



Computer Systems and Networks

ECPE 170 – Jeff Shafer – University of the Pacific

Networking Fundamentals

Lab Schedule

Activities

- **Today**
 - Network programming
 - **Lab 8 – Network Programming**
- **Next Week**
 - **Lab 8 – Network Programming**

Assignments Due

- **Lab 8**
 - **Due by Mar 30th 5:00am**
- **Lab 9**
 - **Due by Apr 6th 5:00am**

Persons of the Day: Vint Cerf / Bob Kahn



- Co-designers of TCP/IP protocol suite
 - Enables reliable communication across unreliable network
 - **Foundation of Internet**
- 2004 *ACM Turing Award* winners (shared)
- 2005 *Presidential Medal of Freedom* winners (shared)

Person of the Day: Tim Berners-Lee



- Inventor of “World Wide Web”
- First implementation of **HTTP** (HyperText Transfer Protocol) to communicate between client and server
- Knighted by Queen Elizabeth II in 2004

Computer Networks



Disclaimer

- **These topics take an entire semester of COMP 177 (Computer Networking) to explore!**
- A few days (*most of which is lab time*) is only sufficient for the briefest of overviews...

Network Model

Application Layer

(Myriad examples: Web browser, web server, etc...)

Transport Layer

(Reliability – e.g. TCP)

Network Layer

(Global Network – e.g. IP)

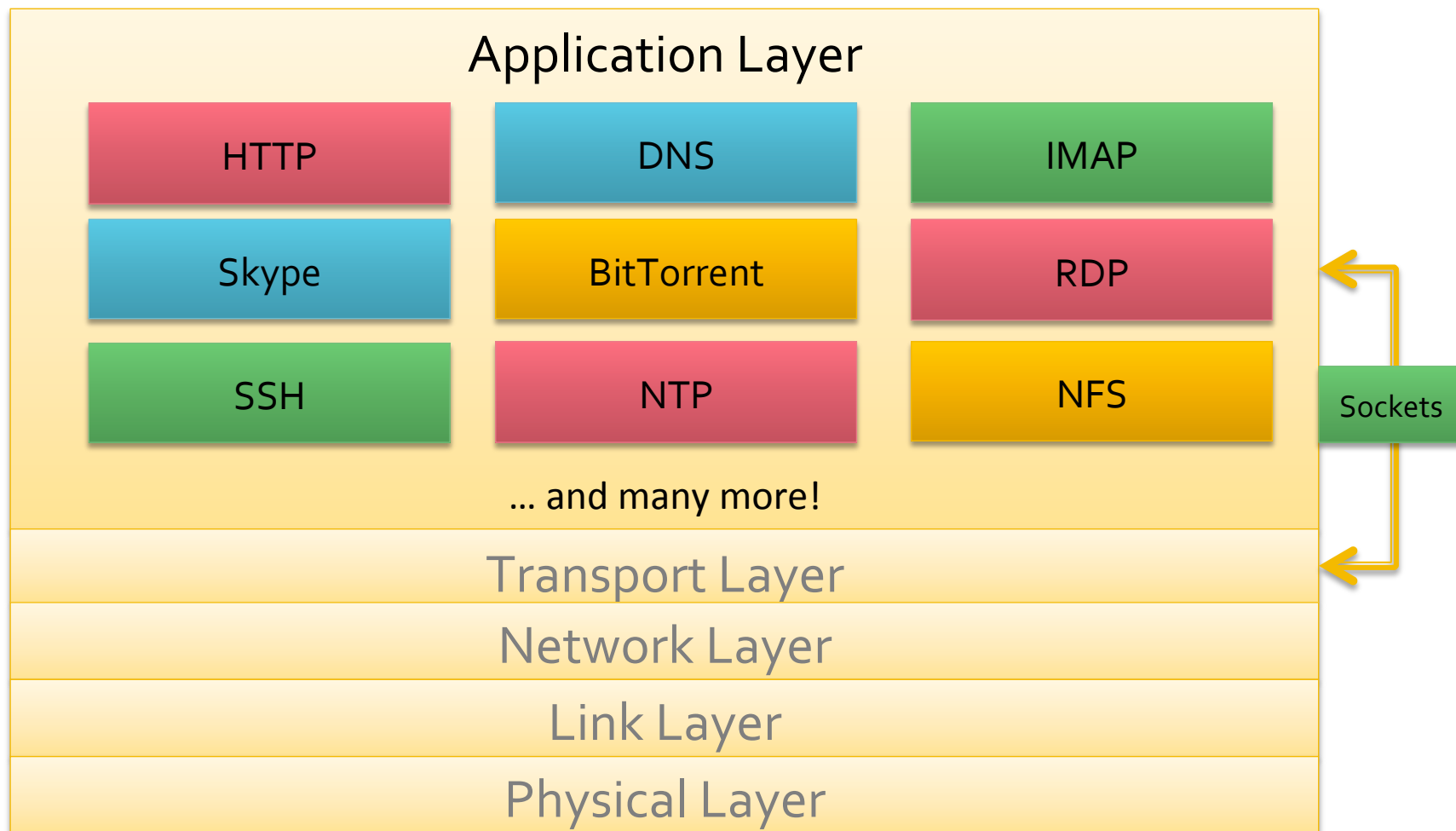
Link Layer

(Local Area Network – e.g. Ethernet)

