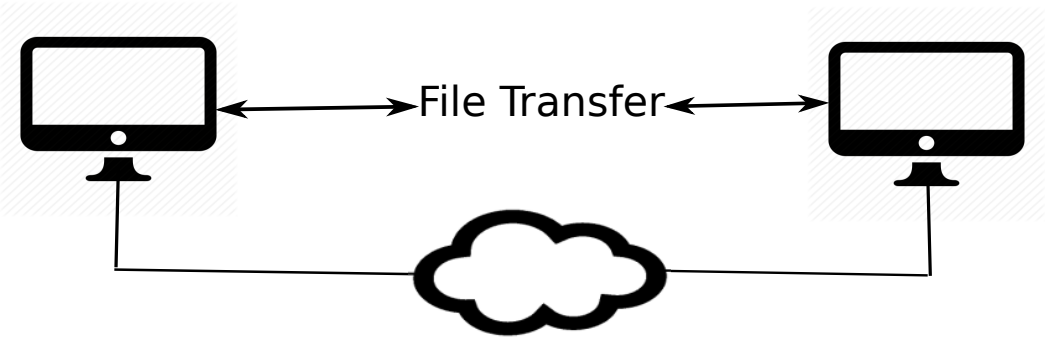
Overview of Computer Networking

Computer Networking

- A collection of interconnected computing devices that communicate with each other for specific goals, for example:
  - Transmit data, e.g., webpages, emails, messages, etc…
  - Distributed computations, e.g., cloud computing, sensor networks, banking, airline reservation, etc…

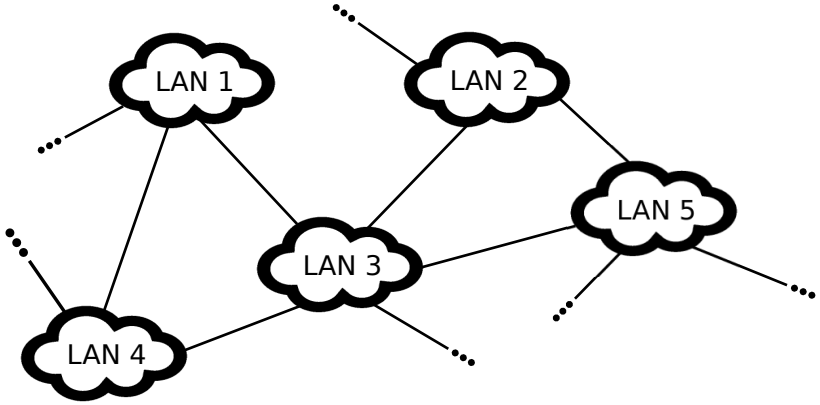


Local Area Networks (LANs)

- Physically connected devices that can communicate with each other “directly”
  - All computers in your home?
  - All computers in your office building? (Or floor? Or room?)
- Devices in a LAN use *physical addresses* (rather than *logical addresses*) to reach each other
- Natural size limit to LANs
  - *Will discuss reasons for Ethernet size limits later this semester*

Internet

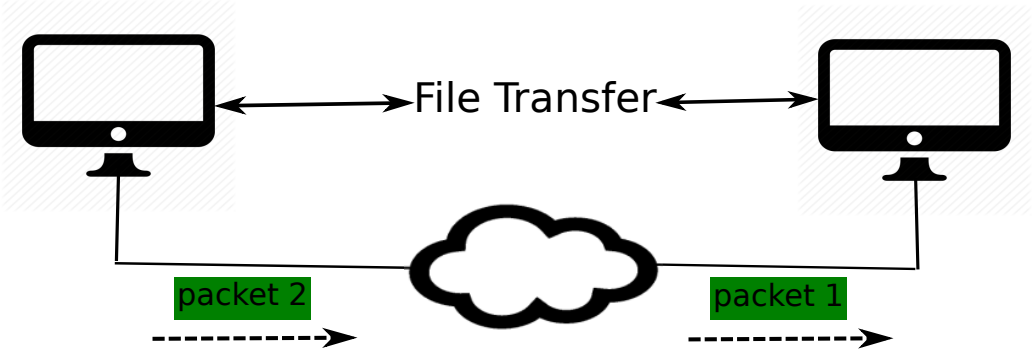
- An ***internet*** is a mesh of two or more interconnected LANs



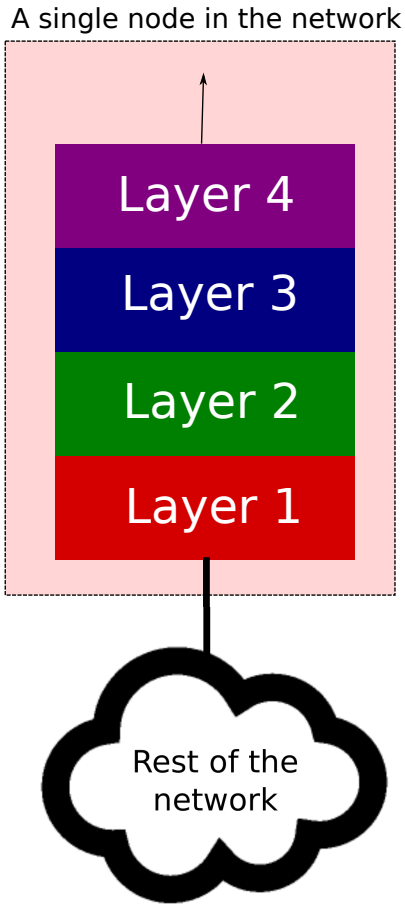
- ***The Internet*** is the global internet that connects all publicly reachable LANs together

Packets

- A ***packet*** is a collection of bits that a node sends to another node in the network, in a *single attempt*
- A packet may include different sorts of data
  - Part of a web page
  - Part of an email
  - A control message reporting an error in message delivery
  - A control message to manage the connection between the two ends

