Intro to Network Design

February 10, 2025

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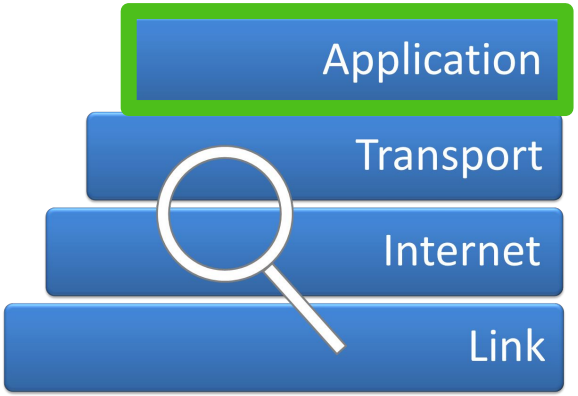
Intro

Computer networking is hard!

iffy analogy:

- Cybersecurity → Medicine
- Networks → Anatomy



Most security is done on applications

But all layers must function for the Internet to work!

(so pls ask questions)

Demo!

Open a terminal/cmd on your laptop

ping: *sending a test message to a destination*

Run: `ping google.com` (pay attention to the time taken)

traceroute: *mapping the route btwn you and a destination*

Run: `traceroute google.com` (pay attention to the # of devices)

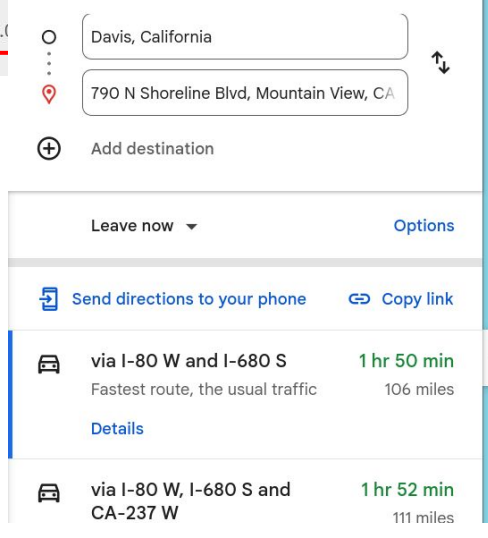
(`tracert` if you're using Windows)

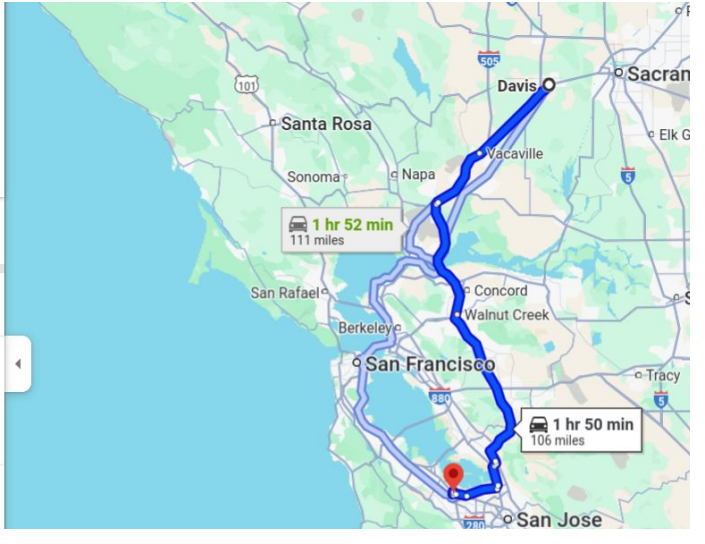
Demo (cont.)

`ping`: Google is at IP 142.250.191.46

IP ADDRESS: 142.250.191.46
COUNTRY: United States
REGION: California
CITY: Mountain View
ISP: Google LLC
ORGANIZATION: Not available
LATITUDE: 37.4060
LONGITUDE: -122.(

(the Internet is [unsurprisingly] very fast)





