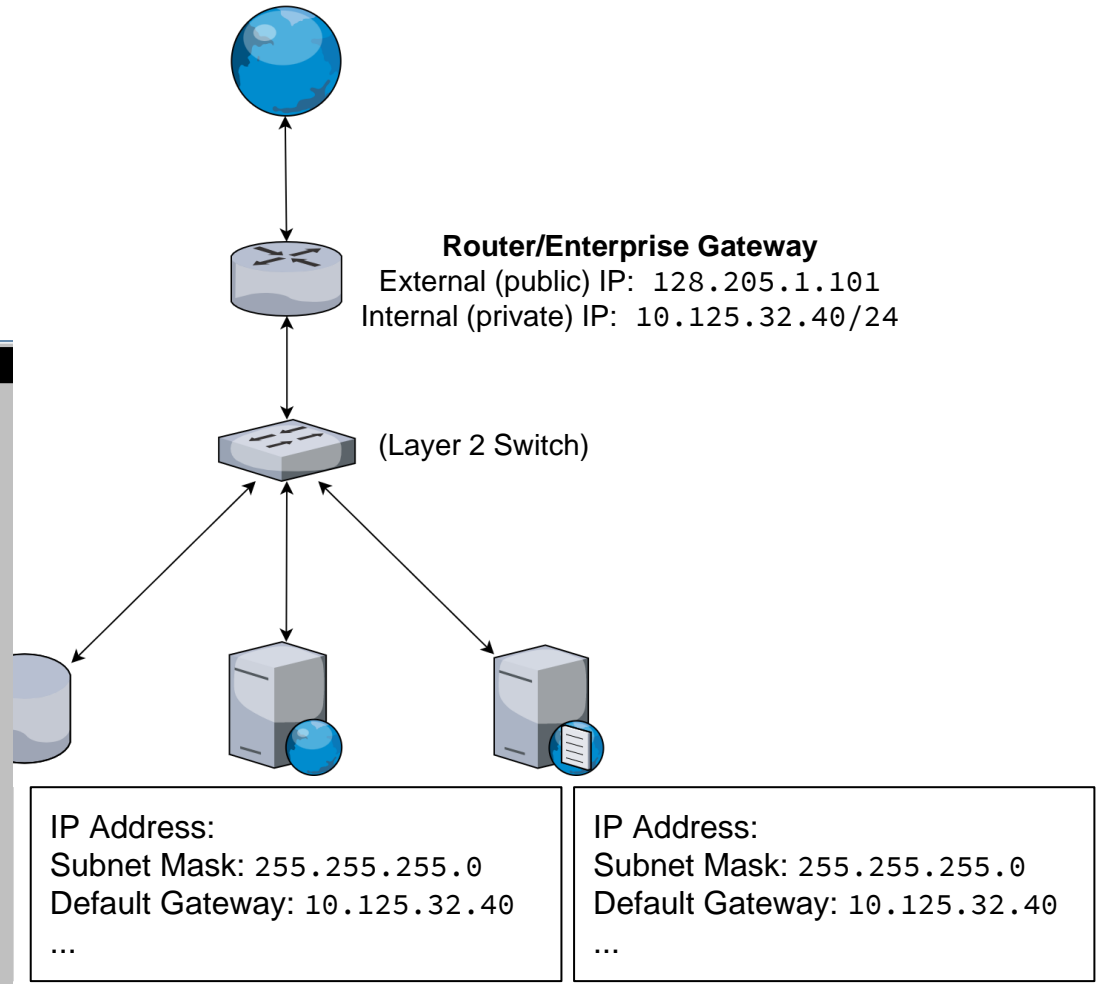
Subnet Bitmap
0nnnnnnn.ssssssss.ssssssss.hhhhhhhh

Router/Enterprise Gateway
External (public) IP: `128.205.1.101`
Internal (private) IP: `10.125.32.40/24`

(Layer 2 Switch)

IP Address:
Subnet Mask: `255.255.255.0`
Default Gateway: `10.125.32.40`
...

IP Address:
Subnet Mask: `255.255.255.0`
Default Gateway: `10.125.32.40`
...