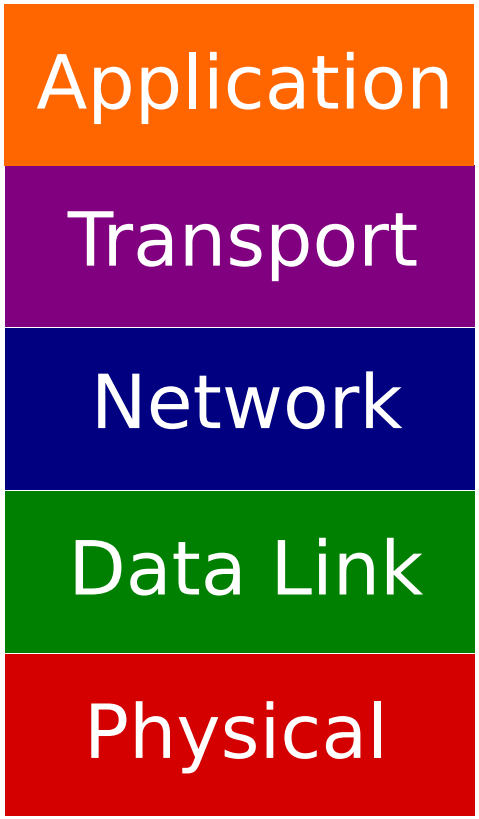


Layered Architecture



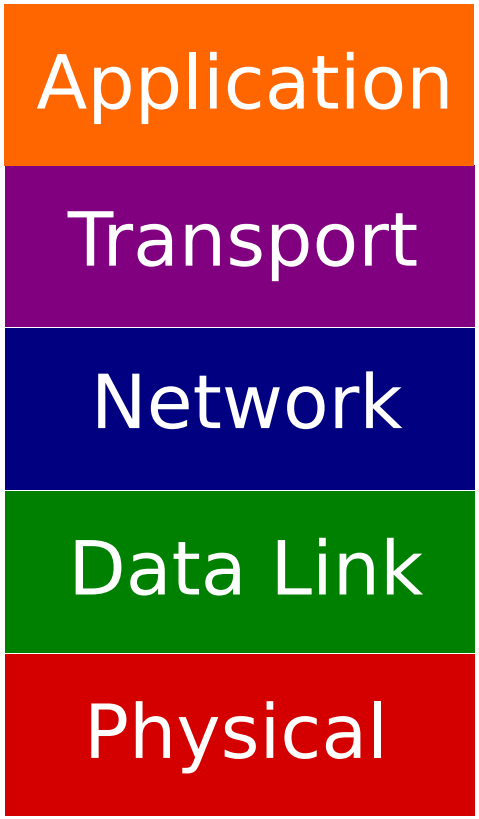
- Each node in the network consists of a *collection of services*. These services are designed in a *layered* fashion.
  - Layer x *provides service* to layer x + 1
  - Layer x *uses the service* provided by layer x – 1
  - Similar to code libraries that depend on each other

TCP/IP Layered Architecture



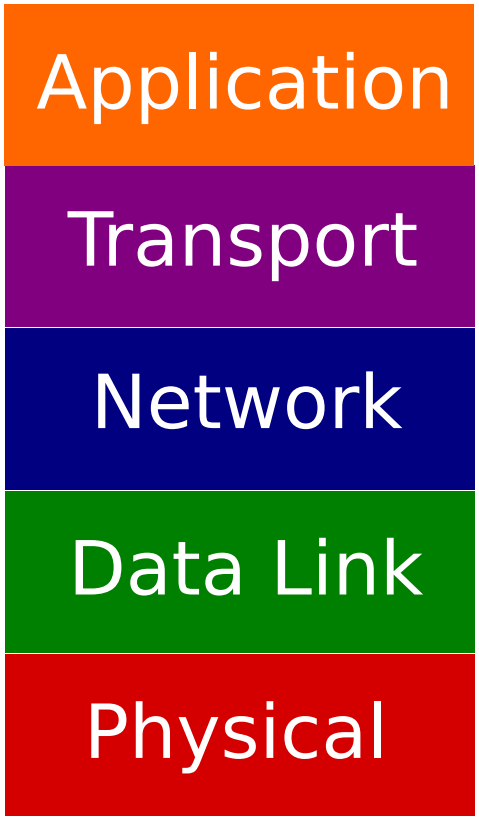
- The *de facto* layered architecture for the Internet is called the ***TCP/IP layered architecture***
- TCP/IP layered architecture consists of **five layers**
  - *Application layer* uses the services provided by the *transport layer*
  - *Transport layer* uses the services provided by *network layer*
  - …

TCP/IP Layered Architecture



- ***Application layer*** provides communication between two *instances of an application*
  - Web browser <-> pacific.edu web server
- ***Transport layer*** provides communication between two *processes* that belong to the application instances
  - Process of web browser <-> Process of server program
- ***Network layer*** provides communication between two *devices* over the network
  - Your PC <-> pacific.edu server machine

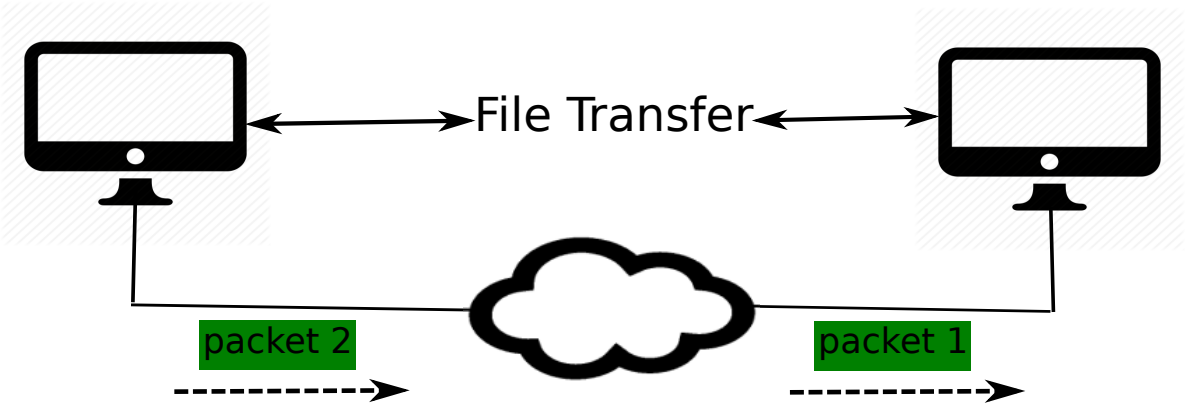
TCP/IP Layered Architecture



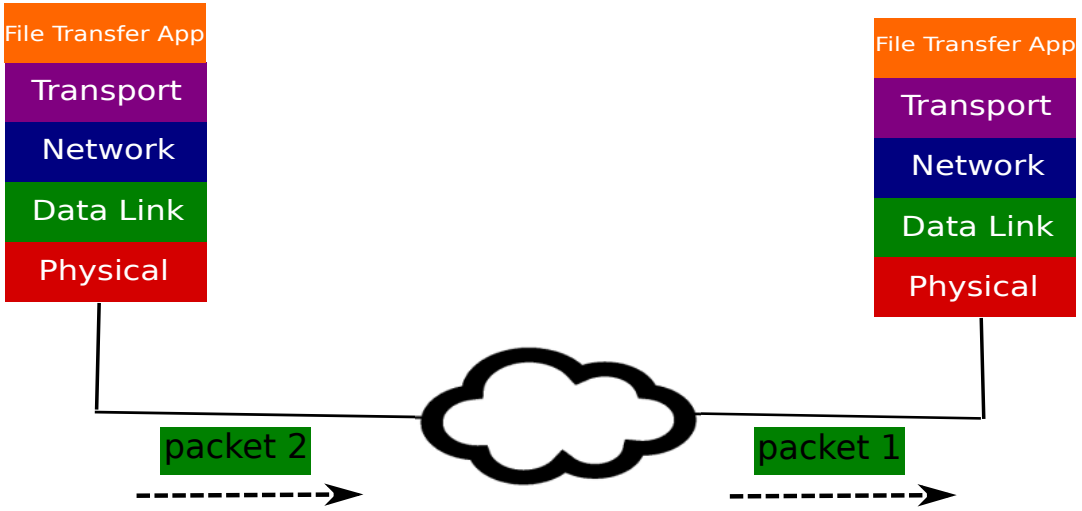
- ***Data link layer*** provides the communication between *two devices in the same LAN*
  - Your phone <-> your smart TV in your home wireless LAN
- ***Physical layer*** provides *bitwise* communication between *two physically connected devices* through the physical channel. Physical channel can be wired or wireless.
  - Your PC <-> wireless access point (AP) in a wireless network

