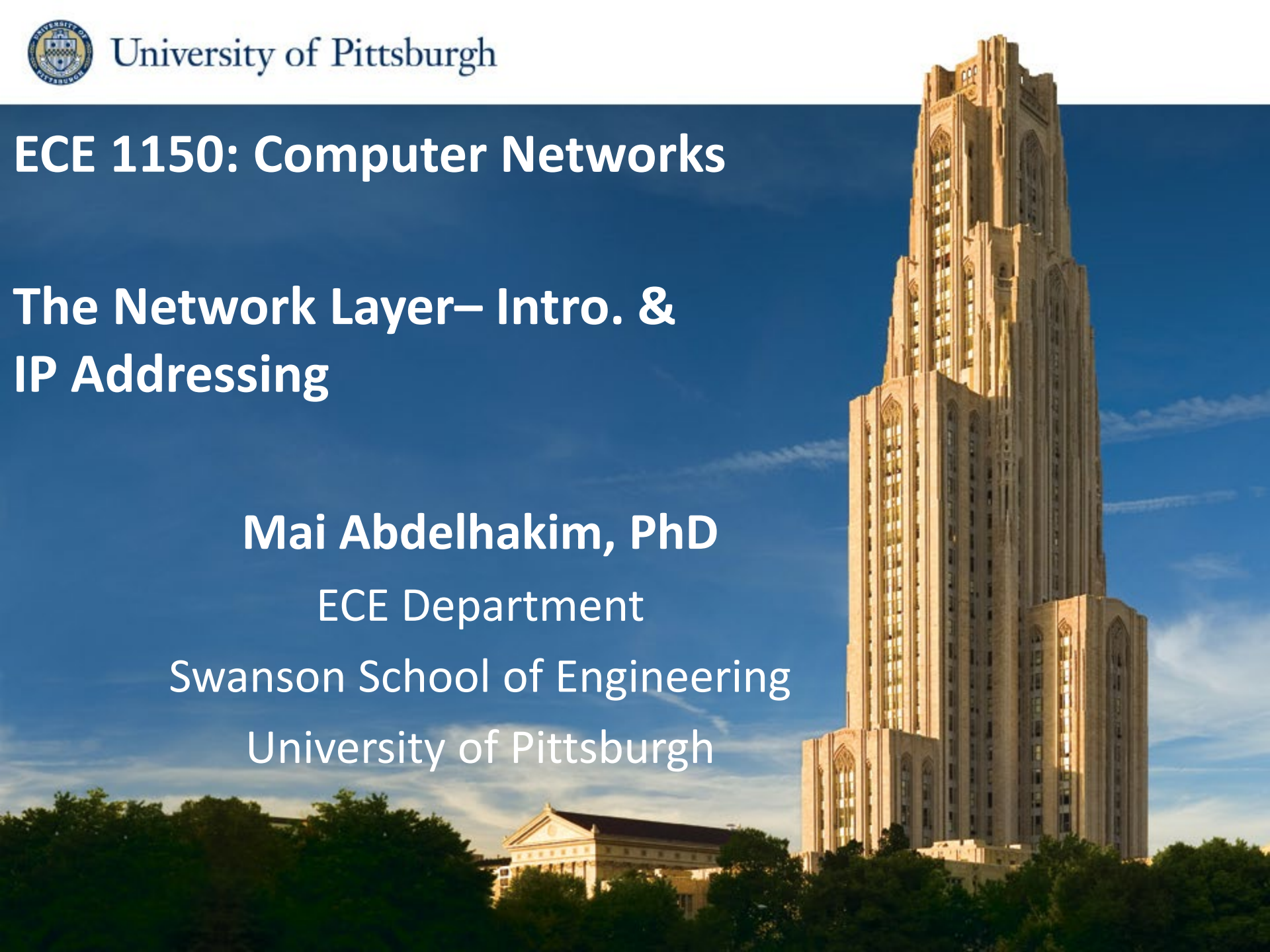

University of Pittsburgh

ECE 1150: Computer Networks

The Network Layer– Intro. & IP Addressing

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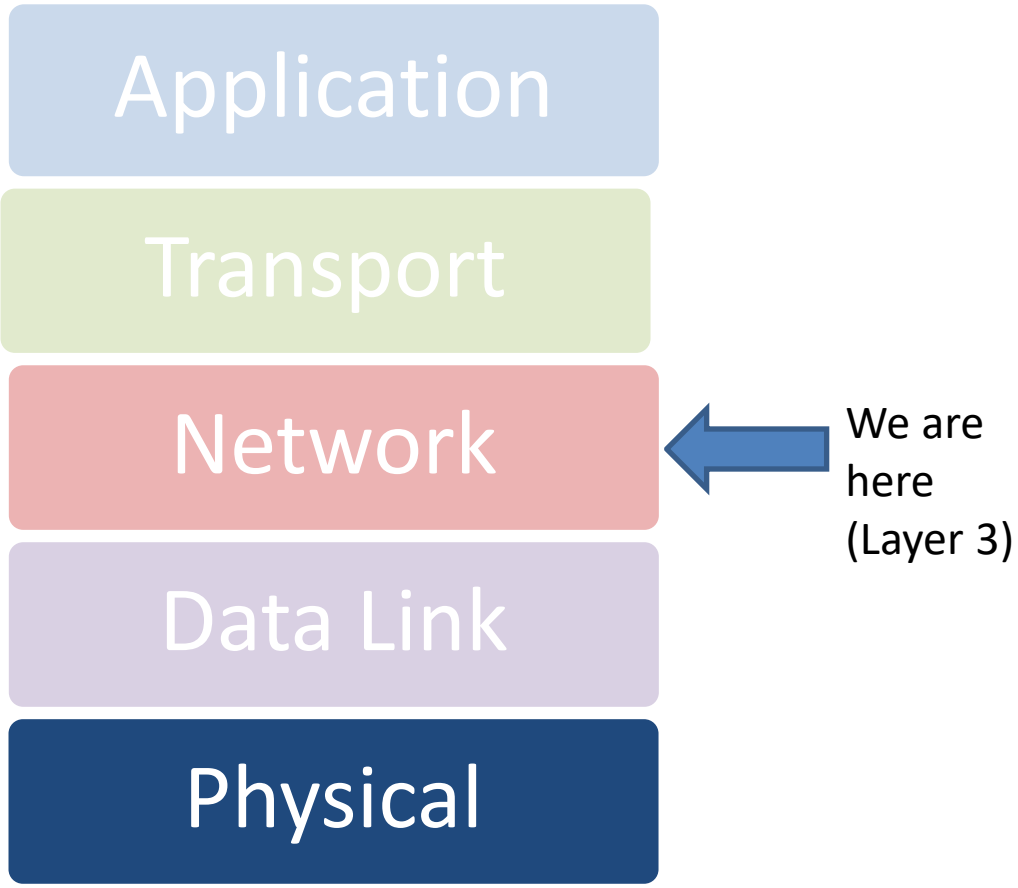
Topics