Router/Enterprise Gateway
External (public) IP: `128.205.1.101`
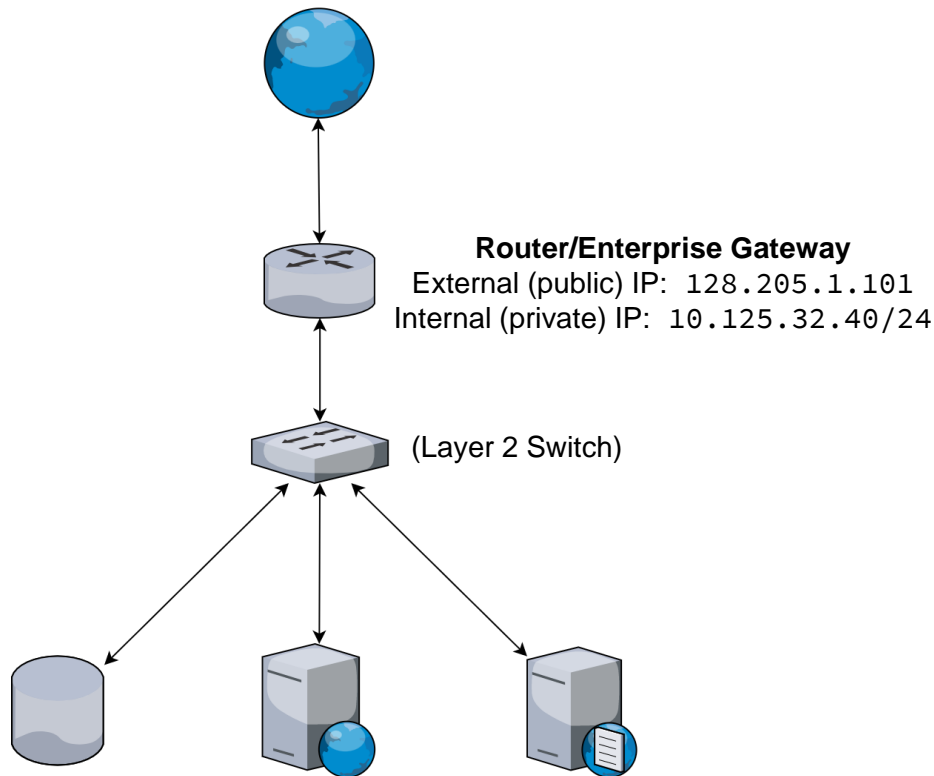Internal (private) IP: `10.125.32.40/24`

(Layer 2 Switch)

Is this address valid?

IP Address: `10.125.32.0`
Subnet Mask: `255.255.255.0`
Default Gateway: `10.125.32.40`
...

IP Address: `10.125.32.110`
Subnet Mask: `255.255.255.0`
Default Gateway: `10.125.32.40`
...

IP Address: `10.125.32.210`
Subnet Mask: `255.255.255.0`
Default Gateway: `10.125.32.40`
...

Router/Enterprise Gateway
External (public) IP: `128.205.1.101`
Internal (private) IP: `10.125.32.40/24`

(Layer 2 Switch)