Physical Layer

(“Bit on a Wire”)

Application Layer



Application Layer

- The **application layer** programmer can make many (fantastic) assumptions about the network
 - The network is reliable
 - Messages are not lost
 - Messages are received in the order they are sent
 - The network can transfer data of infinite length (you can send as much data as desired)
 - You can deliver messages directly to a specific application on a specific computer anywhere on the planet

- The lower layers (transport, network, link, ...) do all the heavy-lifting to make these assumptions true

Client-Server Architecture

Server

- Always-on host
- Always has a known IP address
- Lots of bandwidth
- **Server process:** process that waits to be contacted

Client

- Communicate with server
- May be intermittently connected
- May have dynamic IP addresses
- Do not communicate directly with each other
- **Client process:** process that initiates communication

Why Do We Have Sockets?

- Challenge – **Inter-process communication**
- A **process** is an independent program running on a host
 - Separate memory space
- How do processes communicate with other processes
 - On the same host?
 - On different hosts?
- Send **messages** between each other

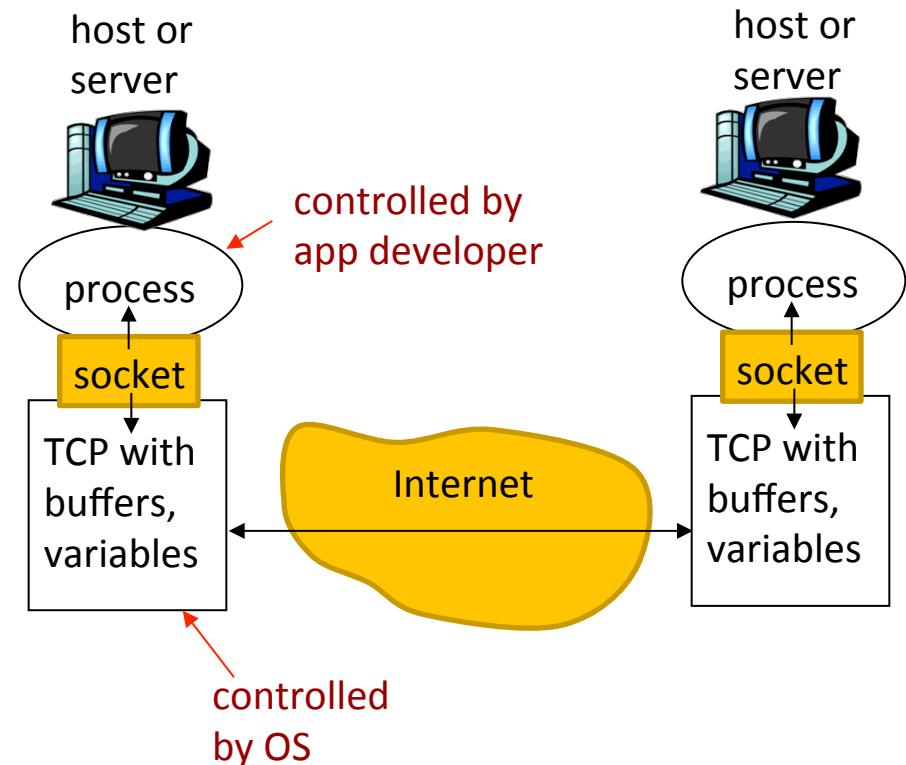
What is a Socket?

- An interface between process (application) and network
 - The application creates a socket
 - The socket *type* dictates the style of communication
 - Reliable vs. best effort
 - Connection-oriented vs. connectionless

- Once configured the application can
 - Pass data to the socket for network transmission
 - Receive data from the socket (transmitted through the network by some other host)

What is a Socket?

- Process sends/receives messages to/from its socket
- Socket analogous to door
 - Sending process shoves message out door
 - Transport infrastructure on other side of door carries message to socket at receiving process
 - **Imagine you are just writing to a file...**
- API allow customization of socket
 - Choose transport protocol
 - Choose parameters of protocol