- The Network layer of the Internet – IP (Internet Protocol)
  - Main Functions
  - Header at network layer
  - IP addresses:
    - Address classes
    - Classless inter-domain routing
  - Routing

The Network Layer

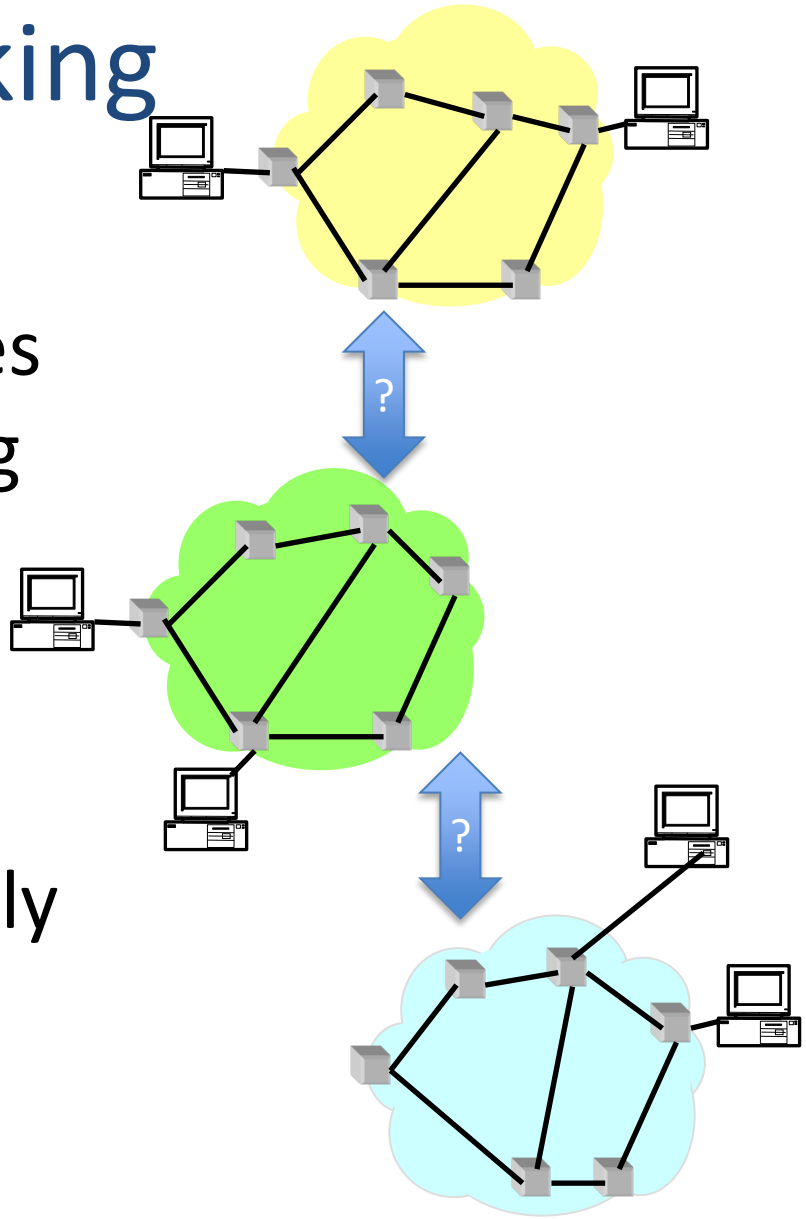
- Network Layer
  - **Layer 3** in the Internet model
  - Responsible for **addressing** and **routing** of message
- RFC = Request for Comments – specifies internet related standards
  - **Developed by IETF – Internet Engineering Task Force**



