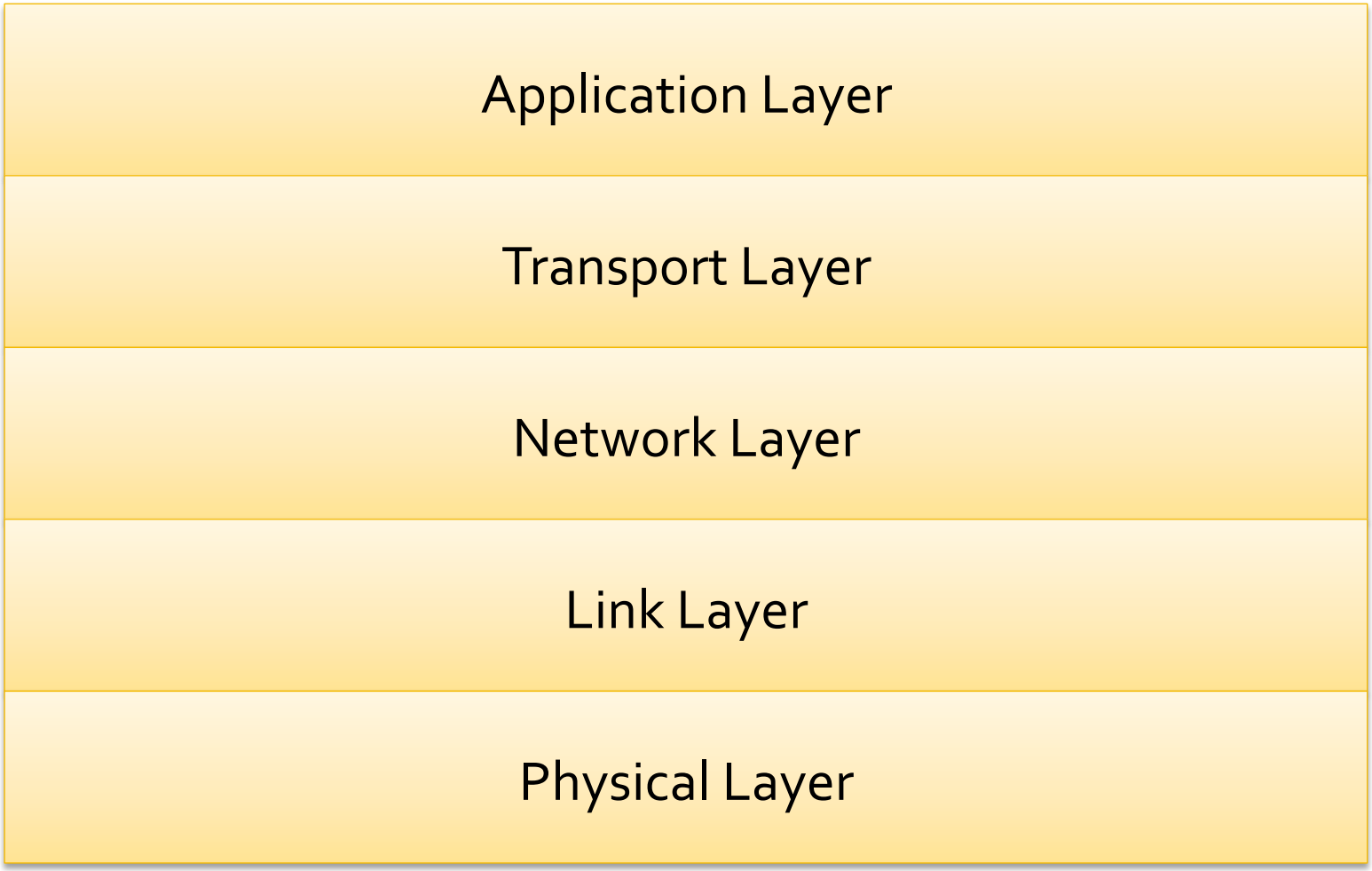
ECPE / COMP 177
Fall 2011

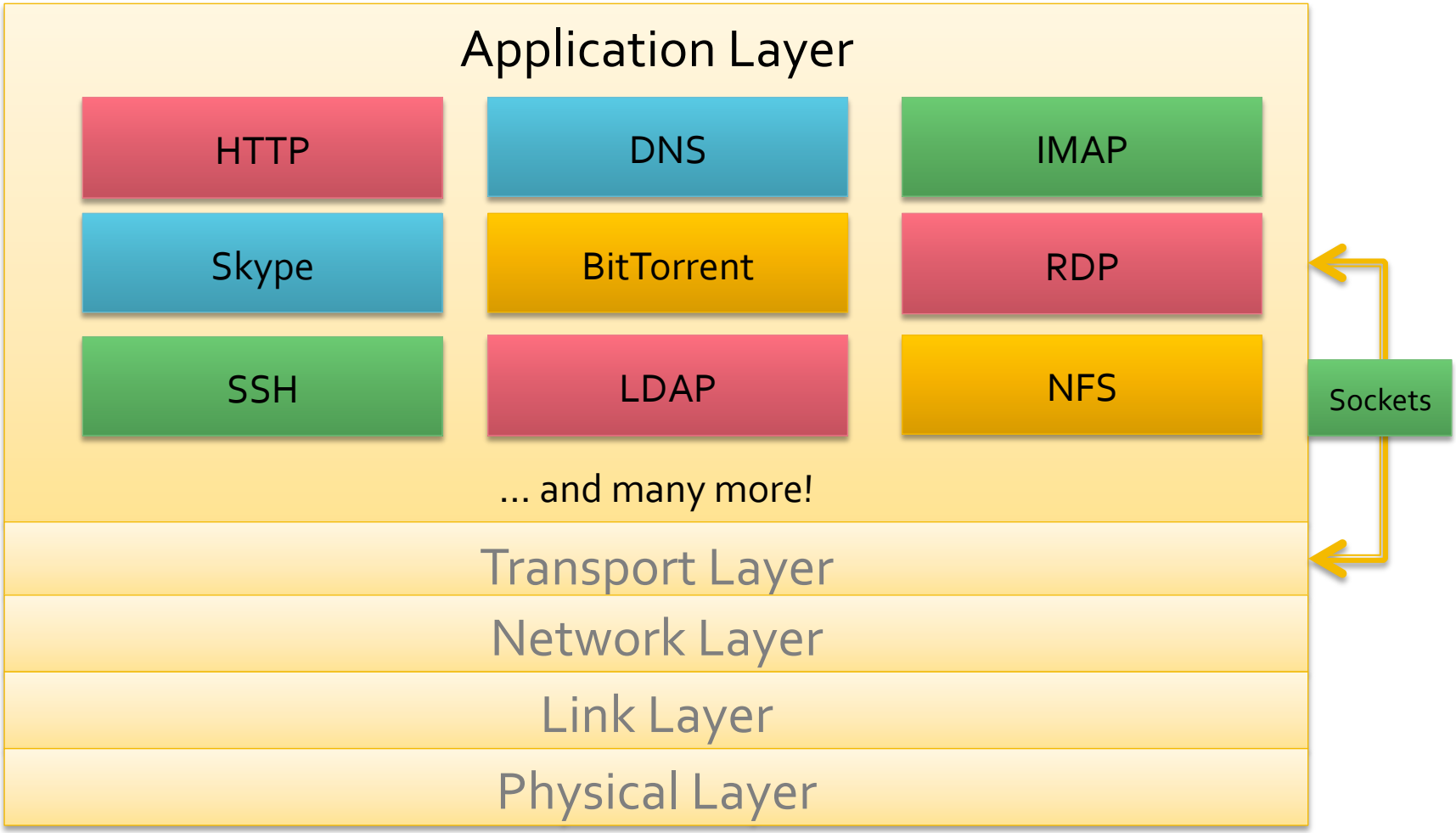
