ECPE / COMP 177
Fall 2016

Computer Networking
➔ Lab Essentials

Some slides from Kurose and Ross, *Computer Networking*, 5th Edition

Lab Essentials - Motivation

- Course Organization – Top-Down!
  - Starting with Applications / App programming
  - Then Transport Layer (TCP/UDP)…
  - Then Network Layer (IP)…
  - Then Link Layer (Ethernet)…
- Challenge for Lab:
  - You're going to start using Ethernet/IP on the first day!
- Solution – 1-day overview of the **essentials**

Host Configuration

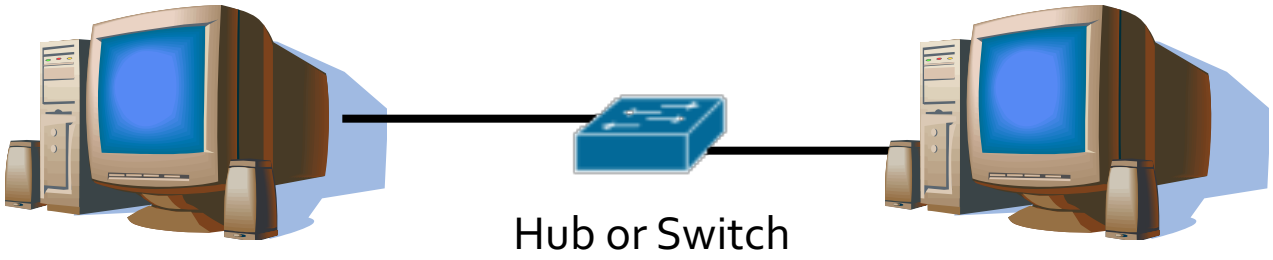
- My computer has several key network settings:
  - My Ethernet / **MAC address**
  - My **IP address**
  - **Netmask** of network I'm connected to
  - **Next-hop gateway** IP address of network I'm connected to
- What do these mean?

Ethernet Basics

The Link Layer

Local Area Network

- Goal: Connect computers across a **Local Area Network**
  - Room?
  - Floor?
  - Building?
  - Few buildings?
- Natural size limit to Ethernet-only networks
  - *Will discuss reasons why later this semester*

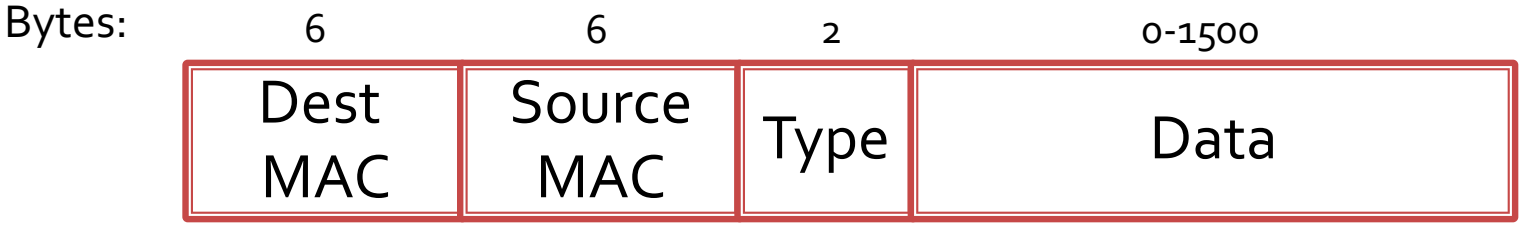


Ethernet - Addressing

- Each device on the network needs a **unique address**
- All Ethernet devices have globally unique 48-bit address assigned by manufacturer
  - Upper 24 bits – Manufacturer
  - Lower 24 bits – Unique device by manufacturer
  - The **MAC address**
- Example: `0x 00-07-E9-CB-79-4F`
  - `0x 00-07-E9` = Intel Corp (assigned by IEEE)
  - `0x CB-79-4F` = Unique address per NIC (picked by Intel)

This is where "my" MAC address comes from

Ethernet Frame Format (Simplified)



- Two MAC addresses saved in Ethernet frame
  - **Destination MAC** – Where is this frame going **to**?
  - **Source MAC** – Who sent this frame?
- Type: Indicates data type or length in bytes
- The Data!
- *Note: The above view is simplified…*