IP Address: 10.125.32.14
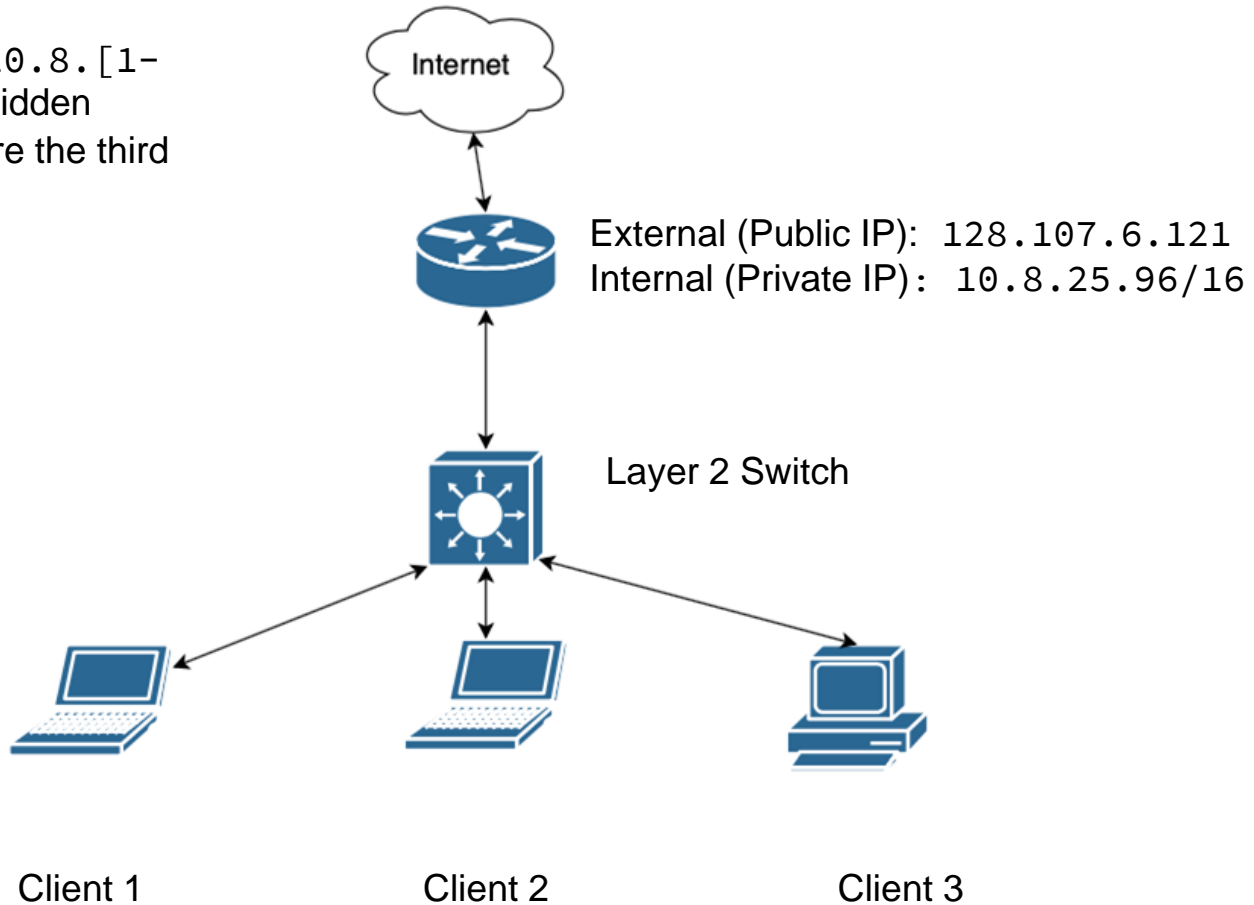Subnet Mask: `255.255.255.0`
Default Gateway: `10.125.32.40`
...

IP Address: 10.125.32.110
Subnet Mask: `255.255.255.0`
Default Gateway: `10.125.32.40`
...

IP Address: 10.125.32.210
Subnet Mask: `255.255.255.0`
Default Gateway: `10.125.32.40`
...

Example 2

Rules:
- IP address range `10.8.[1-24].[any]` is forbidden
- No clients can share the third octet

Internet

External (Public IP): `128.107.6.121`
Internal (Private IP): `10.8.25.96/16`

Layer 2 Switch

Client 1   Client 2   Client 3

Rules:
- IP address range `10.8.[1-24].[any]` is forbidden
- No clients can share the third octet