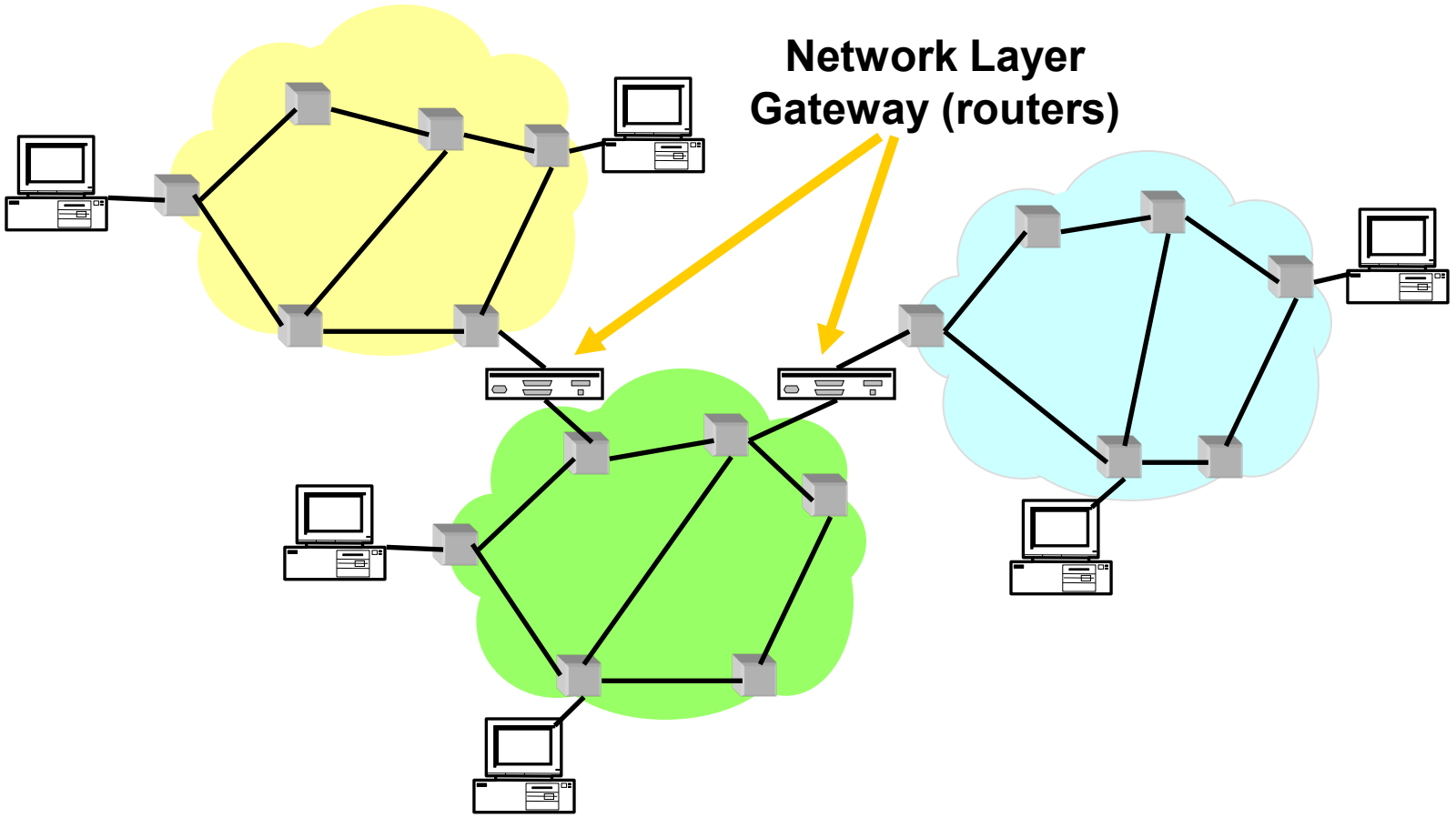
Internetworking

- Before Internet: Only nodes on the same network using same technology could communicate

- How to allow independently owned and administered networks to interconnect?



Internet Solution to Internetworking



- **Gateways** called *"routers"* can route packets between different LANs using the Internet protocol

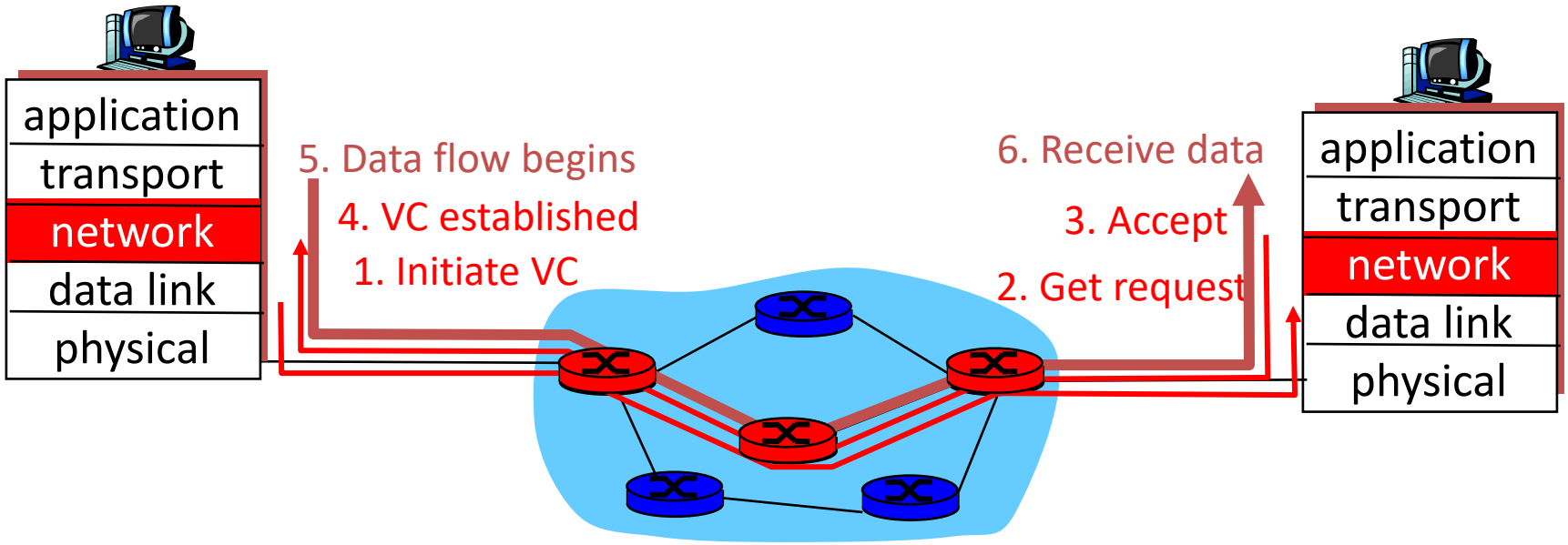
Two Ways for Packet switching

- **Connection Oriented: virtual circuit packet switching**
  - **All packets go on same route**