Computer Networking → Lab Essentials

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

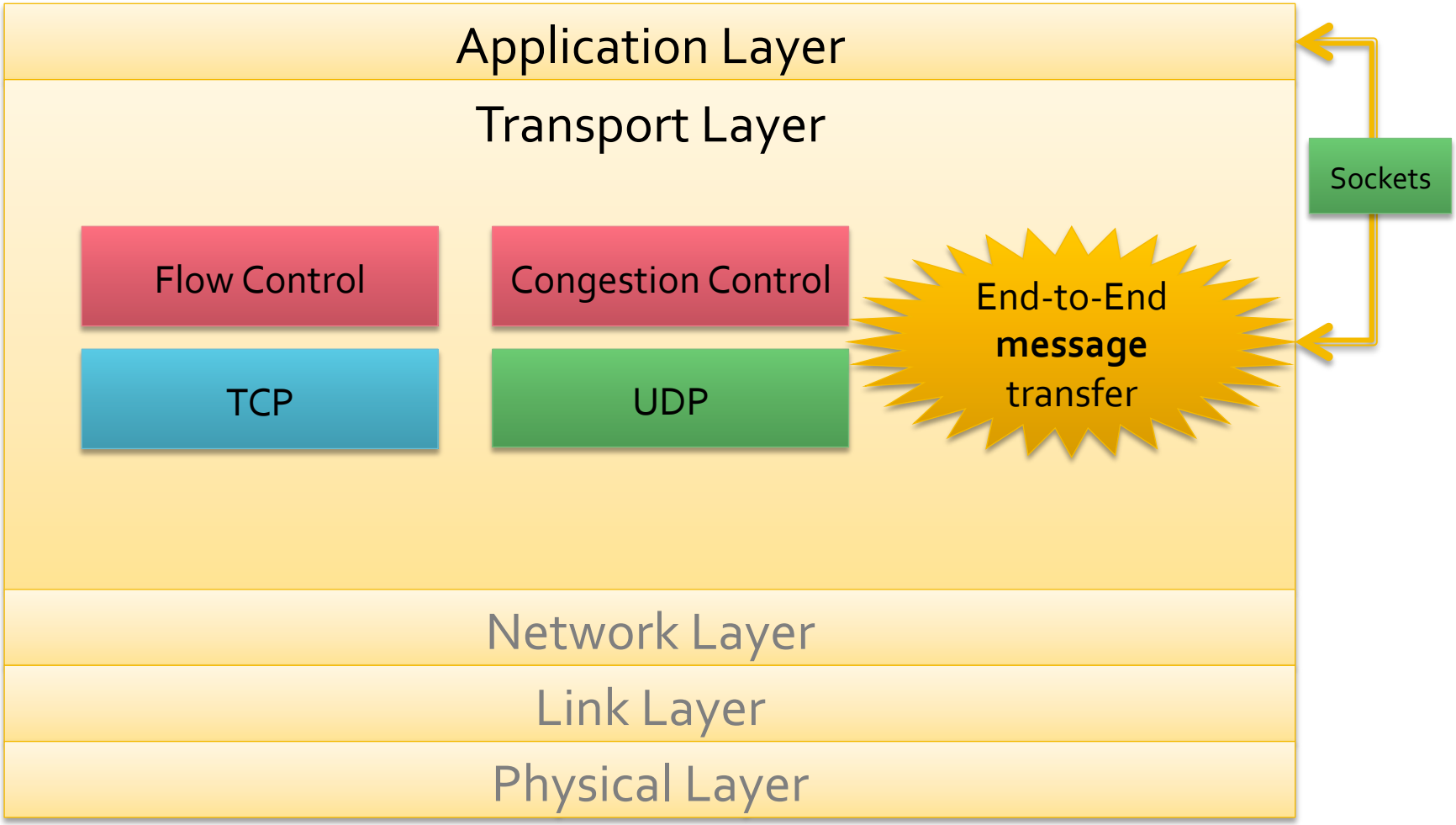
Network Model