Internet

External (Public IP): `128.107.6.121`
Internal (Private IP): `10.8.25.96/16`

Layer 2 Switch

Once again, let's start easy. What are the subnet masks for our 3 clients?
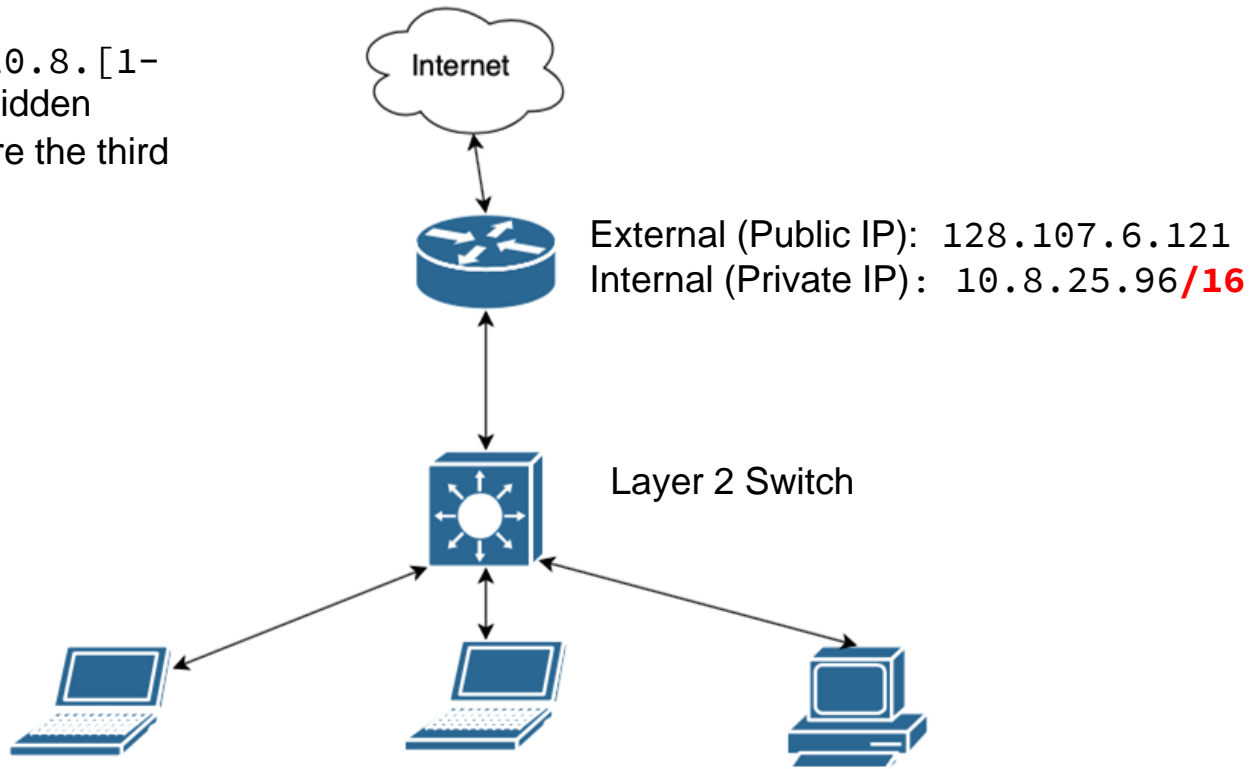
IP Address:
Subnet Mask:
Default Gateway:

IP Address:
Subnet Mask:
Default Gateway:

IP Address:
Subnet Mask:
Default Gateway:

Rules:
- IP address range `10.8.[1-24].[any]` is forbidden
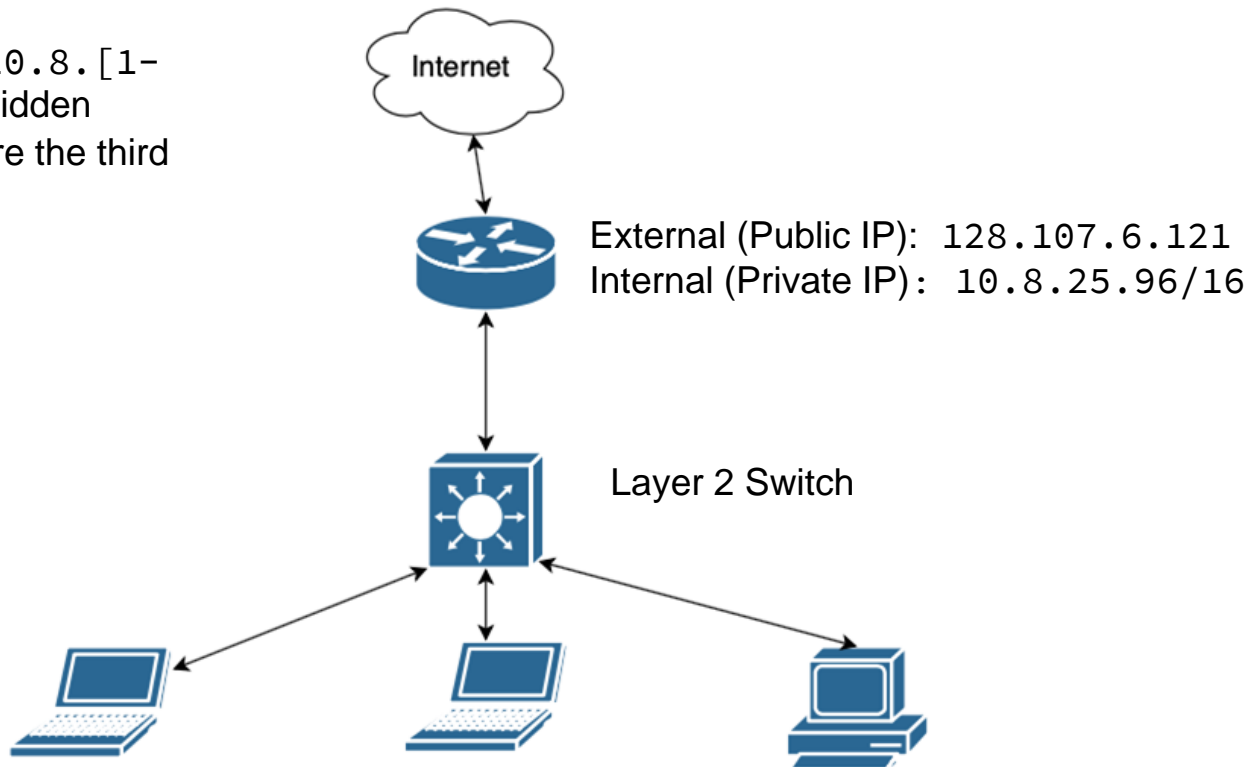- No clients can share the third octet