Topology

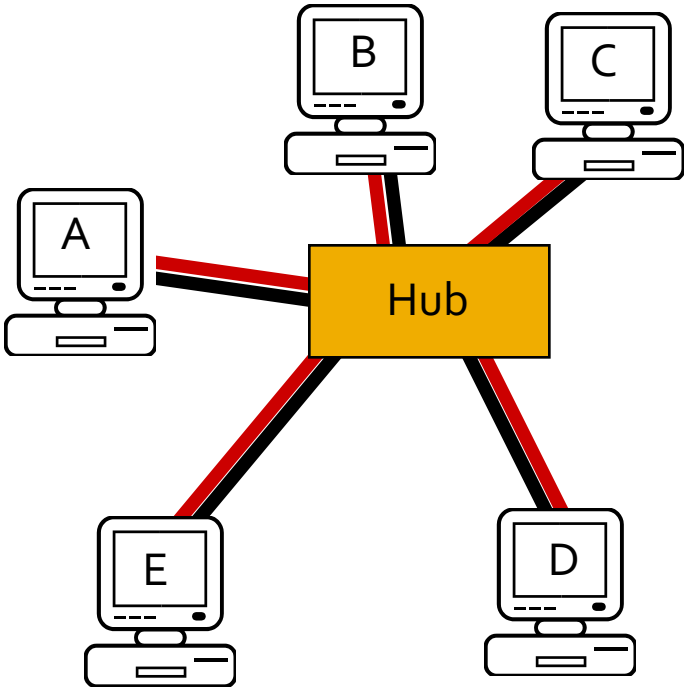
- So how do I connect dozens of computers together?
  - My cable only has two ends…

Ethernet Switch

- **Learns location** of computers on Ethernet network
  - Examine header of each arriving frame
  - What is its source MAC address? (i.e. who sent it?)
    - Note the port it came in on!
    - Save this data in **forwarding table**
- Forwards data out correct port
  - Search forwarding table for **destination** MAC address

Ethernet Hub vs Switch

Ethernet Hub

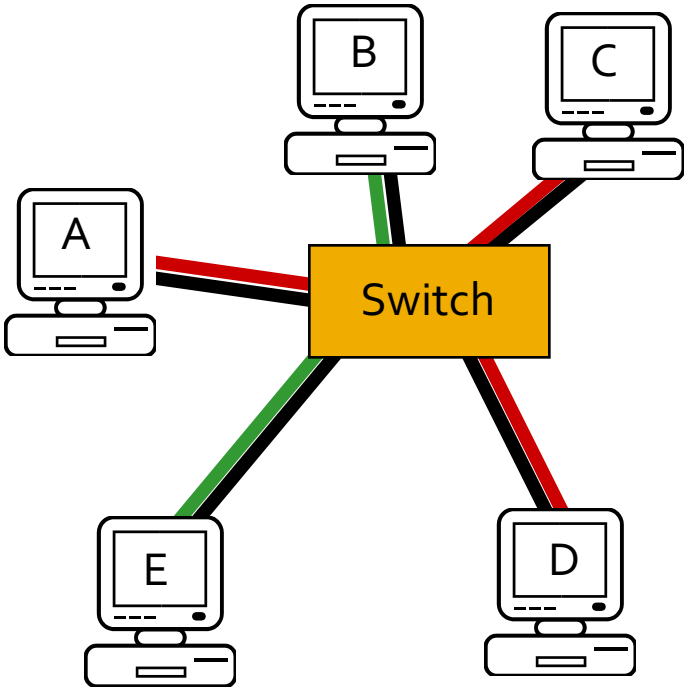


A transmits to D

D replies to A

Ethernet Switch

(assume learning already occurred)



A transmits to D

D replies to A

E transmits to B,
and A to C

Internet Protocol (IP) Basics

The Network Layer

The Internet Protocol - Motivations

- Ethernet is sufficient for a local-area network
- IP is needed for a global network (the **Internet**!)