Devices in the Internet

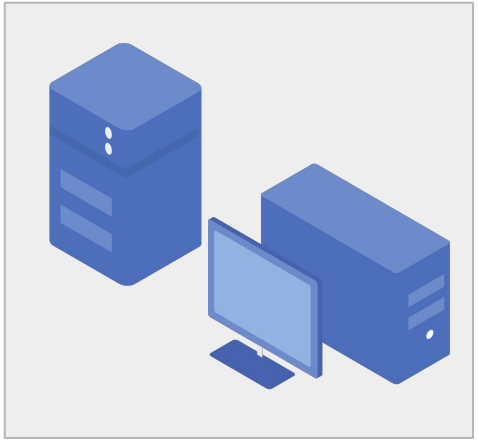
Hosts

Devices at the edge of the network that send and receive Internet data

Ex. laptops, phones, PCs, printers
(the things we're using right now!)

the Internet was made for connecting hosts together

Important subset: Servers
A PC that provides some useful Internet function



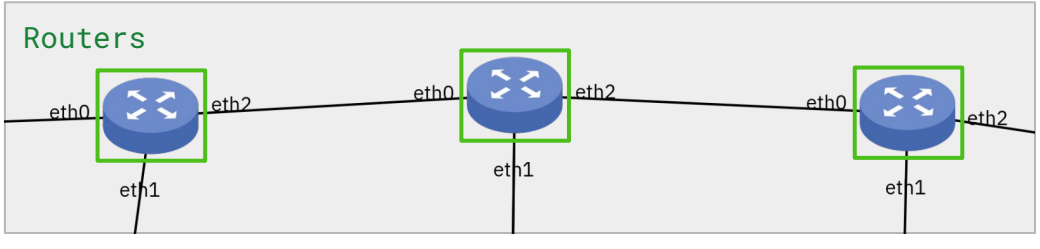
Routers

Main function: routing data across the Internet

routing ≈ postal service

each router is like a postal facility — determines how to move packages **closer** to destination

Purpose: move data (packets) from facility to facility en route to its destination



Switches

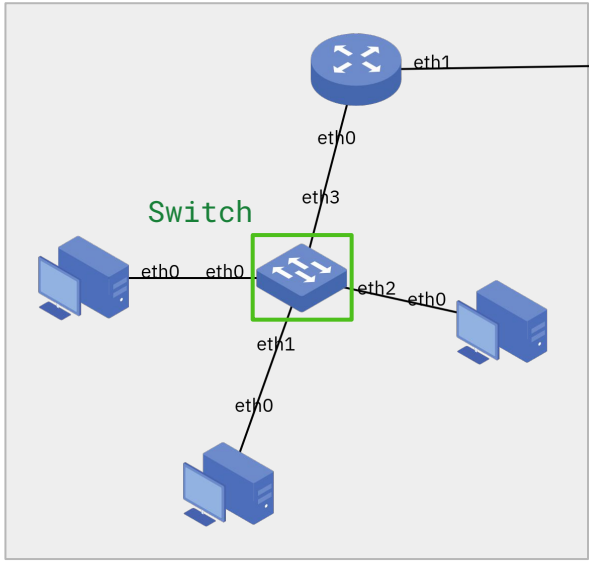
Main function: forward packets from device to device

forwarding ≈ driving a truck w/ a package

Each switch is a road intersection in a city

- package is carried from intersection to intersection until it reaches next postal facility (or final dest.)

Purpose: carry packets to next router, or to destination



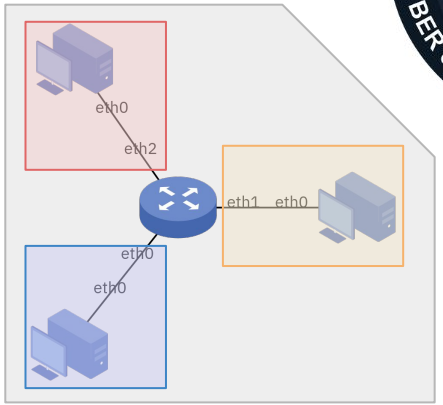
Routers vs. Switches

Routers connect different networks together

Switches connect devices *within* one network

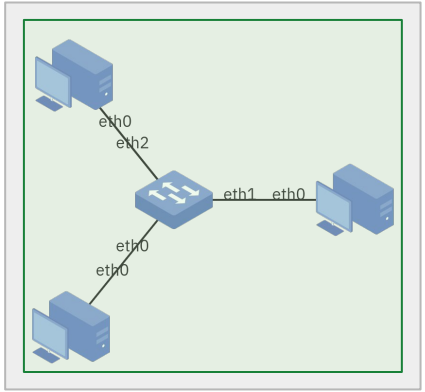
→ What exists within one network?