TCP/IP Layered Architecture

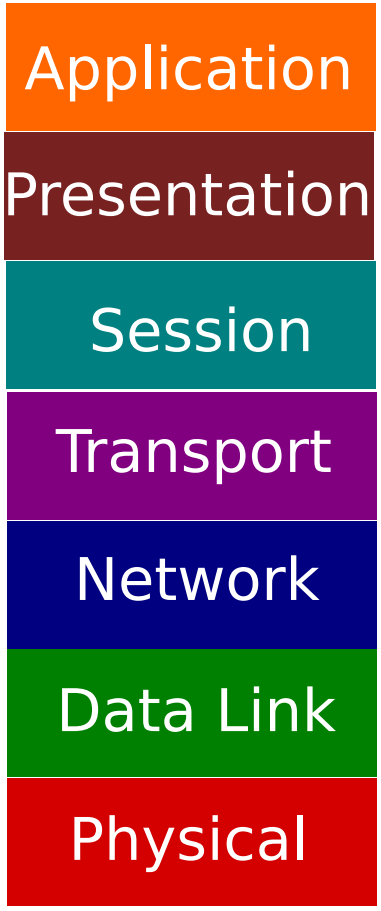
Application Programmer View:



Systems-Level View:

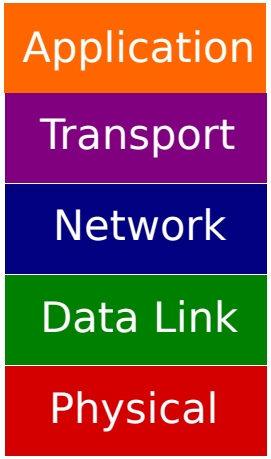


OSI Layered Architecture



- The layered architecture for the Internet is known as ISO/OSI layered architecture
  - ISO refers to *International Organization for Standards*
  - OSI refers to *Open Systems Interconnection* project at ISO.
- OSI layered architecture consists of seven layers
  - Two additional layers are *Presentation* and *Session* layers
- This model does not represent how systems are implemented today!
  - Presentation and session layer functionalities are embedded in application and transport layers in TCP/IP architecture

Network Devices: Hosts



- ***Hosts***, or *end systems*, comprise the full stack of TCP/IP layers
  - PCs, smart phones, servers, smart IoT devices, ...
- Hosts run applications over the network
- End users use hosts to communicate over the network
- Hosts are at the *edge* of the network, i.e., they do not interconnect networks.

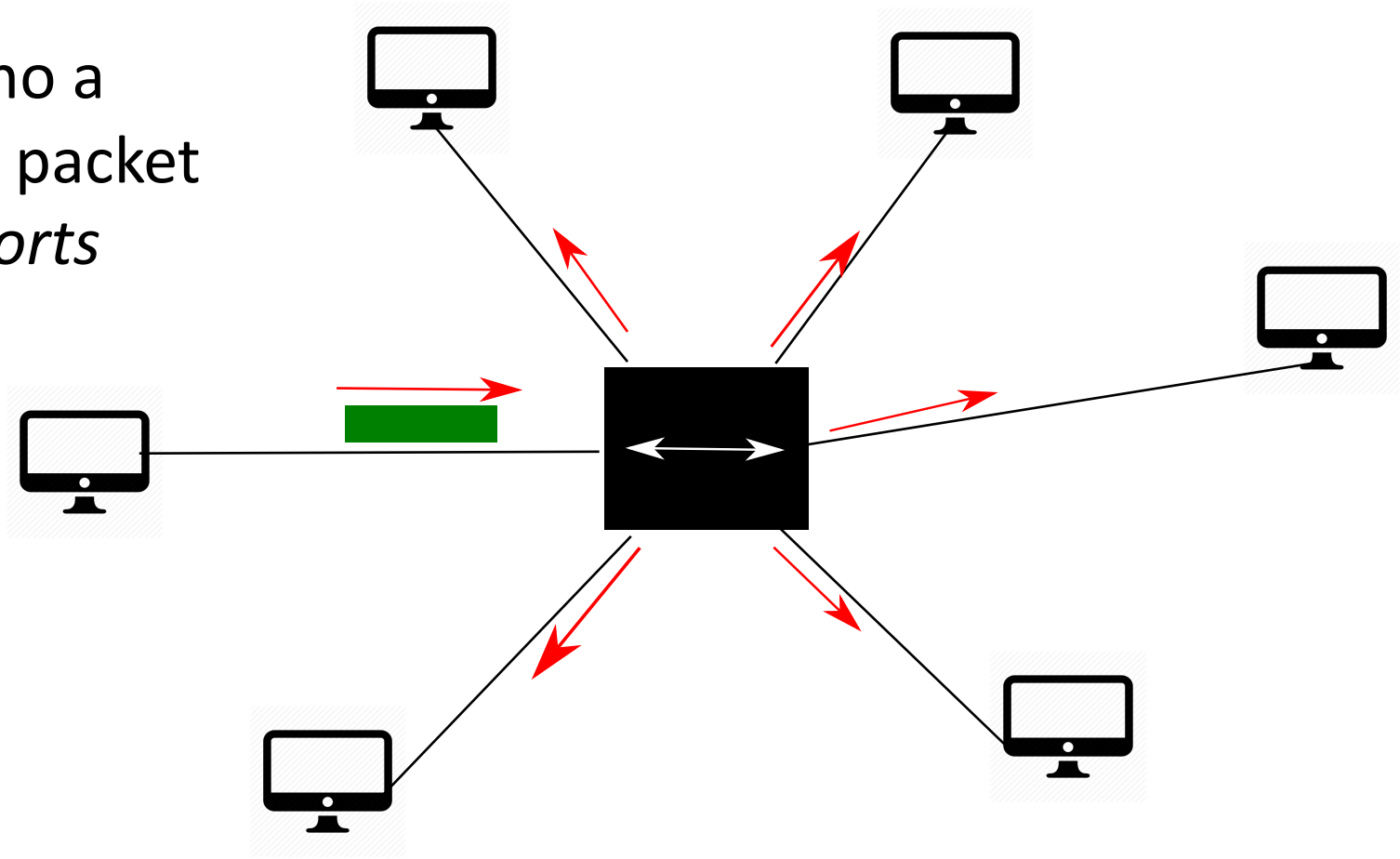
Network Devices: Hubs

Physical

- ***Hubs*** are used to physically interconnect multiple nodes within a LAN
- Hubs have only physical layer
- They emit a received bit on all interfaces
- Replaced by switches in modern LAN topologies