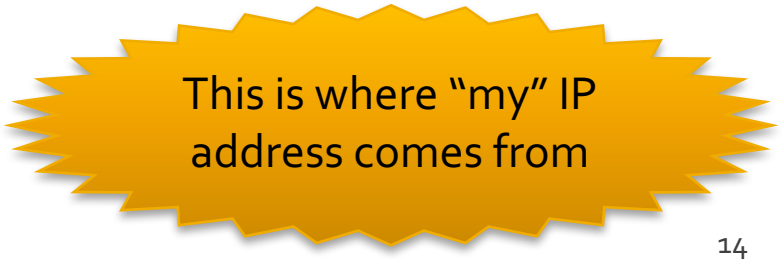
IP Properties

- Datagram
  - Each packet is individually routed
  - Packets may be fragmented or duplicated
    - Due to underlying networks
- Connectionless
  - No guarantee of delivery in sequence
- Unreliable
  - No guarantee of delivery
  - No guarantee of integrity of data
- Best effort
  - Only drop packets when necessary
  - No time guarantee for delivery

This is no different from standard Ethernet networks!

IP Addresses

- IP version 4 addresses are 32 bits long
- IP version 6 addresses are 128 bits
- Every network interface has at least one IP address
  - A computer might have 2 or more IP addresses
  - A router has many IP addresses
  - These addresses can be assigned statically or dynamically



IP Address Format

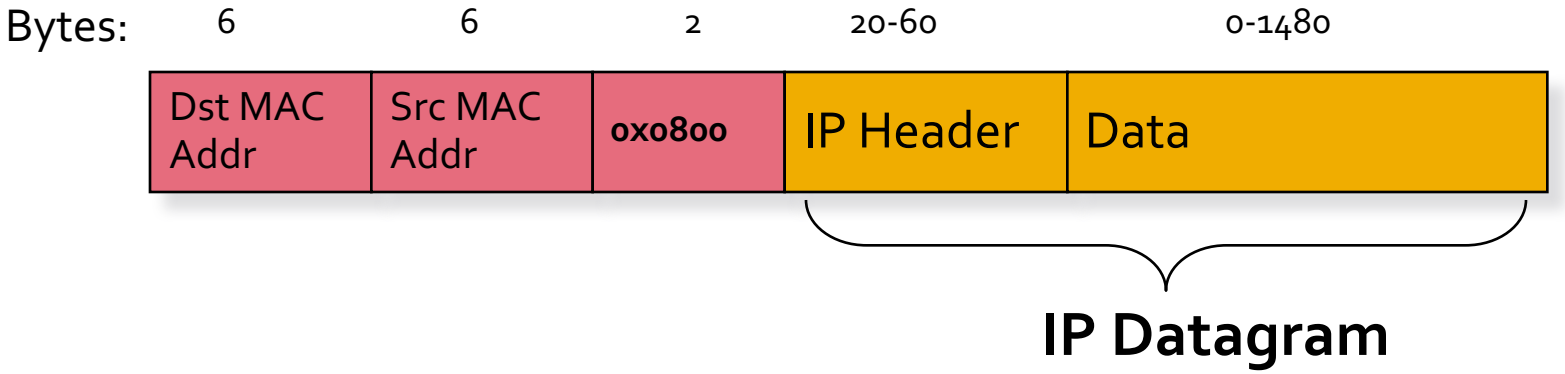
- IPv4 addresses are usually displayed in dotted decimal notation
  - Each byte represented by decimal value
  - Bytes are separated by a period
  - IP address `0x8002C2F2 = 128.2.194.242`

IP Packet Format (Simplified)

- Two IP addresses saved in packet
  - **Destination** IP address
    - Where is this packet going to?
  - **Source** IP address
    - Who sent this packet?
- Checksum
- Length
- Other fields
- The Data!

IP and Ethernet (Simplified View)

- IP datagrams can be *encapsulated* in Ethernet frames



- So what is sent on the *wire* is an **Ethernet frame**
  - Inside of which is an **IP packet**…
    - Inside of which is the **transport layer**…
      - Inside of which is the **application layer**…