→ When should we separate networks?



Each device on each router port is on a different network

All devices on each switch port are on the same network



What exists within one network?

Devices which need direct access to one another should be in one network

Ex. Everything in your home is (probably) on one network

- If you have a printer: your laptop can print something without sending a request into a different network

When should we separate networks?

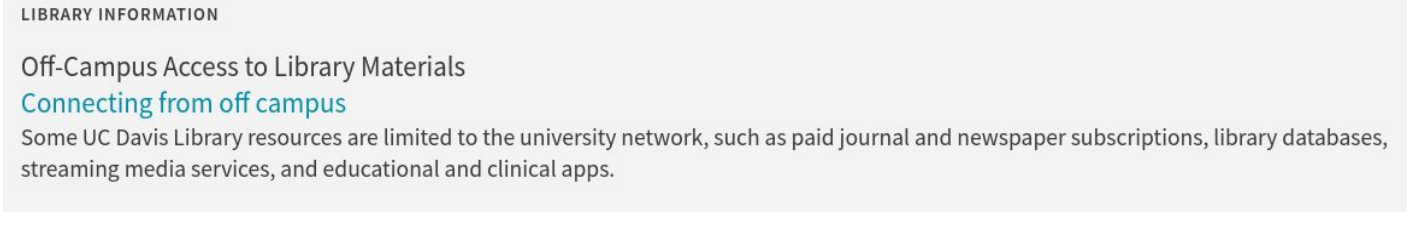
Devices that don't need frequent direct access to each other get split into different networks

Ex. Google's servers aren't in your home network b/c you alone don't need direct access to them

Splitting up networks allows for access control, Ex. Eduroam

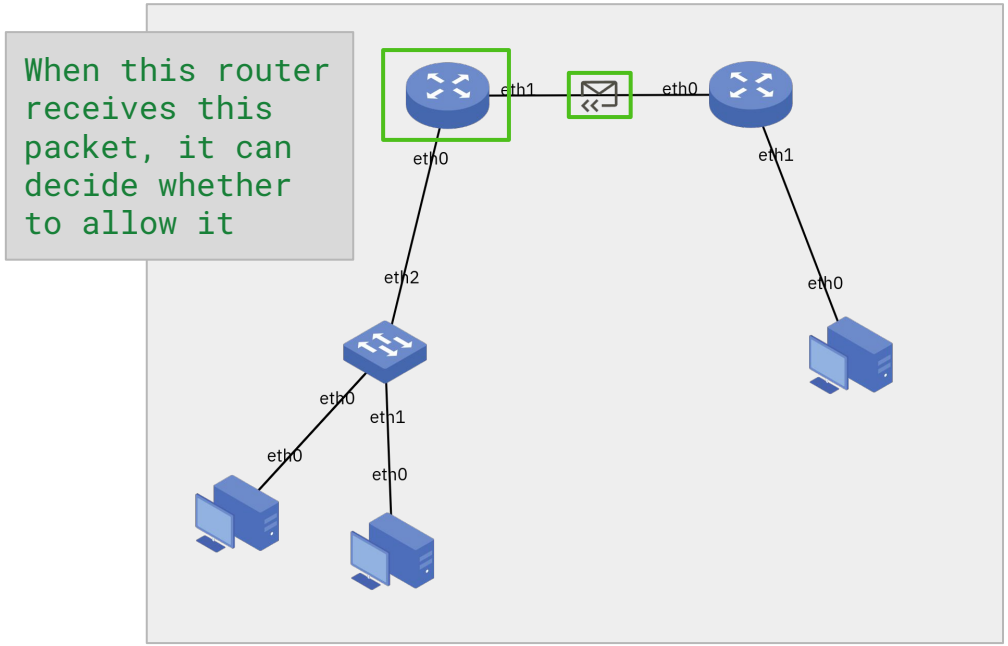
Devices on Eduroam are allowed access to many ebooks, papers, etc.