Internet

External (Public IP): `128.107.6.121`
Internal (Private IP): `10.8.25.96`**/16**

Layer 2 Switch

Once again, let's start easy. What are the subnet masks for our 3 clients?

Subnet Mask	CIDR Prefix	Total IP Addresses	Usable IP Addresses	Number of /24 netw
255.255.0.0	/16	65,536	65,534	256

Rules:
- IP address range `10.8.[1-24].[any]` is forbidden
- No clients can share the third octet

Internet

External (Public IP): `128.107.6.121`
Internal (Private IP): `10.8.25.96/16`

Layer 2 Switch

Once again, let's start easy. What are the subnet masks for our 3 clients?

IP Address:
Subnet Mask: `255.255.0.0`
Default Gateway:

IP Address:
Subnet Mask: `255.255.0.0`
Default Gateway:

IP Address:
Subnet Mask: `255.255.0.0`
Default Gateway:

Rules:
- IP address range `10.8.[1-24].[any]` is forbidden
- No clients can share the third octet

Internet

External (Public IP): `128.107.6.121`
Internal (Private IP): `10.8.25.96/16`
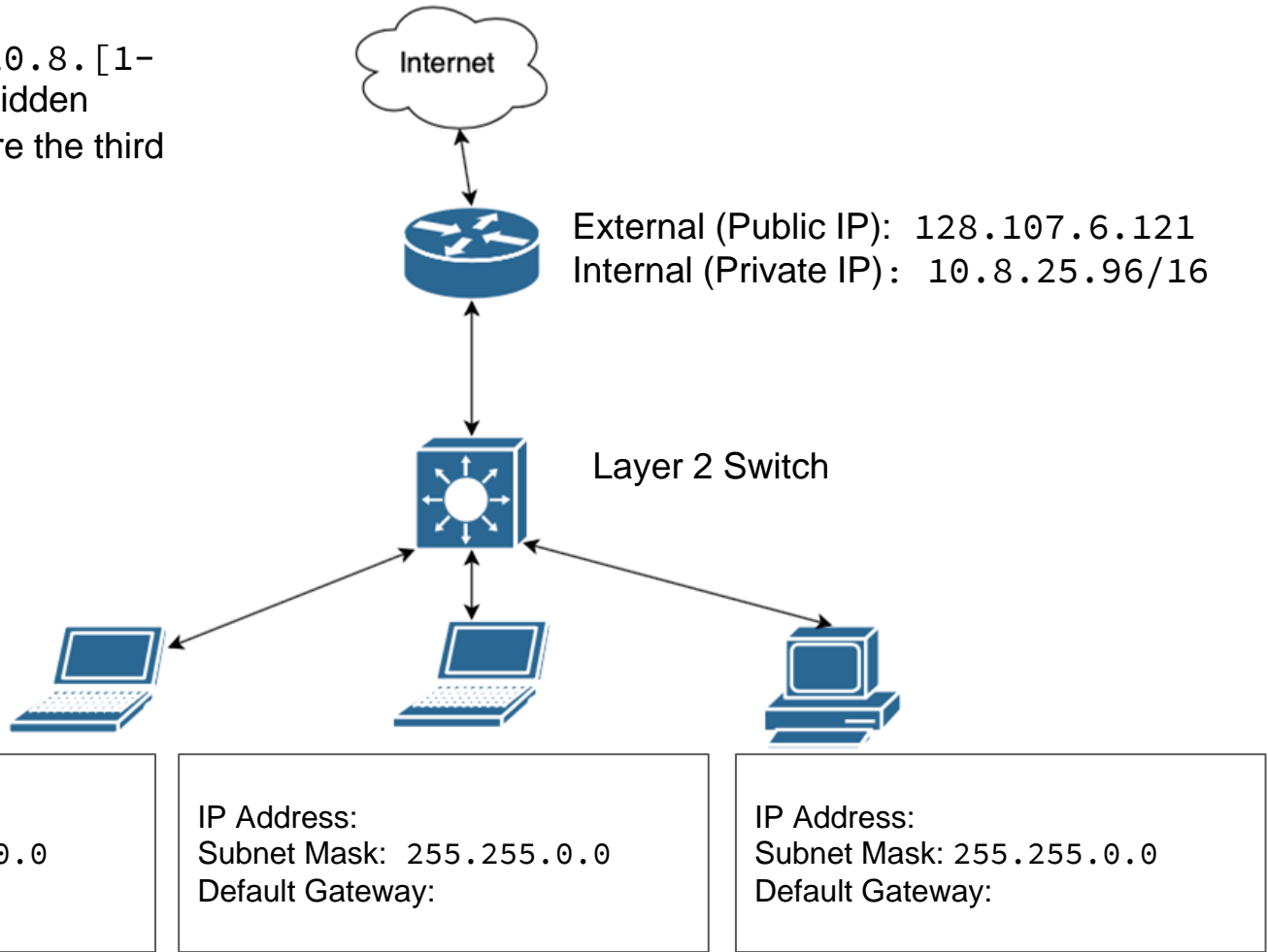
Layer 2 Switch