- **Connection-less: datagram packet switching**
  - **Route each packet independently** through the network

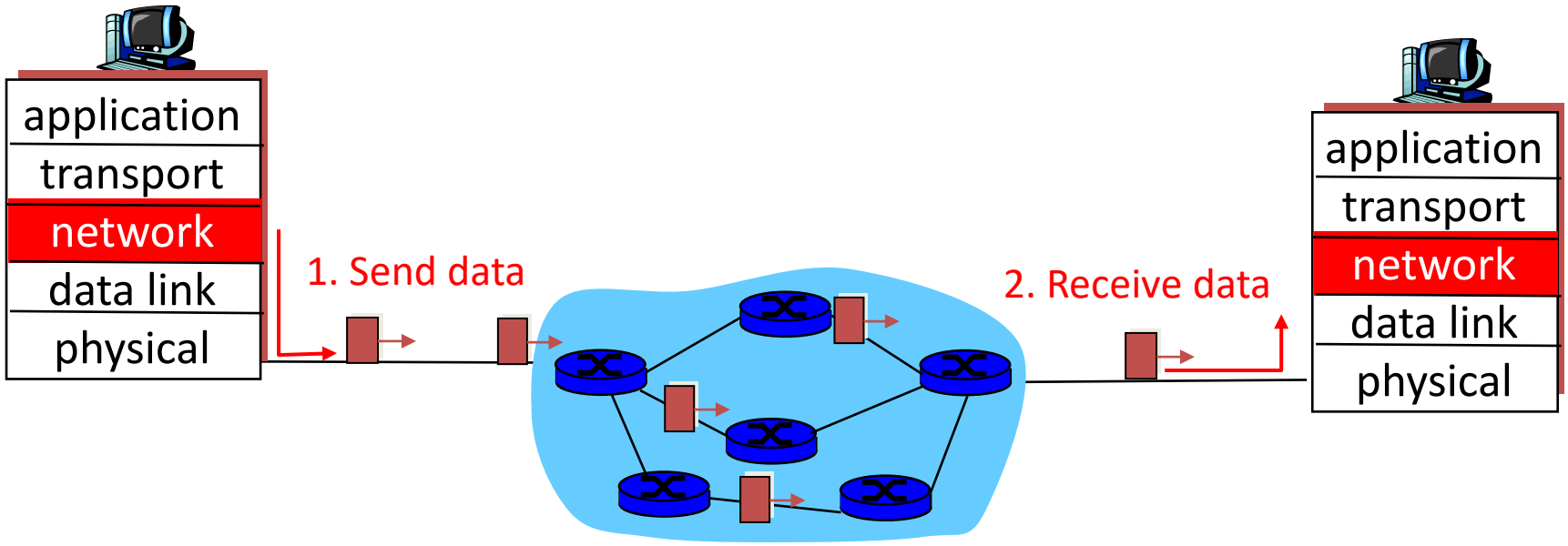
Connection Oriented Service

- Before data flows, end hosts establish connection called virtual Circuit (VC)
- Needs signaling protocol to setup, teardown VC
- Each packet has **VC ID in header** – decision based on ID
  - Used in WAN standards: ATM, frame-relay, X.25