From off-campus, VPN-ing into campus is required to access these



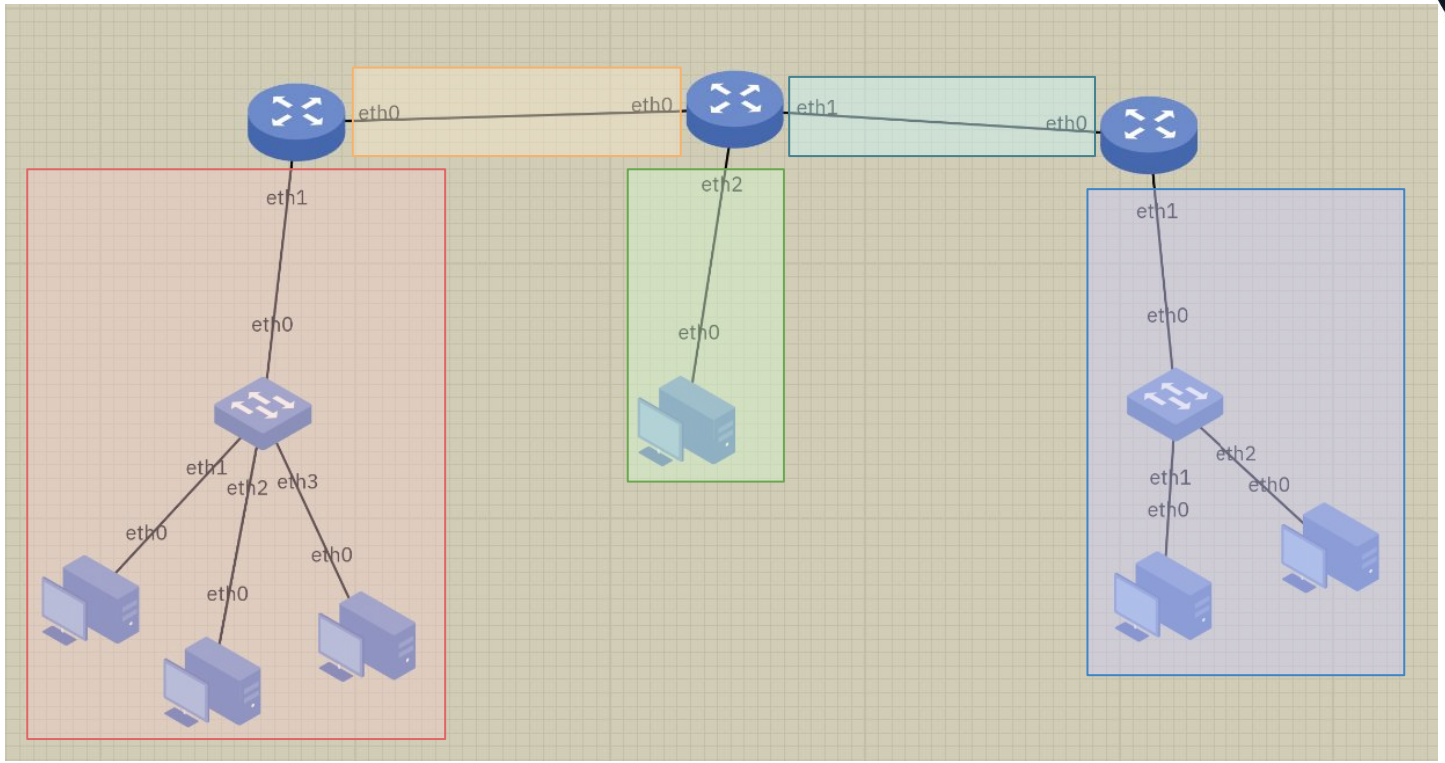
Access Control

Routers make decisions on packets, so they can decide whether to allow/drop



This is the basis behind firewalls

Putting them together



(Each block is a single network)

Sidenote: Home Routers

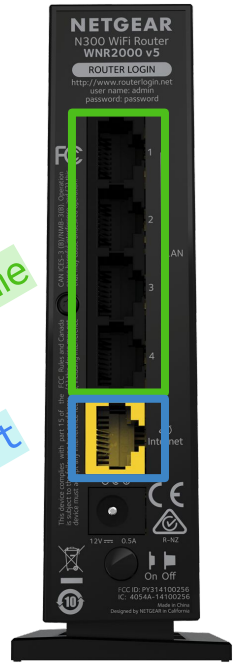
Act as both a router and a switch

Home ports use the internal network

acts as a switch → any devices on any of these ports are on the internal network

Internet port uses the external network

connects to Internet Service Provider (ISP)