Host Configuration

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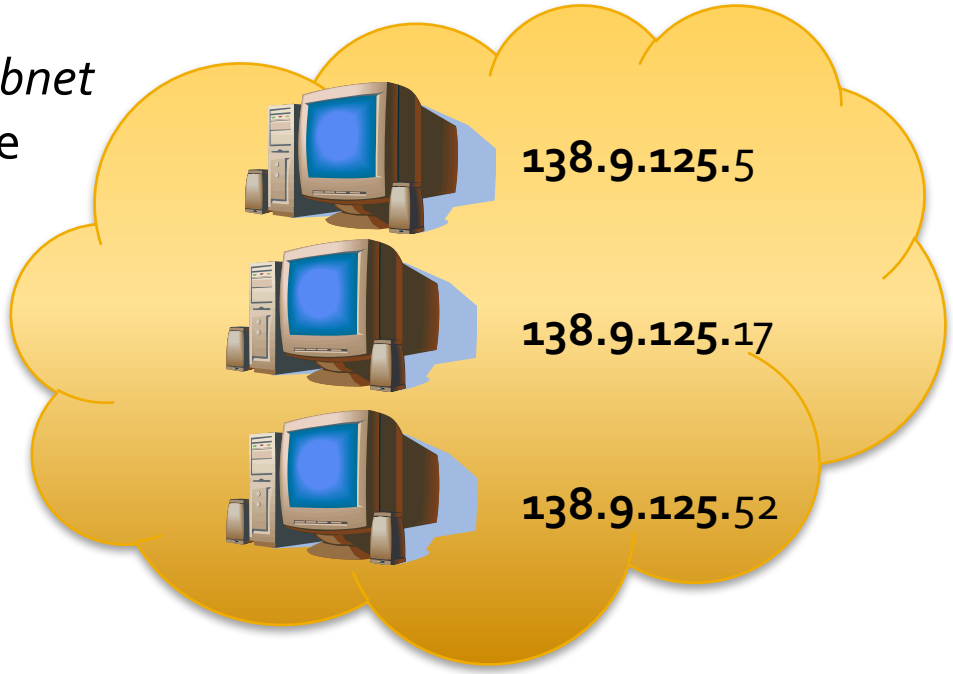
Subnet

- A small network that is part of a larger network
- A collection of computers *(probably in the same physical area)* that have similar IP addresses

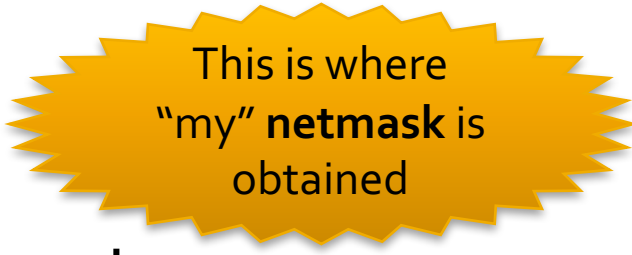
All computers in this *subnet* have IP addresses of the form 138.9.125.x

Note: There is no rule that says subnet addresses have to be at 8-bit boundaries!



Subnet Notation

- A.B.C.D/X
  - IP address of the subnet (with o's in all host ID bits)
  - X = number of bits in the subnet network address
- Examples:
  - 17.0.0.0/8 – Apple's entire class A address space
  - 17.2.3.0/24 – A class C sized subnet in Apple's network
- Can also be represented by subnet IP and a bit mask (netmask)
  - 17.0.0.0/255.0.0.0
  - 17.2.3.0/255.255.255.0
- Network specified by network operator