Network Devices: Hubs

Hubs echo a received packet out *all ports*



Network Devices: Switches

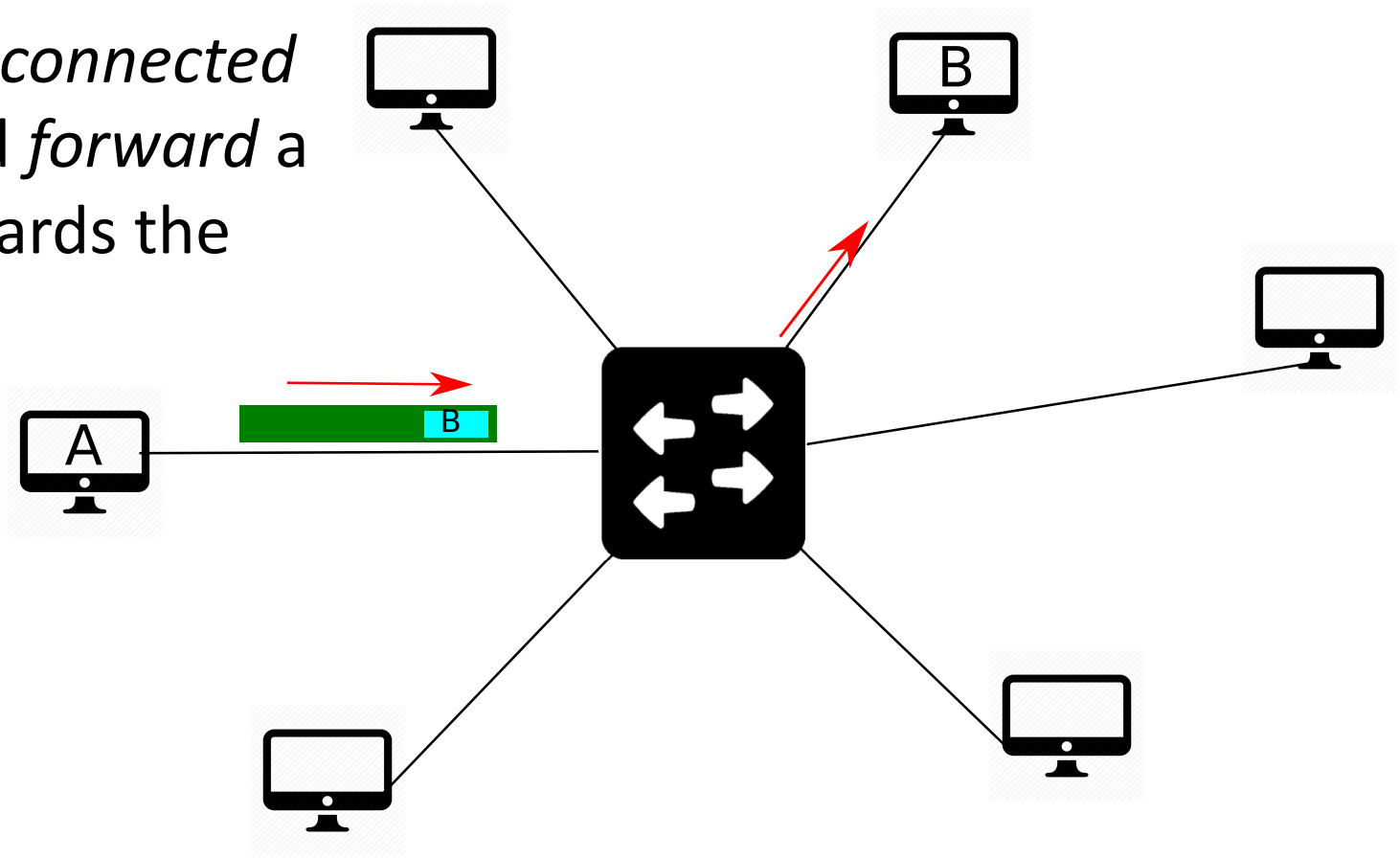
Data Link

Physical

- ***Switches*** are used to physically interconnect multiple nodes within a LAN, similar to hubs
- Switches have physical layer and data link layer
  - Packets include the physical addresses of both the sender and the recipient that resides in the LAN
  - Switches use these addresses to *learn the location of devices in the LAN* and send the received packet to that recipient

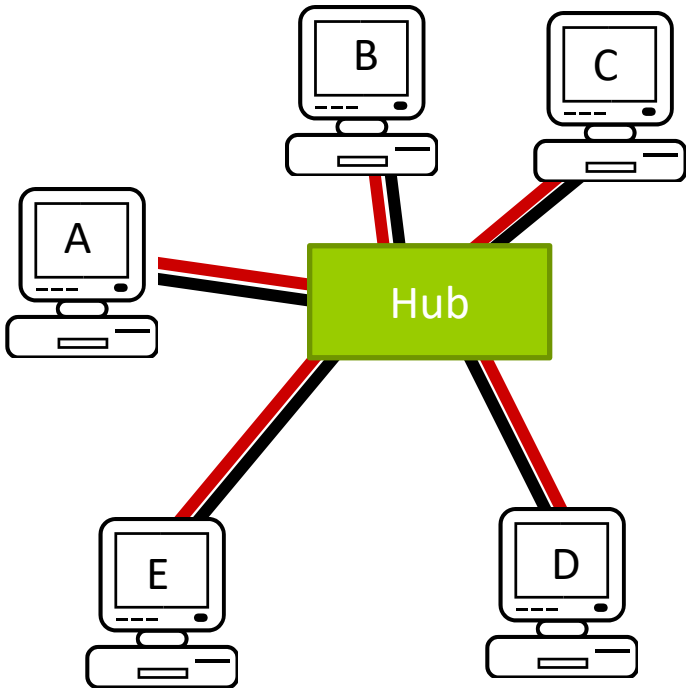
Network Devices: Switches

Switches *learn the location of connected devices* and *forward* a packet towards the destination



Ethernet Hub vs Switch

Ethernet Hub

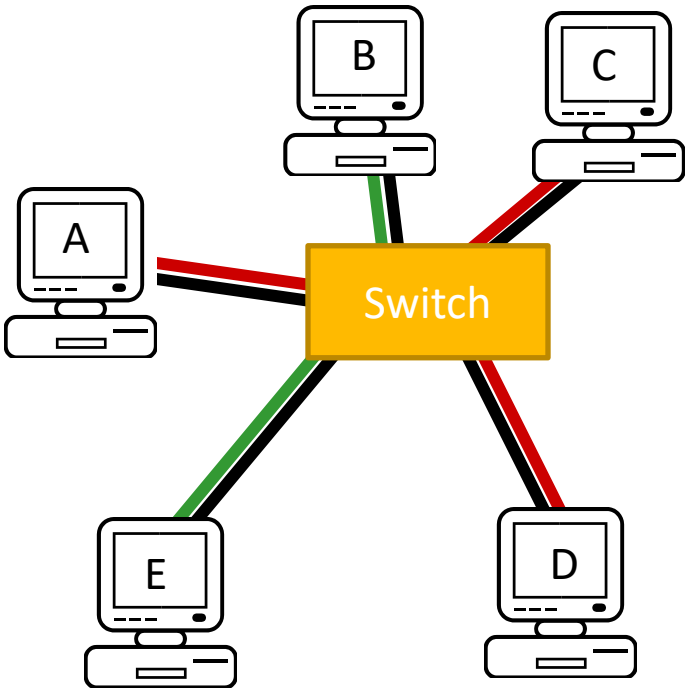


A transmits to D

D replies to A

Ethernet Switch

(assume learning already occurred)