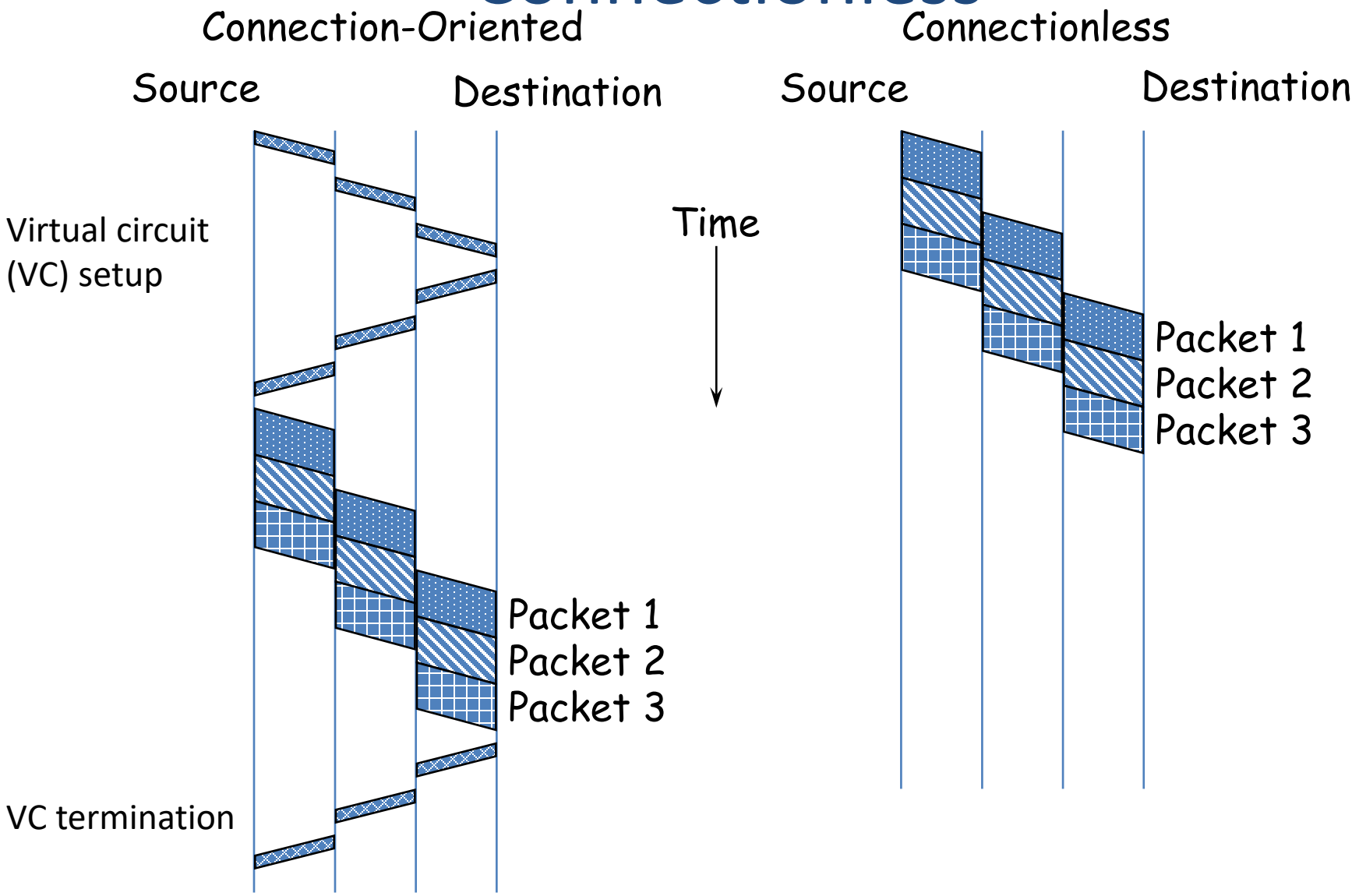


Datagram (IP) Networks

- Packet between same source-destination pair may follow a different routing path
  - Packets forwarded using destination host address
- No setup needed at network layer
- Used in Internet



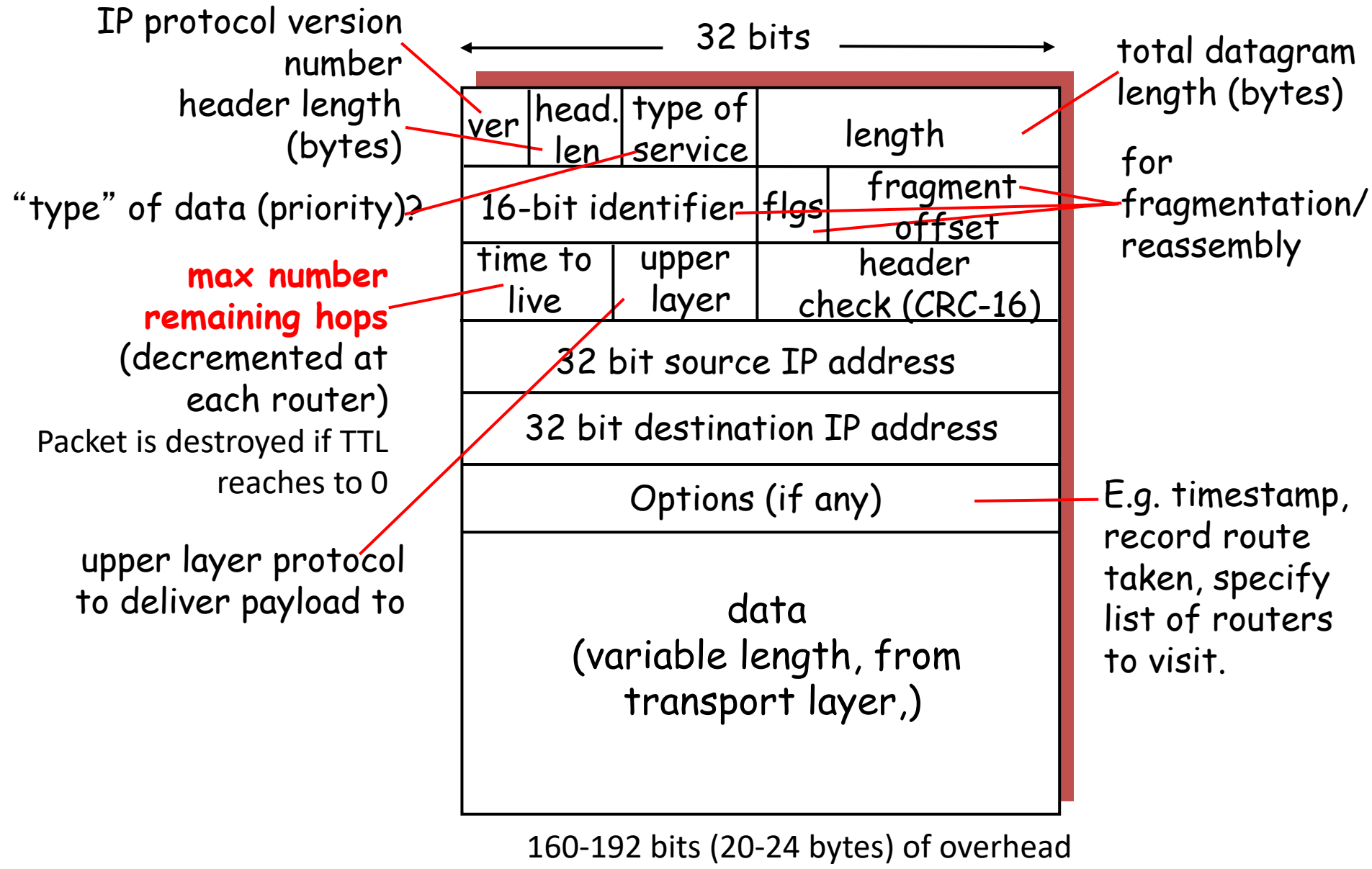
Connection-Oriented *vs.* Connectionless