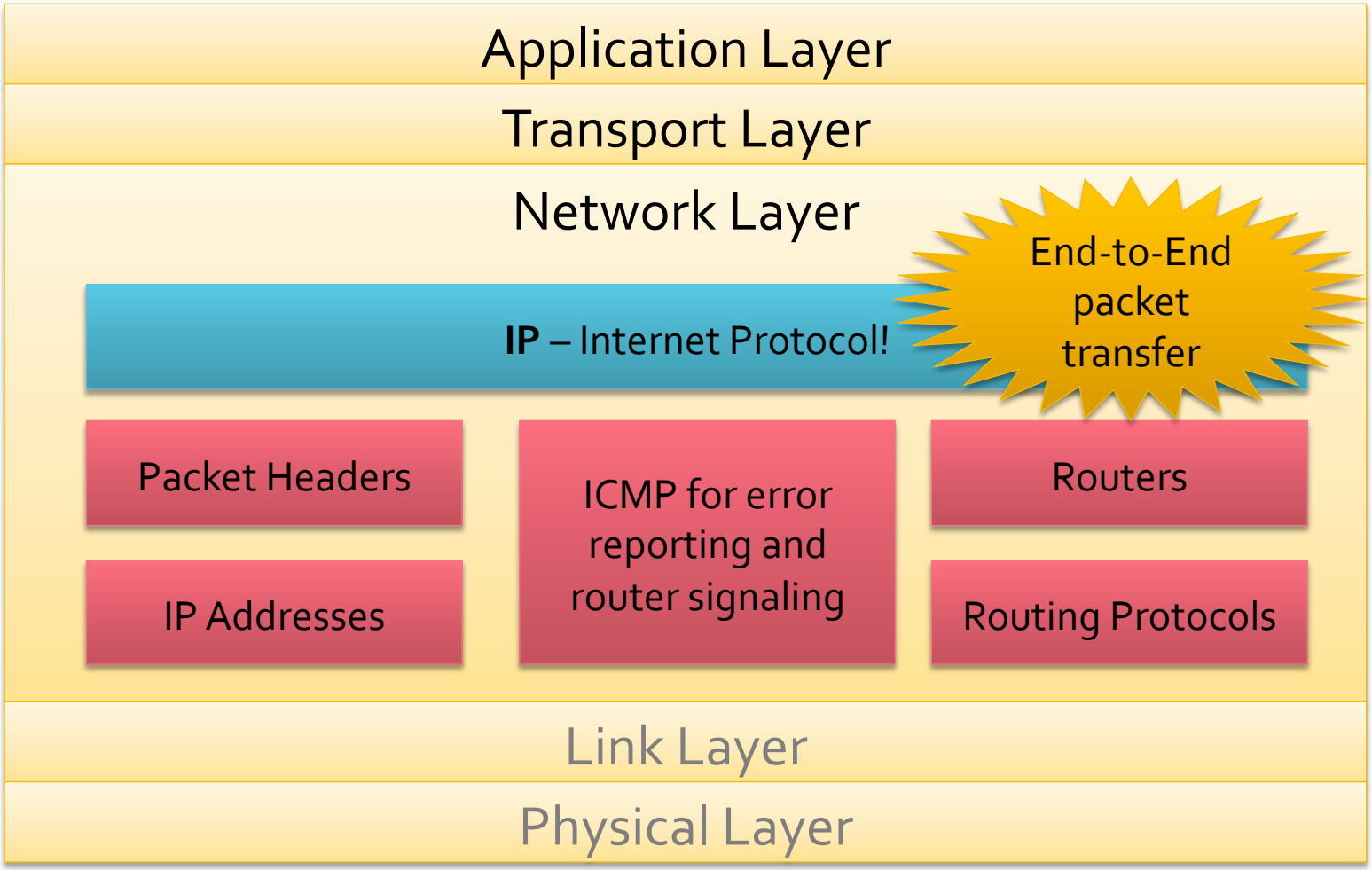
Application Layer



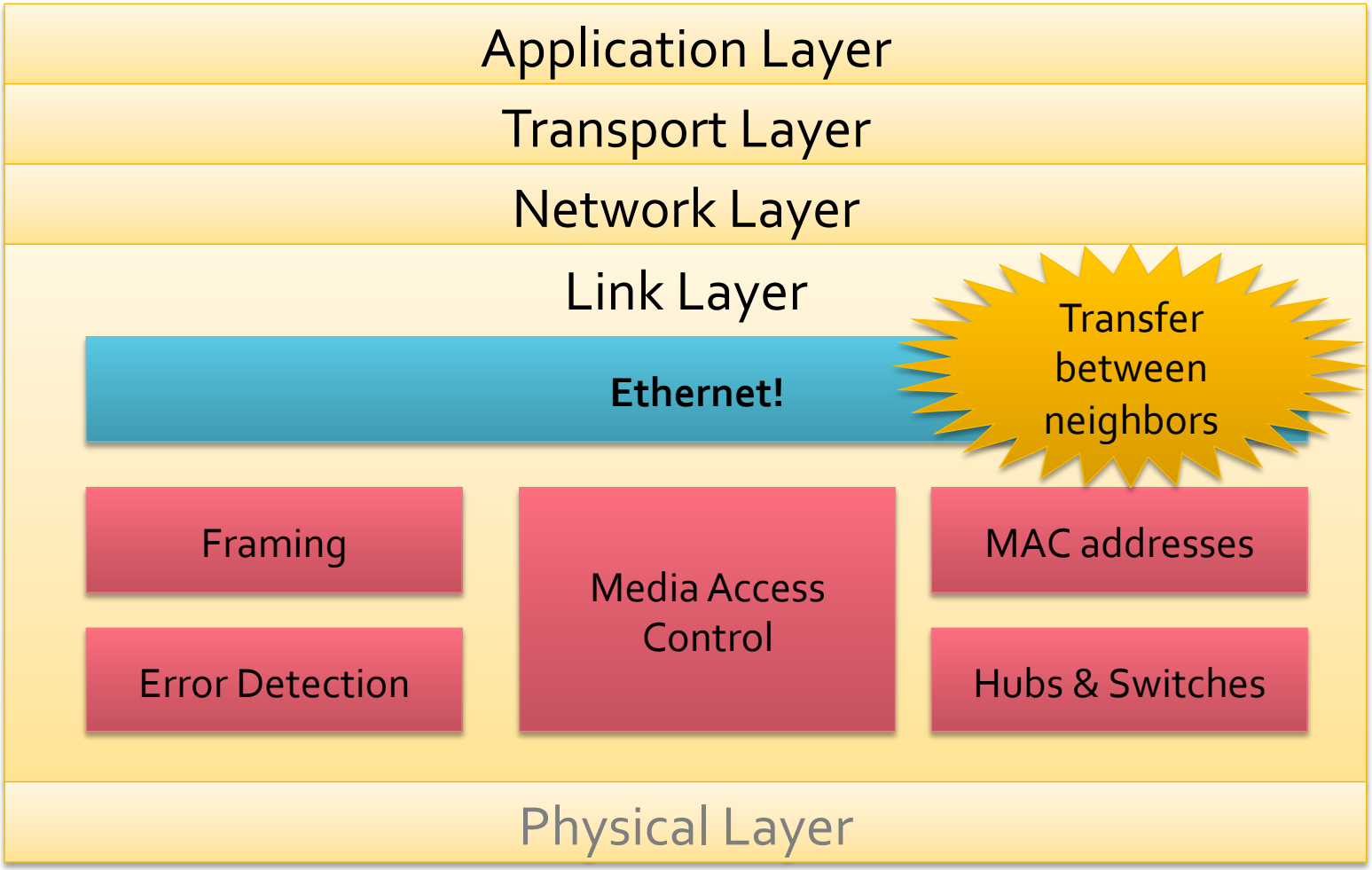
Transport Layer