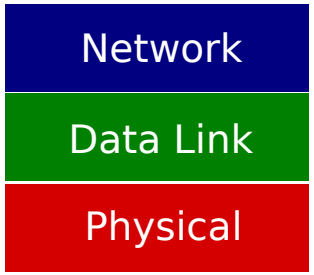
A transmits to D

D replies to A

E transmits to B, and

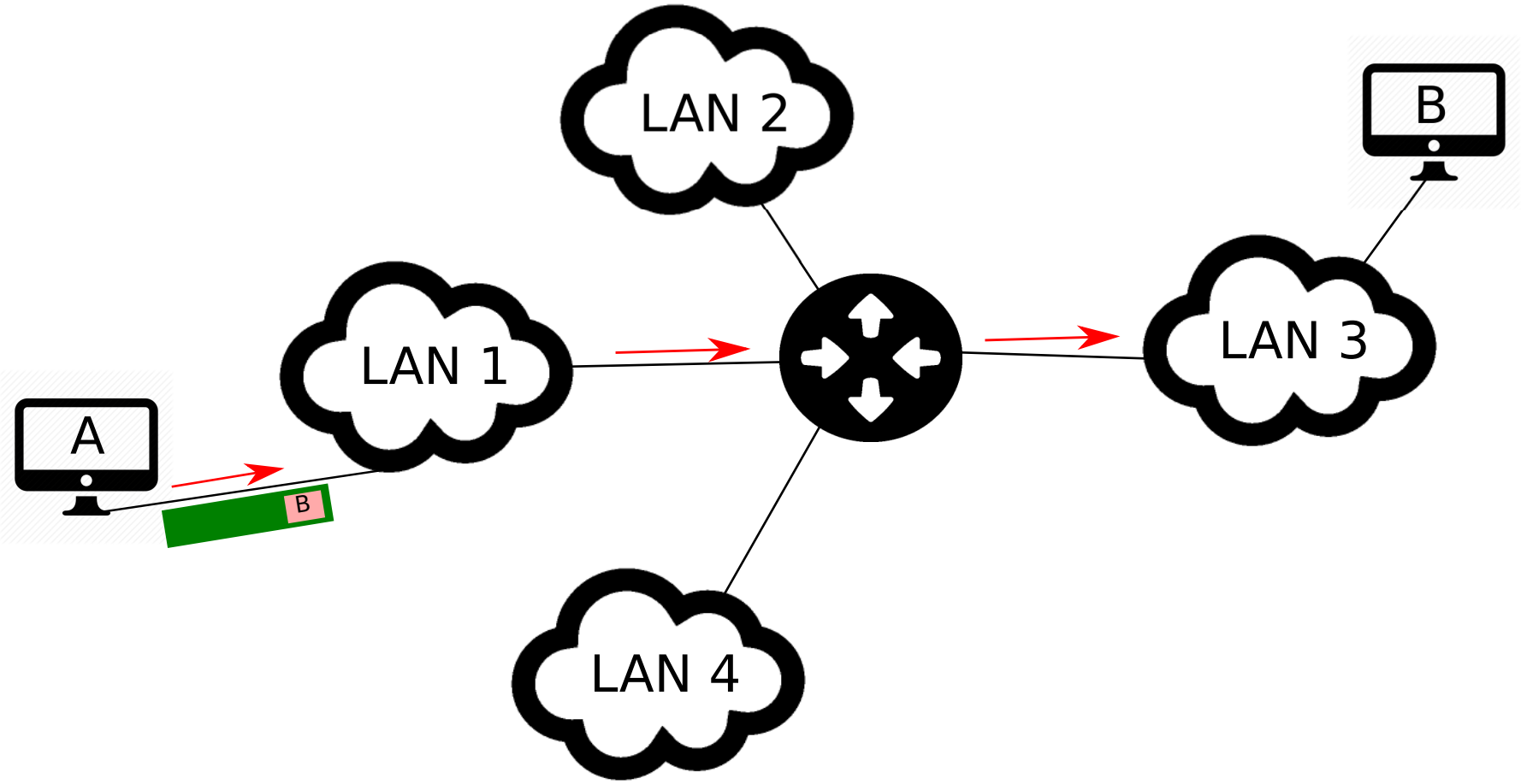
A to C

Network Devices: Routers



- ***Routers*** are used to interconnect multiple LANs to each other
- Routers have physical, data link and network layers
  - The network layer allows identifying networks *outside* of a single LAN
  - Packets include the logical address of the recipient that resides in a potentially remote LAN
  - Routers use this address to forward the received packet toward the recipient