What is our default gateway?

IP Address:
Subnet Mask: `255.255.0.0`
Default Gateway:

IP Address:
Subnet Mask: `255.255.0.0`
Default Gateway:

IP Address:
Subnet Mask: `255.255.0.0`
Default Gateway:

Rules:
- IP address range `10.8.[1-24].[any]` is forbidden
- No clients can share the third octet

Internet

External (Public IP): `128.107.6.121`
Internal (Private IP): `10.8.25.96/16`

Layer 2 Switch

What is our default gateway?

IP Address:
Subnet Mask: `255.255.0.0`
Default Gateway: `10.8.25.96`

IP Address:
Subnet Mask: `255.255.0.0`
Default Gateway: `10.8.25.96`

IP Address:
Subnet Mask: `255.255.0.0`
Default Gateway: `10.8.25.96`

Rules:
- IP address range `10.8.[1-24].[any]` is forbidden
- No clients can share the third octet

What is our IP Address?

Internet

External (Public IP): `128.107.6.121`
Internal (Private IP): `10.8.25.96/16`

Layer 2 Switch

Subnet Calculator

Network Class
A ● B ○ C ○

First Octet Range
1 - 126

IP Address
10.8.25.96

Hex IP Address
0A.08.19.60

Subnet Mask
255.255.0.0

Wildcard Mask
0.0.255.255

Subnet Bits
8

Mask Bits
16

Maximum Subnets
256

Hosts per Subnet
65534

Host Address Range
10.8.0.1 - 10.8.255.254

Subnet ID
10.8.0.0

Broadcast Address
10.8.255.255

Subnet Bitmap
0nnnnnnn.sssssss.hhhhhhhh.hhhhhhhh

IP Address:
Subnet Mask: `255.255.0.0`
Default Gateway: `10.8.25.96`

IP Address:
Subnet Mask: `255.255.0.0`
Default Gateway: `10.8.25.96`

Rules:
- IP address range `10.8.[1-24].[any]` is forbidden
- No clients can share the third octet

Internet

External (Public IP): `128.107.6.121`
Internal (Private IP): `10.8.25.96/16`

Layer 2 Switch

Is this a valid IP address?