Sending & Receiving

Network Interfaces

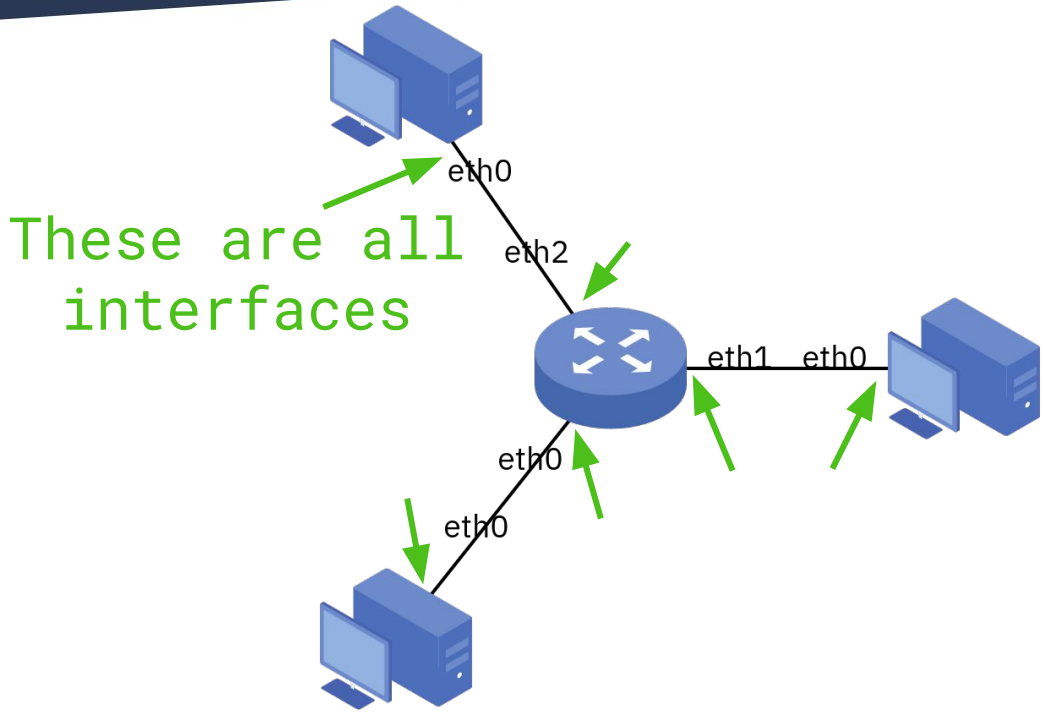
The part of a device's hardware which allows it to connect to a network

Ex. on laptops, a WiFi card
Ex. on other devices, an Ethernet port

Links: the connection between interfaces

- E.g. the WiFi connection between your laptop and the Eduroam access point

Network Interfaces (cont.)



Network Interface (Demo)

Open a terminal/cmd

Windows: run `ipconfig`
Linux/Mac: run `ifconfig`

Each interface has a **MAC Address**
In-use interfaces should have an **IP Address**
(more on these later)

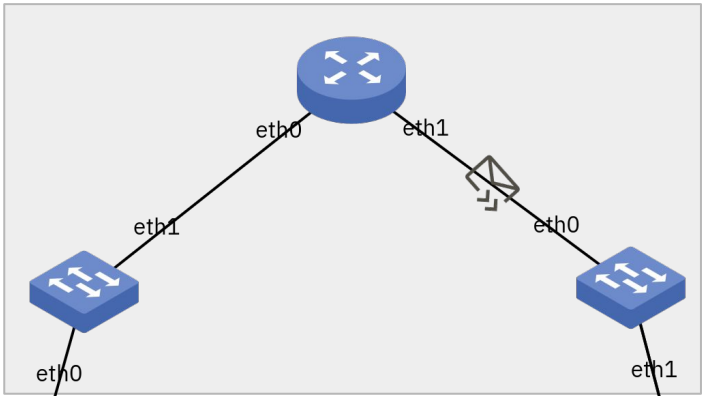
Network Data – Packets

Packets ≈ Packages

- Packages are moved from facility to facility, towards destination
  - Packets are moved from router to router towards destination
- At each router, the packet's destination address is read

  → next router to send it to is decided

Routing: step-by-step sending *across networks* that gets a packet closer to its destination



Network Data (cont.)