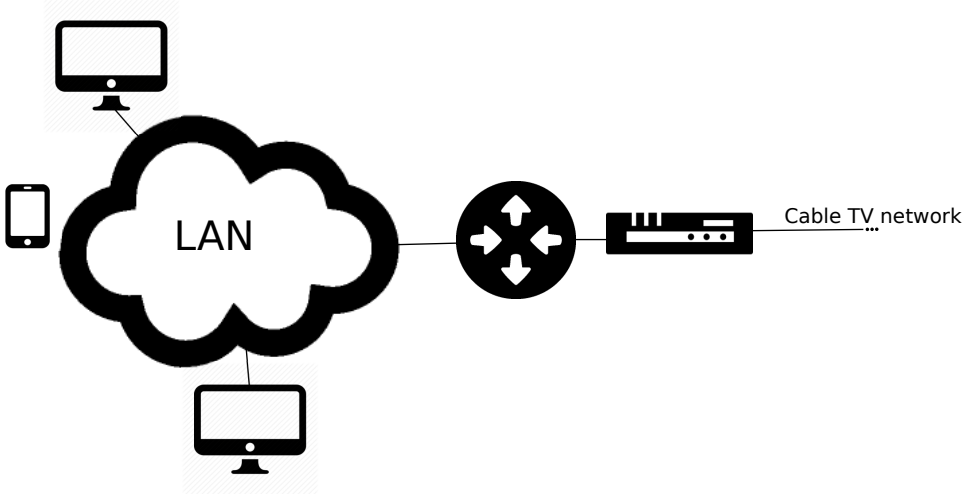
Network Devices: Routers



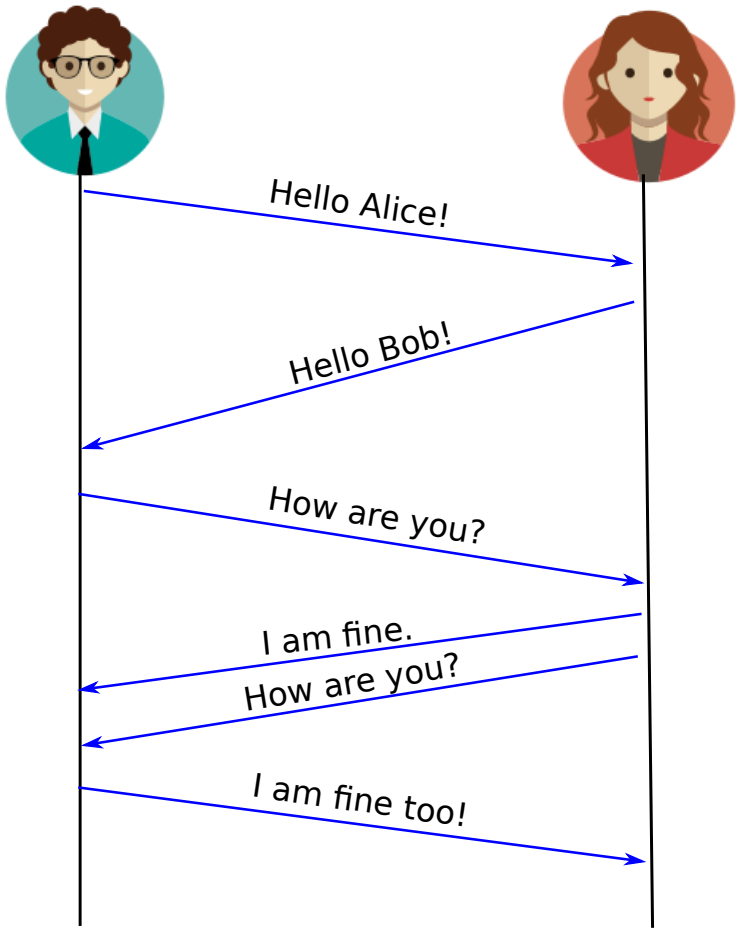
Network Devices: Modems

Physical

- ***Modems*** are used to modulate signals to encode digital information
  - Modems encode and decode signals to interpret the transmitted data in analog and digital formats
  - Since modems work in signal level, they only have physical layer



Protocols



- A protocol is a set of guidelines according to which two entities communicate

Network Protocols

- A *networking protocol* is a set of guidelines according to which two devices communicate with each other through the network
- Examples
  - Data link layer: Ethernet, Wi-Fi, ARP, ...
  - Network layer: IP, ICMP, ...
  - Transport layer: TCP, UDP
  - Application layer: HTTP, SMTP, FTP, DNS, ...

Network Protocols

- Protocols need to be standardized for interoperability
- Two major sources for networking protocol specifications:
  - **"Request For Comments"** documents (**RFCs**) administered by Internet Engineering Task Force (IETF)
    - Freely available at ietf.org
    - Examples: TCP, UDP, IP, HTTP
  - Institute of Electrical and Electronics Engineers (**IEEE**) standards
    - Accessible to members ($$)
    - Examples: 802.3 (Ethernet), 802.11 (WiFi)

Protocol Packets

- Each protocol defines the structure (syntax) of the packets that need to be communicated
- Different protocols have different packet structure
- Generally, a packet may consist of the following components:
  - Packet header
  - Packet body (payload)
  - Packet trailer

Protocol Packets

- In the literature, specific terms may refer to a protocol packet
  - TCP *segment*
  - UDP *datagram*
  - IP *datagram*
  - Ethernet *frame*
  - For application layer protocols, a packet is sometimes called *message*: HTTP message, etc.