Network Protocols

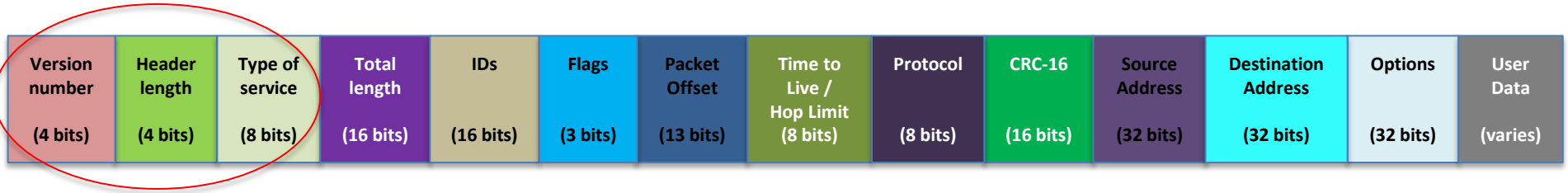
- IPv4 Packet
  - 160-192 bits (20-24 bytes) of overhead
  - Options field: rarely used

IP Datagram Format



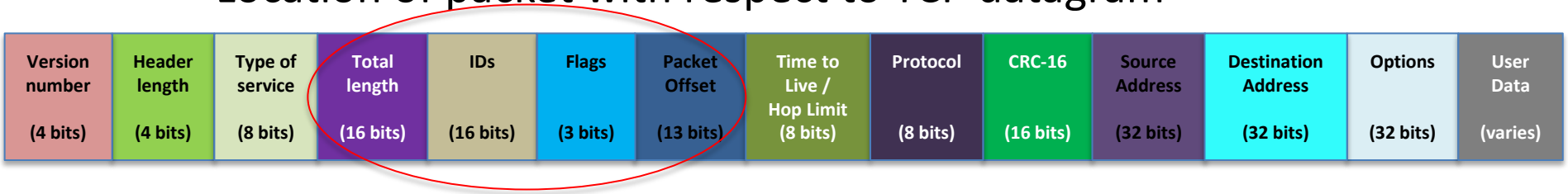
IP Header fields

- Like other layers, IP header fields enable IP functionality
  - Used primarily by routers to find addresses
- Version of network protocol (IPv4 or IPv6)
  - IPv4 expected to be popular for some more years
- Header length
  - Length of header in multiples of 32 bits
- Type of service
  - Packets with higher value should get higher priority



IP Header fields

- Total length
  - Size of packet in bytes, including header and data
  - **Maximum packet size of 65,536 bytes**
- ID
  - Used to re-assemble packet if it is fragmented by intermediate routers (since datalink layer has maximum frame size, fragmentation may be required)
  - All fragments will have the same ID
- Flags
  - Indicates whether packet may be further fragmented, and whether it has in fact been fragmented
- Fragment offset
  - Location of packet with respect to TCP datagram



IP Header fields

- Time to live (TTL)
  - Each router subtracts 1 from the field when a packet passes through it
  - Packet is destroyed if TTL = 0
  - Helps clear stale packets from the network
- Protocol: defines transport layer technology
- Header checksum with **CRC-16 calculated over header** only
- **Source address, destination address: 32 bits IP address** (IPv4)
- Options for routing, padding can be added after that

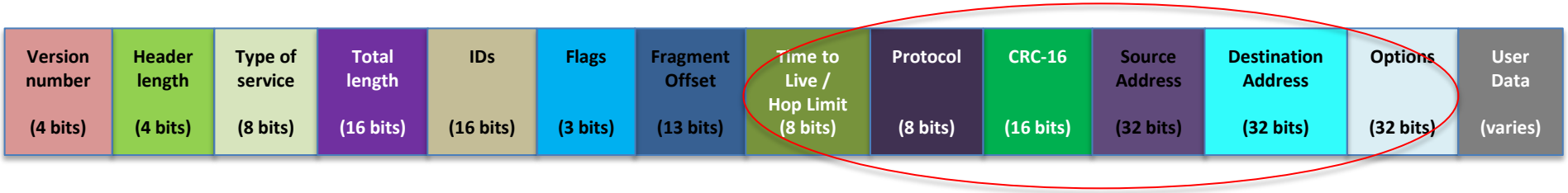
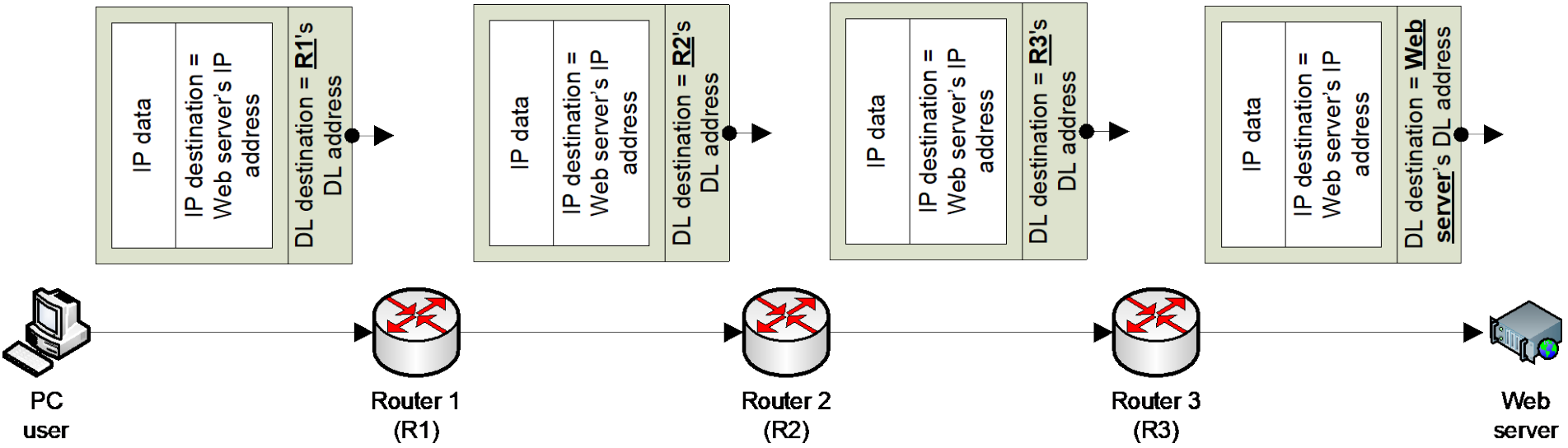