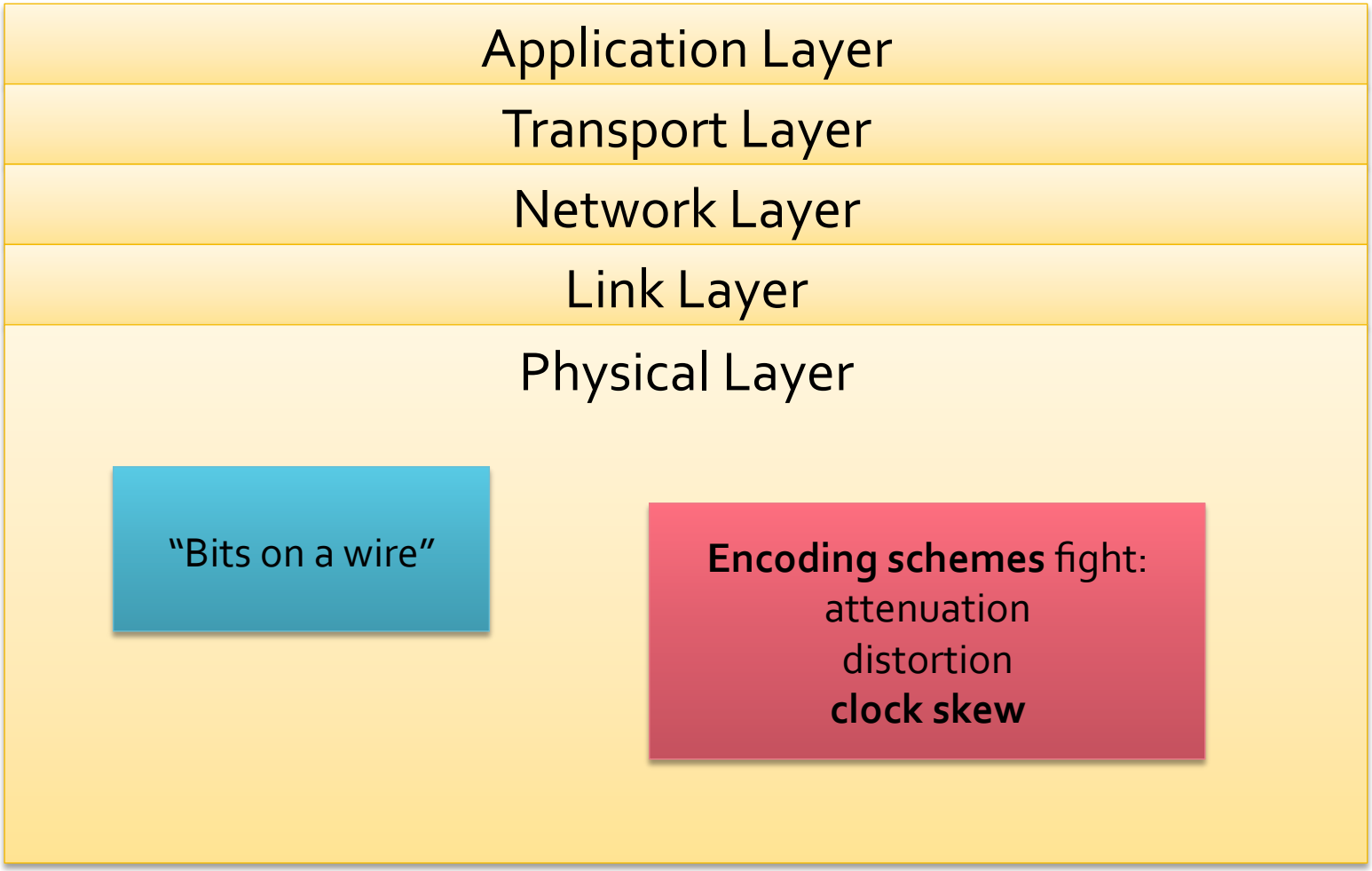
Network Layer



Link Layer


Application Layer
Transport Layer
Network Layer
Link Layer
Ethernet!
Transfer between neighbors
Framing
Error Detection
Media Access Control
MAC addresses
Hubs & Switches
Physical Layer