Packets in *(Generic)* Layered Structure

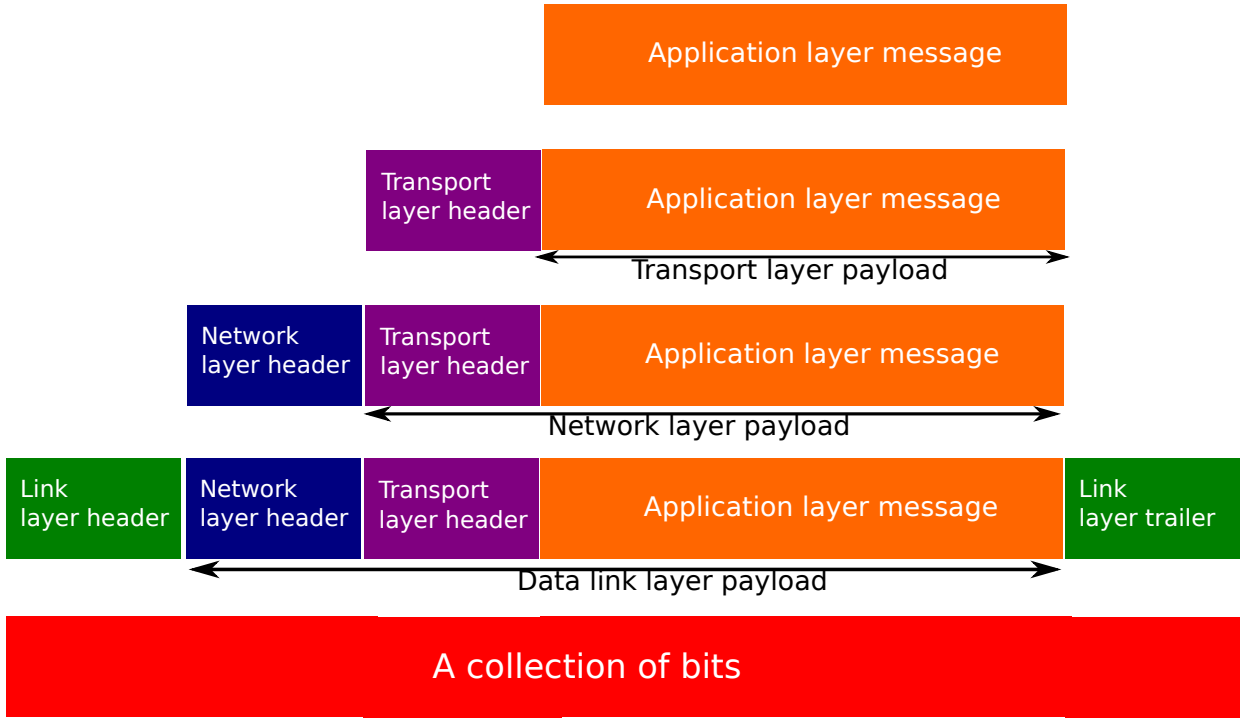
Application

Transport

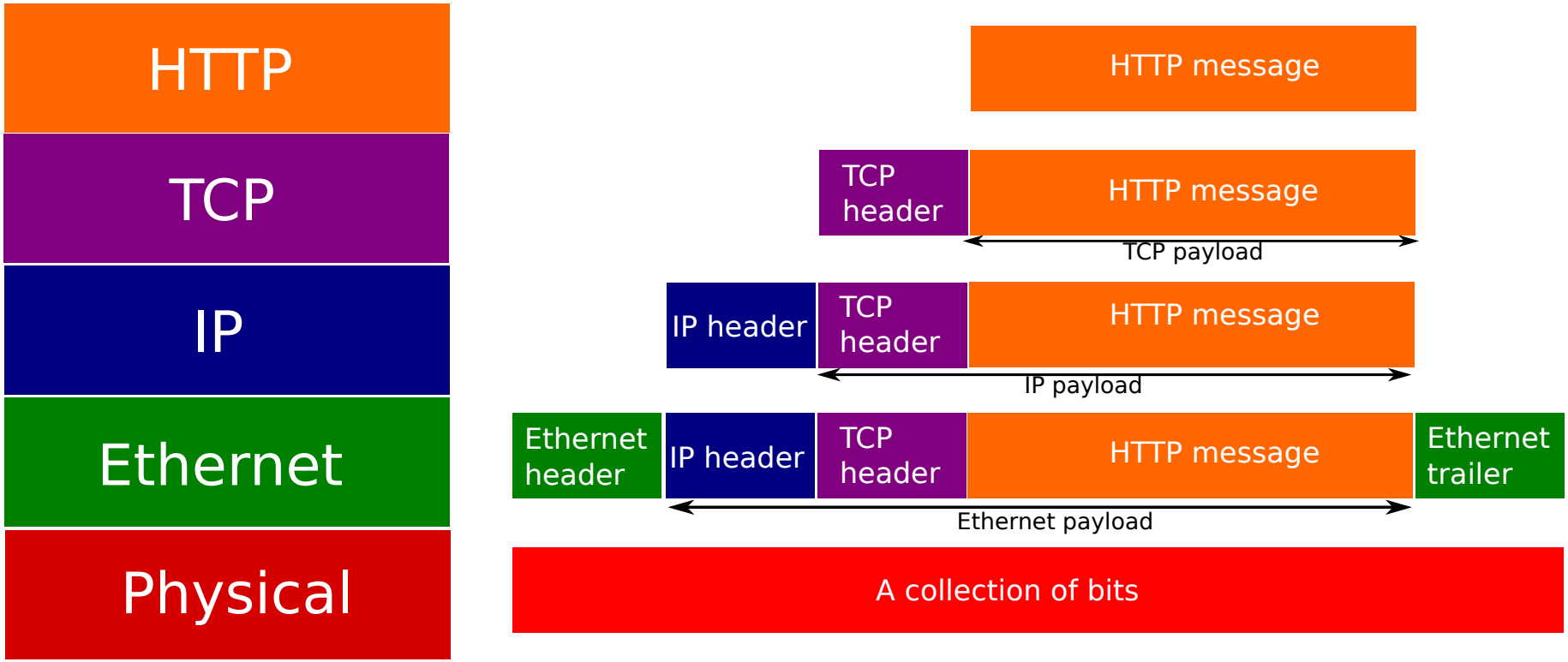
Network

Data Link

Physical



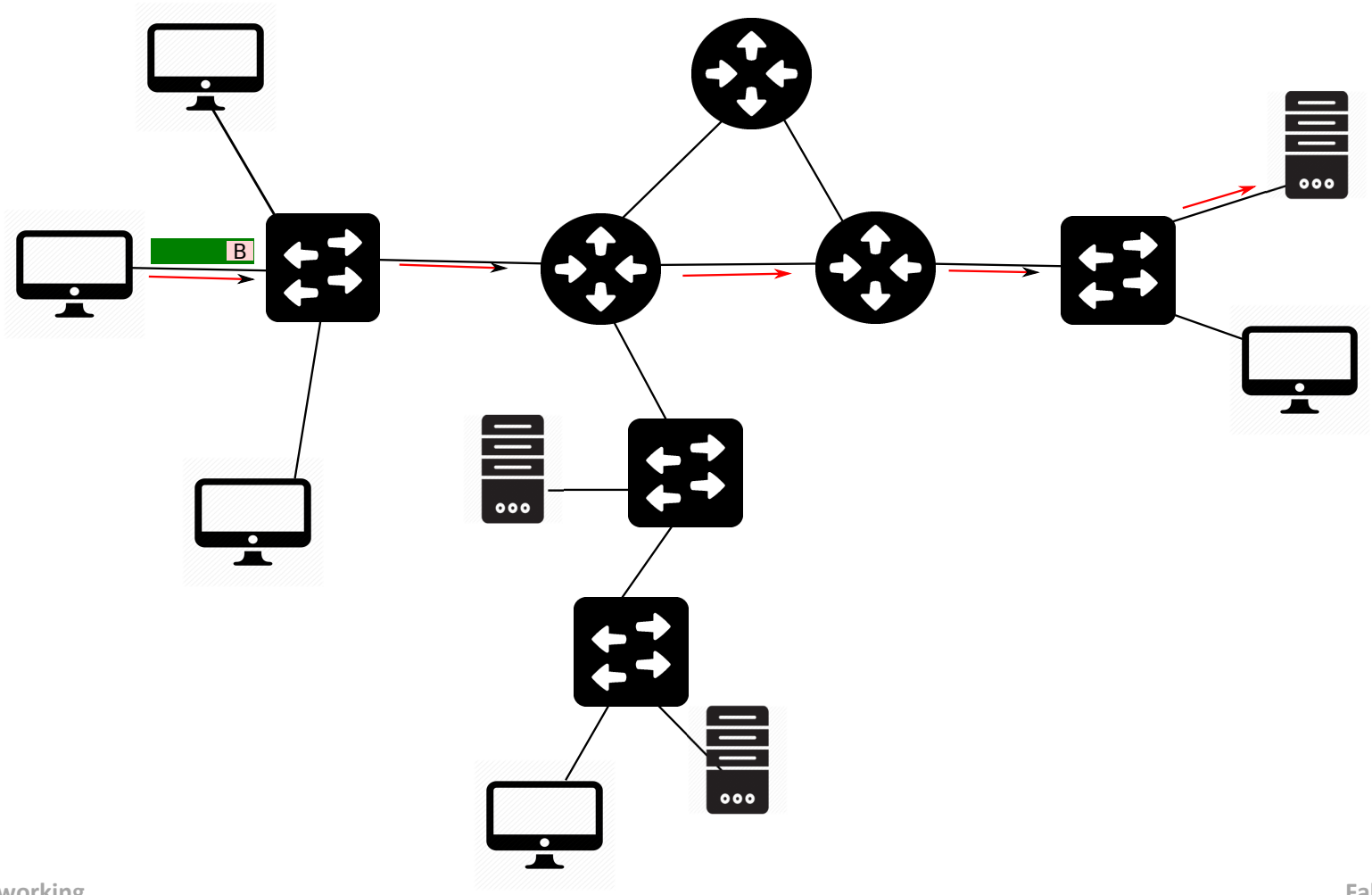
Packets in a *Sample* Stack of Protocols