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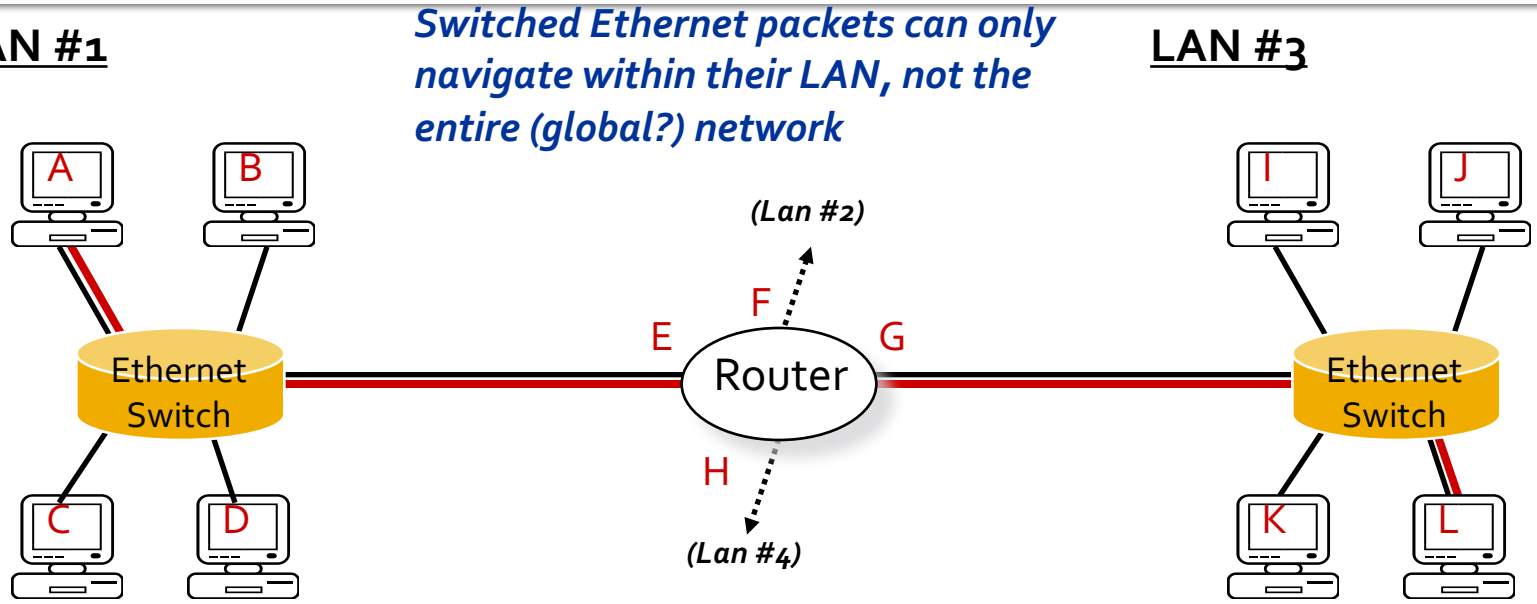
Routers

- "Similar" to switches, but only at a high level
  - Packet comes in
  - Switch/router looks up the destination address
  - Packet forwarded out correct port
- Key difference #1: Routers forward based on IP addresses!
  - Router works at *network* layer, switch works at *link* layer

Routing Between LANs

This is where "my" **netmask** and **next-hop gateway** are used



(1) A transmits to L using higher-level protocol (e.g. IP)
Ethernet frame destination is router

Frame:

DA (E)	SA (A)	Type / Data	CRC

(2) Switch forwards frame to router

(3) Router uses higher-level protocol (e.g, IP) to determine destination, and updates Ethernet frame destination, source and CRC

Frame:

DA (L)	SA (G)	Type / Data	CRC

(4) Switch forwards frame to destination

ARP Basics

Address Resolution Protocol

Address Resolution Protocol

- Find link layer address given a network layer address
  - i.e., what is the **Ethernet address** for a given **IP address**?
- Every IP node (hosts and routers) has an ARP table
  - Mapping from IP to Ethernet addresses on their LAN
  - May be incomplete
  - Can include both static and dynamic entries

Dynamic ARP Entries

- Systems "discover" IP → Ethernet address mappings, as needed
- Each entry has an IP address, an Ethernet address, and a timeout (typically around 20 minutes)
- ARP messages are **broadcast** on the LAN to discover mappings
  - All computers on the network receive the ARP requests

Learning MAC addresses

- Hosts learn IP → Ethernet address mappings
  - ARP responses are stored in ARP tables
  - ARP requests are stored in ARP tables (whether the host is the target or not!)
- ARP entries time out
  - Allow machines to change IP and/or MAC addresses transparently
  - Eliminate stale entries (machines turn off, move, crash, etc.)

Recap

Networking Essentials for Lab

Recap – Forwarding

- **What field do Ethernet switches forward data on?**
  - Destination MAC address (in Ethernet header)
- **What field do IP routers forward data on?**
  - Destination IP address (in IP header)

Recap – Addresses

- **How many bits long is a MAC address?**
  - 48 bits
  - Example: `0x 00-07-E9-CB-79-4F`

- **How many bits long is an IPv4 address?**
  - 32 bits
  - Example: 138.9.215.87

Recap

- "My" MAC address
  - Comes from?
  - Used in?
- "My" IP address
  - Comes from?
  - Used in?
- "My" Netmask
  - Comes from?
  - Used in?
- "My" Next Hop Gateway
  - Comes from?
  - Used in?