Physical Layer



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

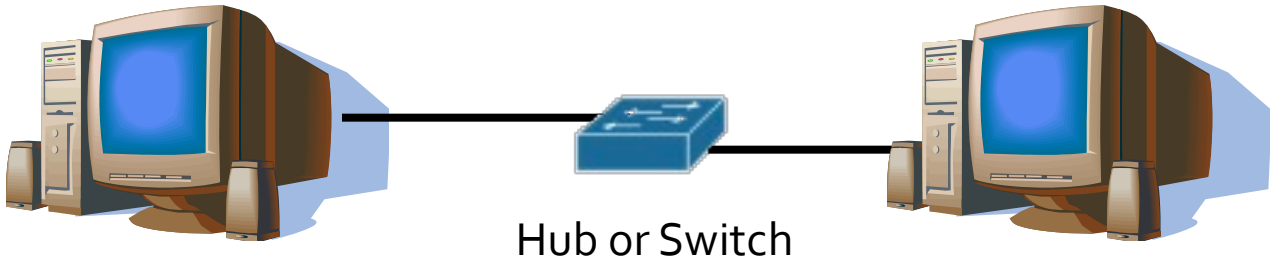
- My computer has several key network settings:
  - My Ethernet / **MAC address**
  - My **IP address**
  - **Netmask** of network I'm connected to
  - **Next-hop gateway** IP address of network I'm connected to
- What do these mean?

Ethernet Basics

The Link Layer

Local Area Network

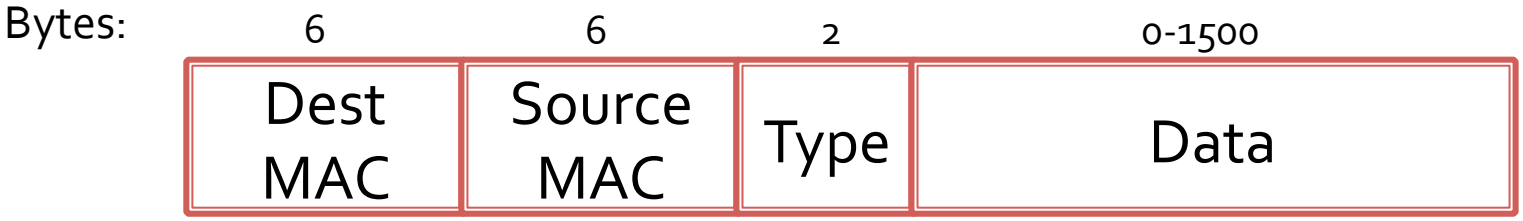
- Goal: Connect computers across a **Local Area Network**
  - Room?
  - Floor?
  - Building?
  - Few buildings?
- Natural size limit to Ethernet-only networks
  - *Will discuss reasons why later this semester*



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)

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

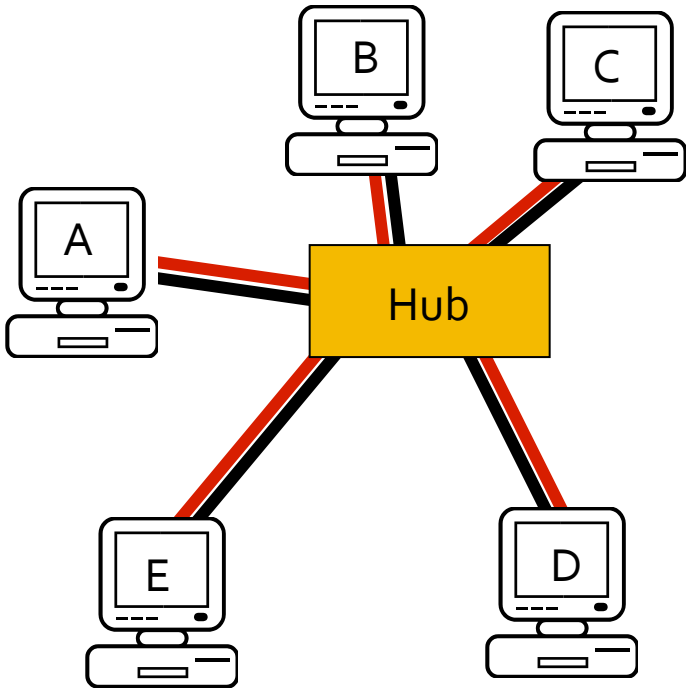
- So how do I connect dozens of computers together?
  - My cable only has two ends…