Goal for the Internet: create one packet-routing protocol that can be implemented on any system

The Internet Protocol

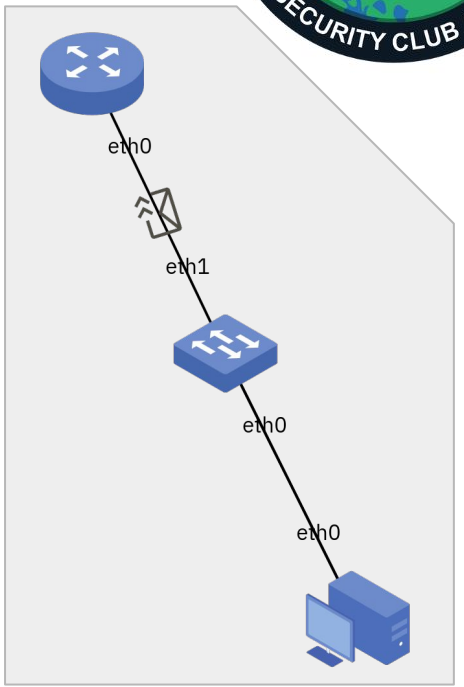
But we have so many types of links! (WiFi, ethernet, fiber)

So how do we keep packet-forwarding consistent across different mediums?

Network Data — Frames

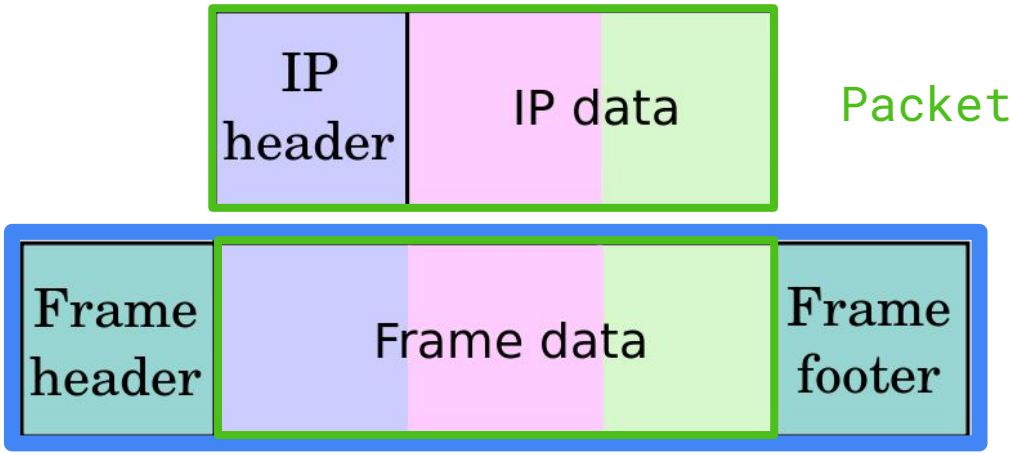
Frame ≈ truck carrying a package

- Many different types of links exist: WiFi, Ethernet, Fiber, etc.
- Packets have to be sent on all of these somehow
- We put packets inside of frames and forward the frames across links
    - Each link type has a different frame format



Forwarding: step-by-step sending *across a link* that gets a packet closer to its destination

Network Data (cont.)



Packet

Packet contained inside a frame

Network Data (cont.)

General rule:

Routing is the primary job of routers

Forwarding is the primary job of switches

Addressing

Packages can only be routed to buildings with addresses

Packets can only be routed to devices with **IP addresses**

IP = Internet Protocol

IP header: part of packet which contains source and destination IP address

IPv4 Address

Ex. `192.168.0.1`

Structure: 32 bits stuck together

(Or 4 groups of 8)

Identifies Internet devices

Use in packets: routers check the destination IP address to determine how to route the packet

IPv4 Address Exhaustion

IP addresses are each 32 bits long → how many addresses exist?