Figure modified from Agrawal

Why Need Addressing at Network and Link Layers?



- Data Link(DL) Layer address is addressing over a link ➔ Changes every link (every hop)
  - Source address is address of device transmitting over a link
  - Destination address is the address of the device receiving at end of a link

- IP (network layer) addressing is end-to-end
  - IP destination address is that of the final destination
  - May not change throughout routing path

Internet (IP) Addresses

- **IP addresses** are **assigned by network administrators**
  - Provides flexibility in addressing

- The current addresses consist of **32 bit binary** numbers (IPv4)
  - Theoretically up to 2^{32} = 4.29 billion addresses
  - IPV6 expands the address space

IP Addresses

- Binary numbers are hard to remember→use decimal equivalents
- IP addresses are written in **dotted decimal notation**
  - 32 bit addresses broken into 4 numbers, each of 8 bits
  - Each block converted to decimal representation
  - Decimals are separated by dots

  - **E.g. 136.142.185.57**
    - **Decimal to Binary**
      - **10001000 10001110 10111001 00111001**

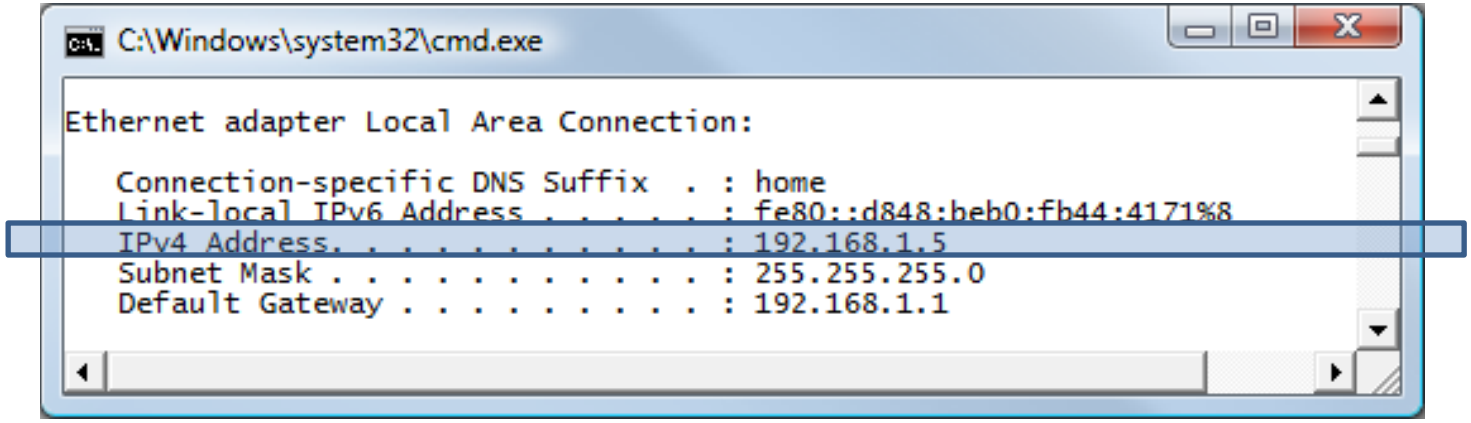
IP Addresses (dotted decimal notation)

- Examples

Recall Decimal to binary video link on Canvas.

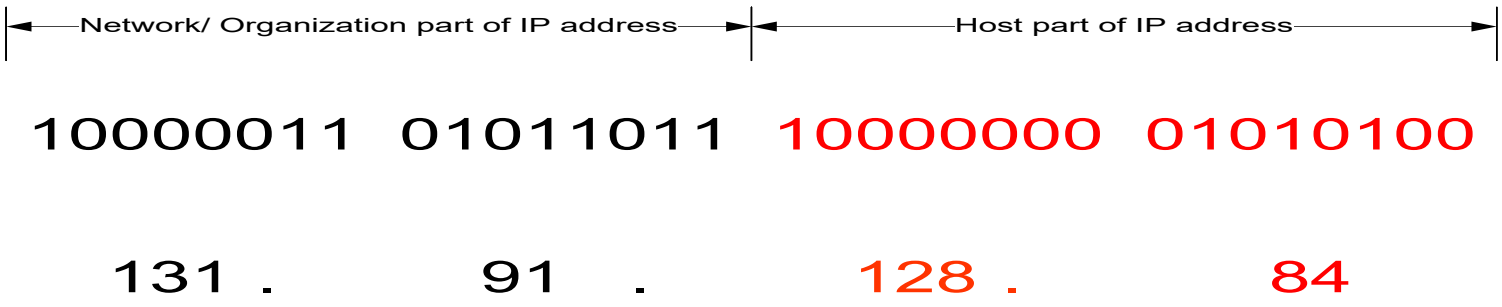
11000000 10101000 00000001 00000101

192 . 168 . 1 5



IP Addresses – 2 Part Structure

- IP address has **network part** and **host part**
- **Network part:** The first few bits **define organization** to which the address belongs
- **Host part:** Remaining bits are unique to the **computer (host) within the organization**
  - Host part is generally broken further into subnets (discussed later)