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

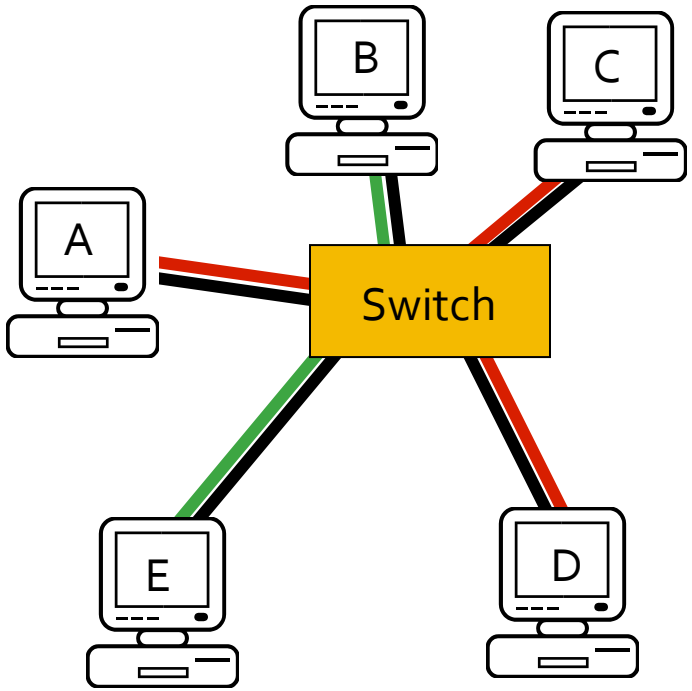


A transmits to D

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**!)

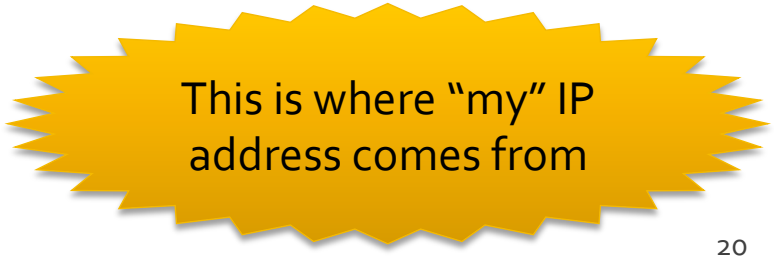
IP Properties

- 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
  - *Version 6 address 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

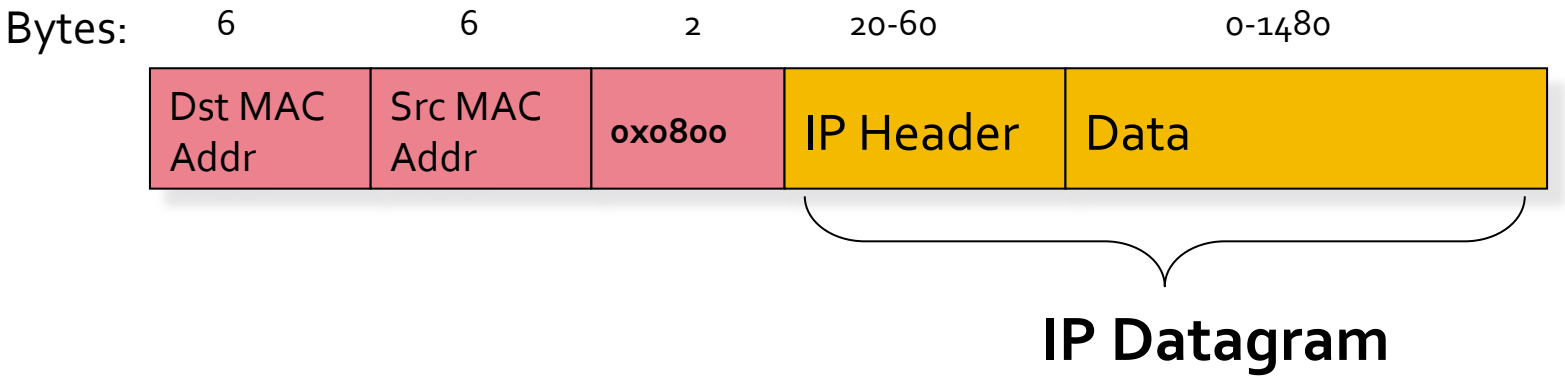
- IPv4 addresses are usually displayed in dotted decimal notation
  - Each byte represented by decimal value
  - Bytes are separated by a period
  - IP address `0x8002C2F2 = 128.2.194.242`