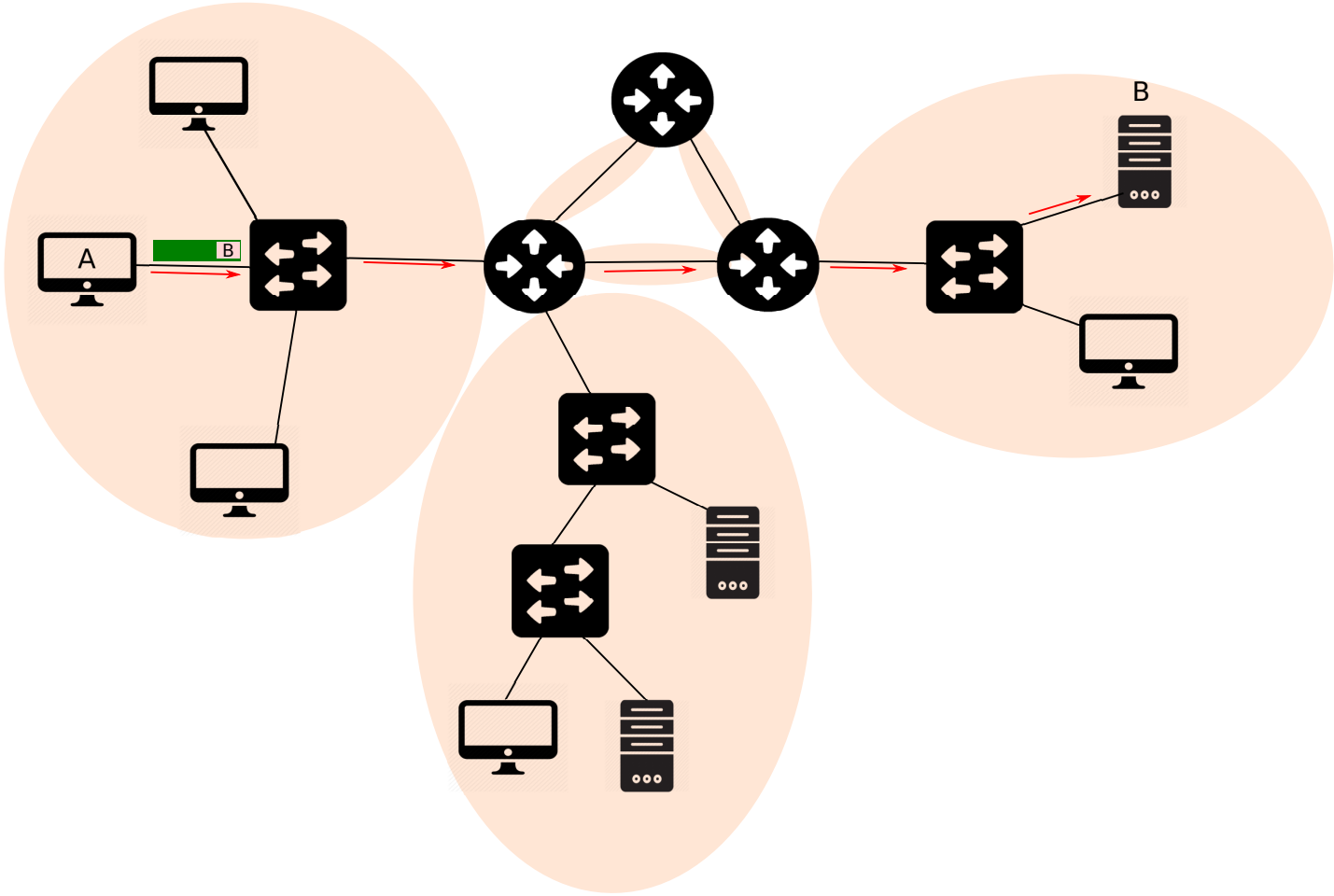
The payload that the user cares about!

(Not to scale…)

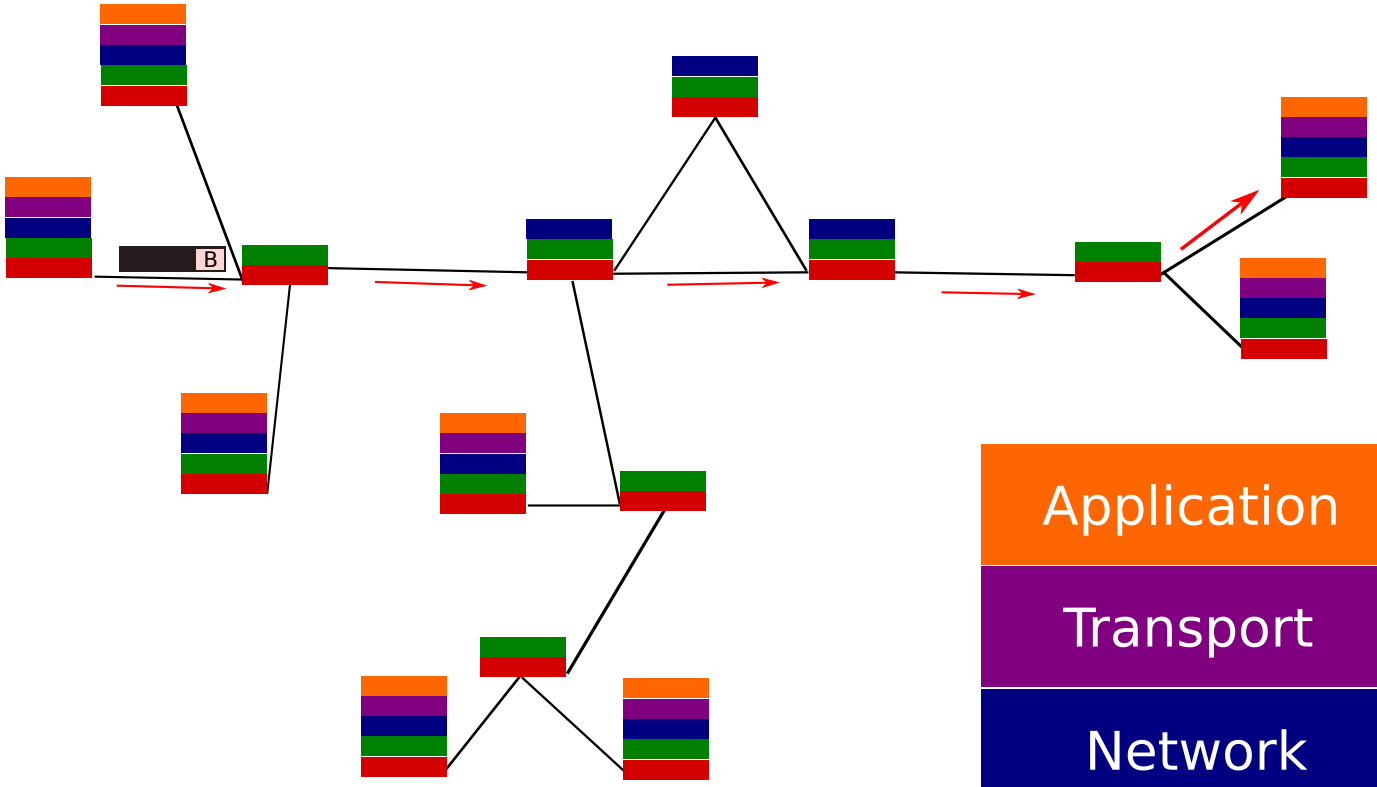
Example: An internet!



Identifying LANs in Internet



Layered View of Internet



Wrapup

Recap

- We introduced preliminary concepts in networking:
  - LANs, internet, packets
  - TCP/IP and OSI layered architectures
  - Networking devices: hosts, hubs, switches, routers, and modems
  - Networking protocols and packet structure in layered model

Next Class

- Introduce packet sniffing and Wireshark
- **Class Activity 1** – Introducing Wireshark