Florida Atlantic University Network ID

Internet (IP) Addresses

- When an organization connects to the Internet, it obtains a set of IP addresses for its computers
  - Internet Assigned Numbers Authority (IANA) manages IP addresses at top level
    - IANA is part of ICANN (Internet Corporation for Assigned Names and Numbers)
  - **IANA** distribute pool of addresses to **registries** in counties
  - **ISPs get IP addresses from registries**
  - **Organizations/users get IP addresses from ISP**

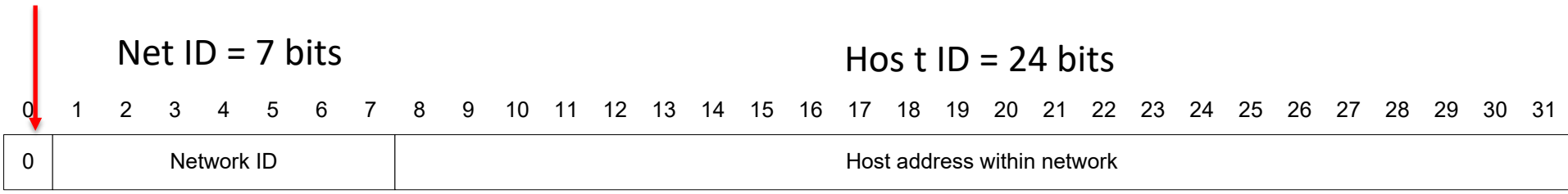
ICANN: The Internet Corporation for Assigned Names and Numbers

IP Address Classes (Old Technique)

- **Addresses are allocated in blocks (chunks)**
- **Defined 3 address classes**
  - Allowed **three possible network sizes**
- An organization could request from ISP an **address block** depending on its needs
  - **Class A** for the largest organizations
    - Need to support huge number of devices (hosts)
  - **Class B** for organizations like Universities
  - **Class C** for small businesses

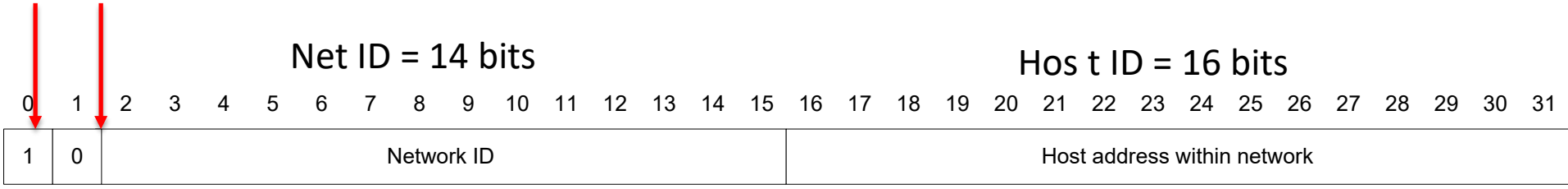
Address Classes

First bit is always ‘0’ for class A



Class A addresses

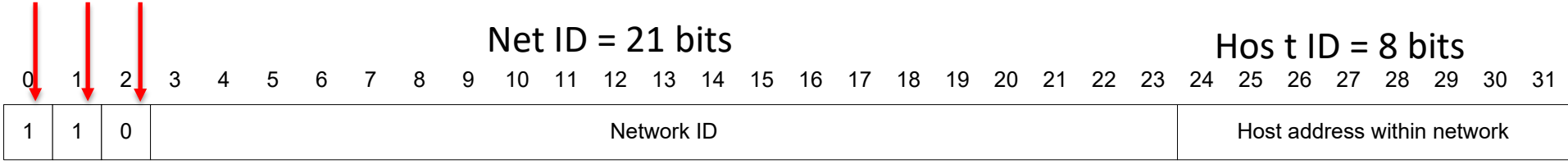
First two bits are ‘1 0’ for class B



65k hosts

Class B addresses

First three bits are ‘1 1 0’ for class C



256 hosts

Class C addresses

CIDR: **Classless Inter-Domain Routing**

- What if you need 2000 addresses in your organization
  - Get 8 blocks of class C (complex to handle) or one class B (waste addresses)
  - Ideally how many bits do we need?
- **CIDR: Stands for Classless Inter-Domain Routing**
  - **Eliminates address classes**
  - CIDR aims to solve unavailability of address **blocks of reasonable size**
  - Defined in RFC 1519

CIDR

- With CIDR
  - **Choose any number of bit for the network part** of the **IP** address block

- If we need 2000 addresses,
  - we want IP address with 11 bits in host ID part (2^{11}=2048)
  - Thus, the network ID part is 21 bits
    - 32 - 11=21 bits
      - » 32 is the **total length of IP**

CIDR Notation

- With CIDR, **a number along with the IP address to specify how many bits are in the network ID part**
  - The number denotes the number of bits in the network part of the address
  - E.g. 73.5.0.0/ 17
    - The number after the dash is the number of bits for network ID (17 bits)

CIDR Notation

- If an organization has CIDR address of: 73.5.0.0**/ 17**,

  Means that the network part of IP address is 17 bits, hence the host part is 32-17

  - First 17 bits of the address are the network part
  - Called a /17 network
  - The remaining 15 bits (32-17) identify the host
  - So, the network can have 2^{15} = 32,768 computers

Key takeaways

- IP frame format
  - Splits into parts to specify organization and host (i.e., device) in organization
- IP address classes
  - Fixed number of bits for each part of IP address
- CIDR: Classless Inter-Domain Routing
  - Any number of bits in net ID