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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  - My Ethernet / **MAC address** ✓
  - My **IP address** ✓
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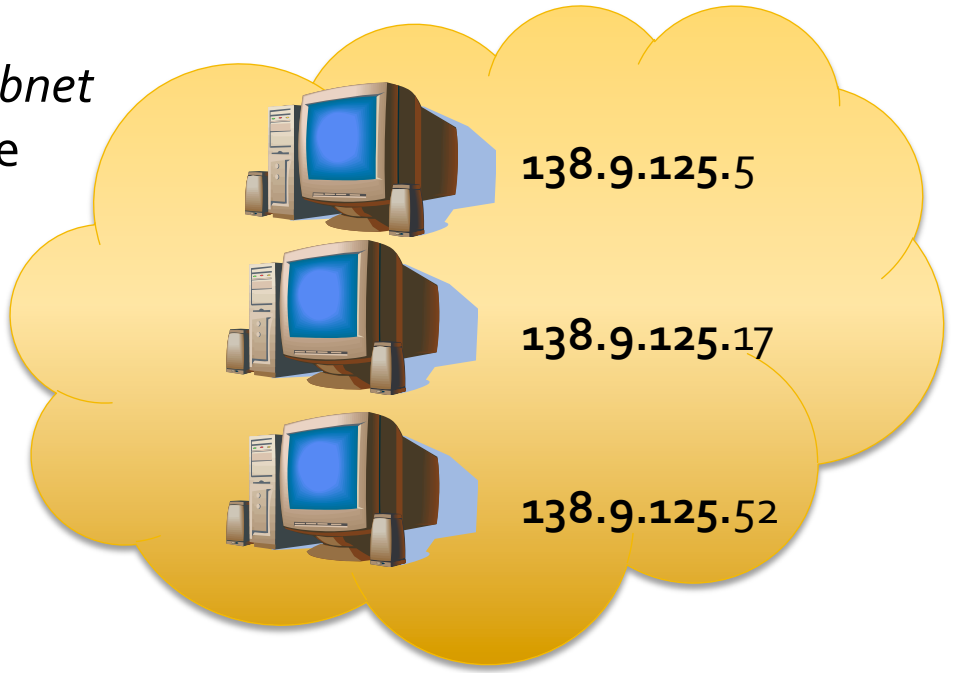
- What do these mean?

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 0'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
- Alternatively 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

This is where "my" **netmask** is obtained

Host Configuration

- My computer has several key network settings:
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  - My **IP address** ✓
  - **Netmask** of network I'm connected to ✓
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Routers

- "Similar" to switches, both 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

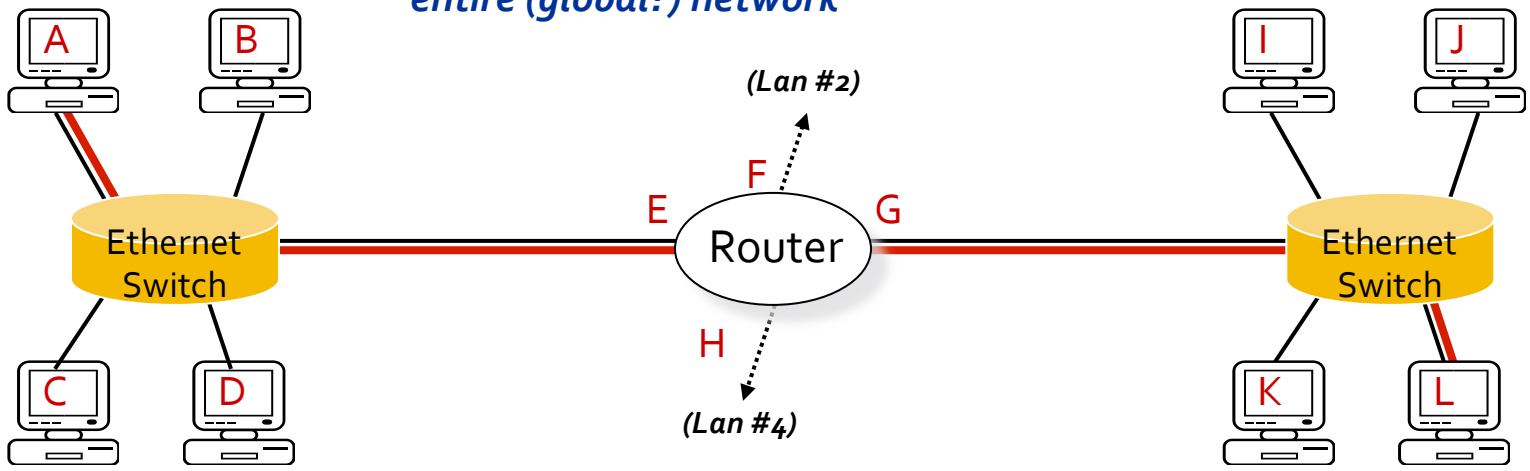
Routing Between LANs

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

LAN #1

Switched Ethernet packets can only navigate within their LAN, not the entire (global?) network

LAN #3



(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 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?

Upcoming Schedule

- **Thursday lecture**: Application layer
- **Homework #1**
  - Assigned Thursday
  - Due in one week
  - Application layer: DNS, HTTP, protocols
  - Submit PDF file online via Sakai
- **Lab #1**
  - Thursday afternoon (2pm) in Baun 212