IP Address: `10.8.0.254`
Subnet Mask: `255.255.0.0`
Default Gateway: `10.8.25.96`

IP Address: `10.8.55.1`
Subnet Mask: `255.255.0.0`
Default Gateway: `10.8.25.96`

IP Address: `10.8.0.33`
Subnet Mask: `255.255.0.0`
Default Gateway: `10.8.25.96`

Rules:
- IP address range `10.8.[1-24].[any]` is forbidden
- No clients can share the third octet

Internet

External (Public IP): `128.107.6.121`
Internal (Private IP): `10.8.25.96/16`

Switch (Layer 2)

IP Address: `10.8.32.254`
Subnet Mask: `255.255.0.0`
Default Gateway: `10.8.25.96`

IP Address: `10.8.55.1`
Subnet Mask: `255.255.0.0`
Default Gateway: `10.8.25.96`

IP Address: `10.8.0.33`
Subnet Mask: `255.255.0.0`
Default Gateway: `10.8.25.96`
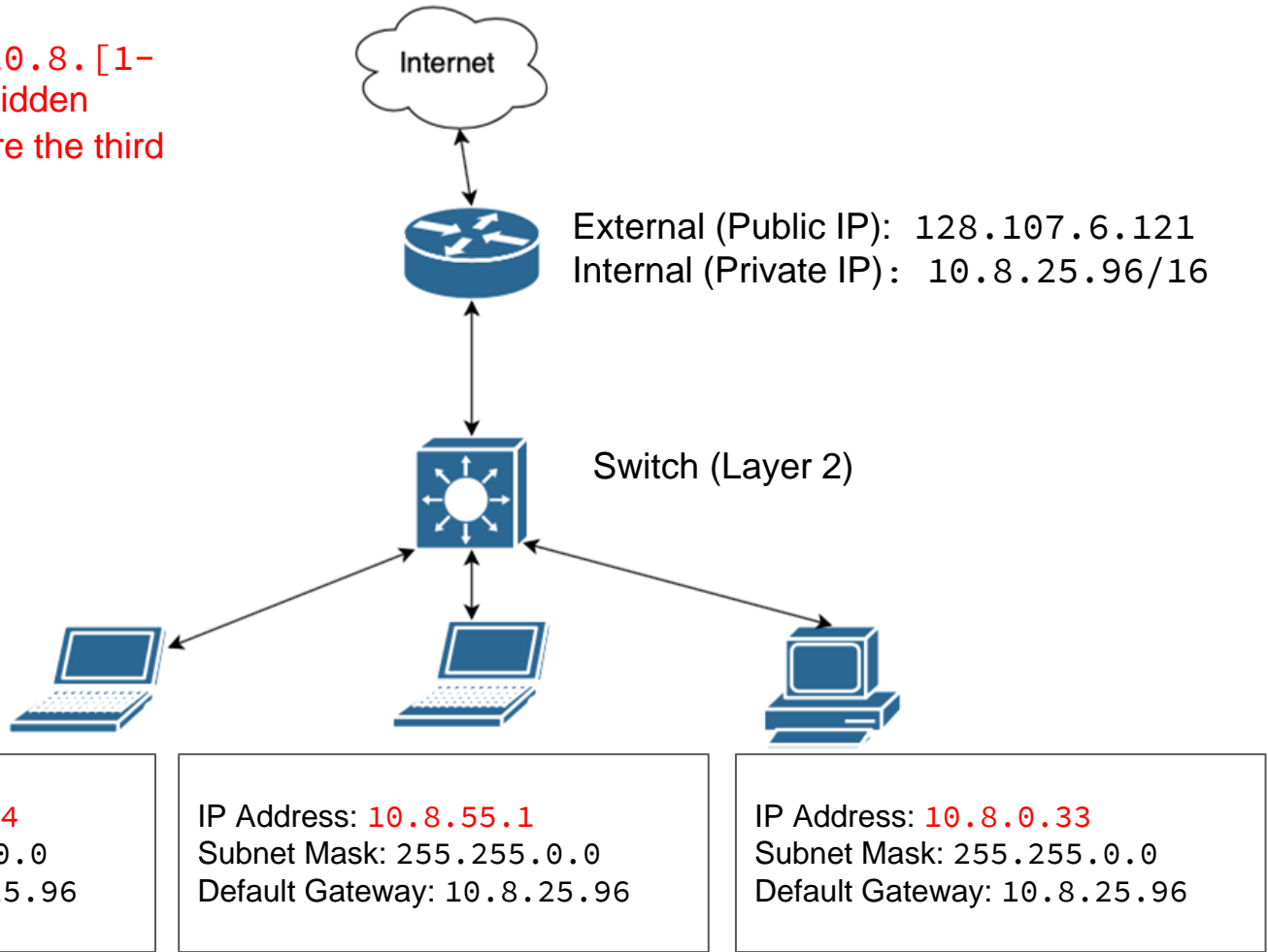
Composite Network Device

- When one hardware device manages more than one network interface

- Style guide has a great explanation and example

Why does layering matter?