$2^{32} \approx 4.3$ bil → *not nearly enough*

Solutions exist:

- **N**etwork **A**ddress **T**ranslation → using one IP to refer to many addresses
- IPv6 → new version of the Internet Protocol with 128-bit addresses

(for the most part, we're using IPv4 + NAT)

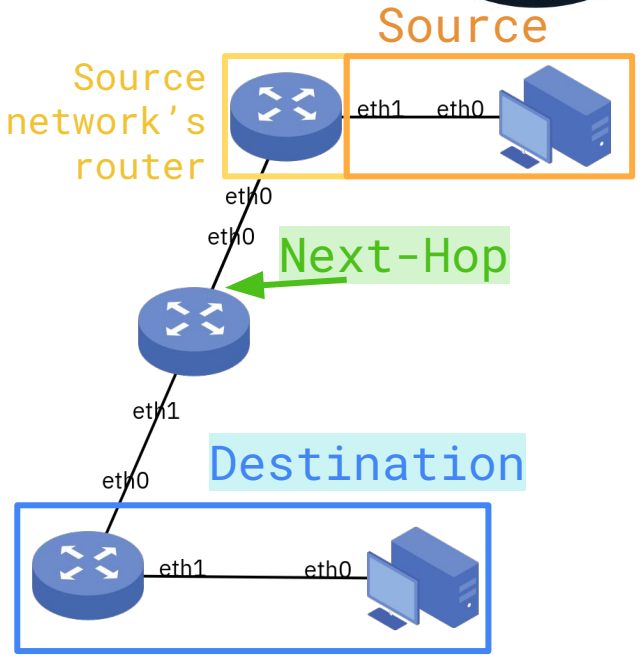
Network Routes

The paths that routers use to decide where to forward packets

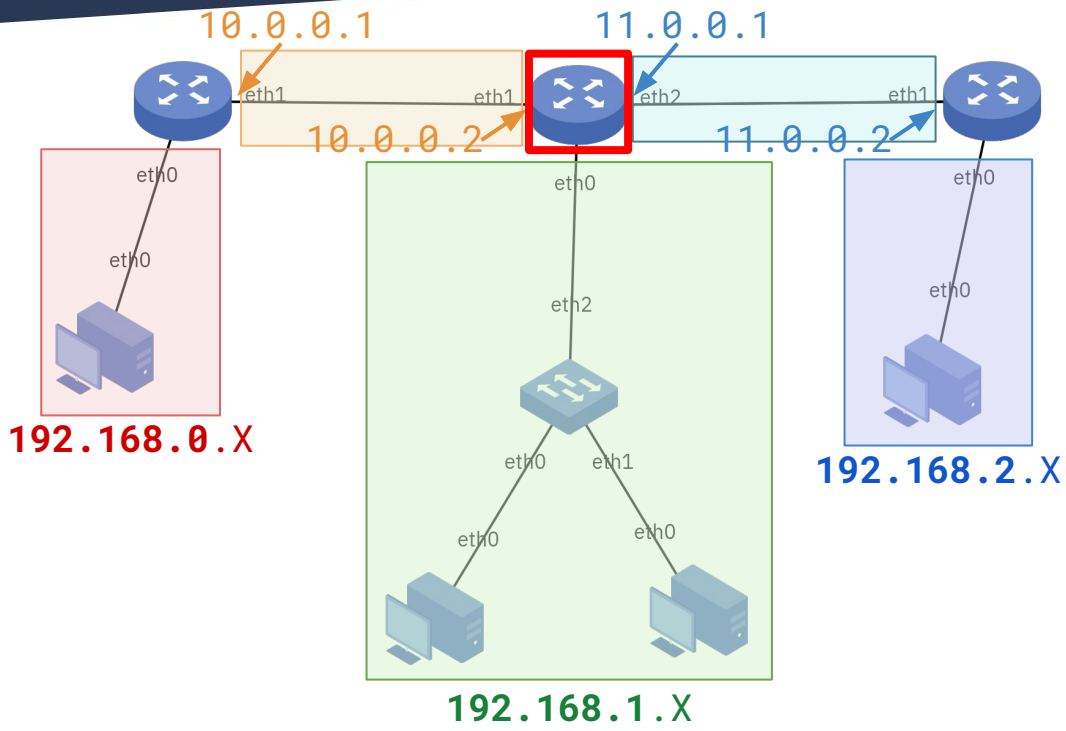
i.e. how routers route ¯_(ツ)_/¯

Stored as a list of:
[destination network, next-hop] tuples

- destination network: the network we are trying to reach
- next-hop: the IP address of the next router on path to the destination



Network Routes (cont.)



How would the **outlined** router get to the 192.168.0.X network?

How would it get to 192.168.1.X?

Routes

Destination	Next-Hop
192.168.0.X	10.0.0.1
192.168.2.X	11.0.0.2

Thank you!

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