- Each device will have 2 types of addresses
  - MAC addresses
  - IP addresses
- You will need to properly identify them and their use cases

Why does layering matter?

- There are 2 different types of network devices
  - Layer 2 devices
    - E.g., switches
    - Operate exclusively with MAC addresses
  - Layer 3 devices
    - E.g., routers, gateways, modems
   - Provide connectivity using IP addresses

In Class Activity

Network Topology Walkthrough

Creating a Network Topology

- In `draw.io`:
  - Open a new diagram
  - Click on `+ More Shapes`
  - Select one of the following
    - `Clipart`, `Cisco19`, `Citrix`
  - Click on `Apply`
  - Expand your selection from the dropdown list
  - Drag and drop the figures corresponding to their device
  - Connect each device with an arrow indicating the flow of network traffic
  - Select a `Rectangle` to label each network device
  - See the Topology Style Guide for more details
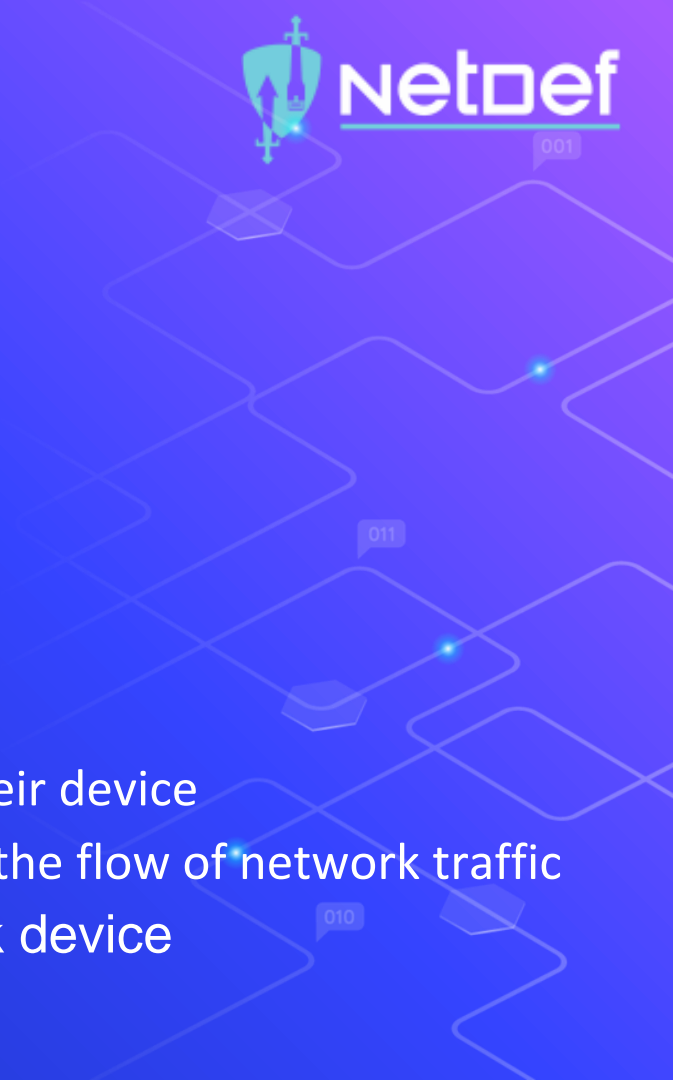
ARP

- Address Resolution Protocol
  - How devices on the same LAN find out each others MAC address.
  - Stored in ARP cache

Summary and Wrap-up

Today's achievements:

- We learned how network devices work with network traffic.
- We reviewed the components of a network topology.
- We examined the OSI networking layers 1-3.
- We explored why layering matters.

Homework 02

Parting questions

Now is the time!

Class dismissed

See you next week!