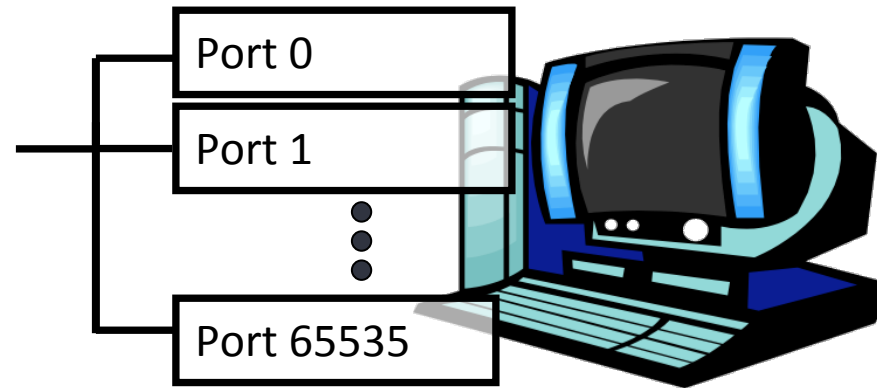


Addressing Processes

- To receive messages, each process on a host must have an **identifier**
 - IP addresses are unique
 - **Is this sufficient?**
- No, there can thousands of processes running on a single machine (with one IP address)
- Identifier must include
 - IP address
 - **and** port number (example: 80 for web)

Ports

- Each host has 65,536 ports
- Some ports are *reserved for specific apps*
 - FTP (20, 21), Telnet (23), HTTP (80), etc...
- Outgoing ports (on clients) can be dynamically assigned by OS in upper region (above 49,152) – called **ephemeral ports**
- See http://en.wikipedia.org/wiki/List_of_TCP_and_UDP_port_numbers



Socket Usage: Client Program

- Basic socket functions for **connection-oriented (TCP) clients**
- 1. **socket ()** create the socket descriptor
- 2. **connect ()** connect to the remote server
- 3. **send () , recv ()** communicate with the server
- 4. **close ()** end communication by closing socket descriptor

Application-Layer Protocol

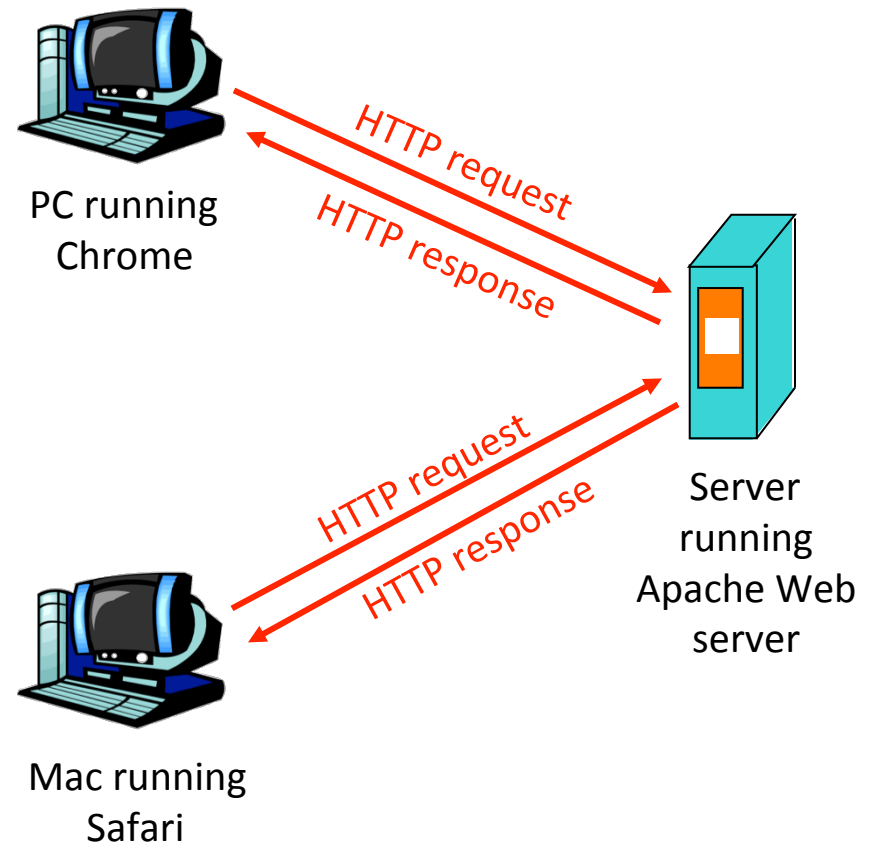
- Sockets just allow us to send raw messages between processes on different hosts
 - Transport service takes care of moving the data
- **What** exactly is sent is up to the application
 - An **application-layer** protocol
 - HTTP, NTP, IMAP, SFTP, Skype, etc...

Application-Layer Protocol

- Both the client and server speaking the protocol must agree on
 - **Types of messages exchanged**
 - e.g., request, response
 - **Message syntax**
 - What fields are in messages
 - How fields are delineated
 - **Message semantics**
 - Meaning of information in fields
 - Rules for **when** and **how** processes send and respond to messages

Hypertext Transfer Protocol Overview

- **HTTP** is the *application layer protocol* for the web
- It is how the client and server communicate
- Client/server model
 - **Client:** browser that requests, receives, “displays” Web objects
 - **Server:** Web server sends objects in response to requests



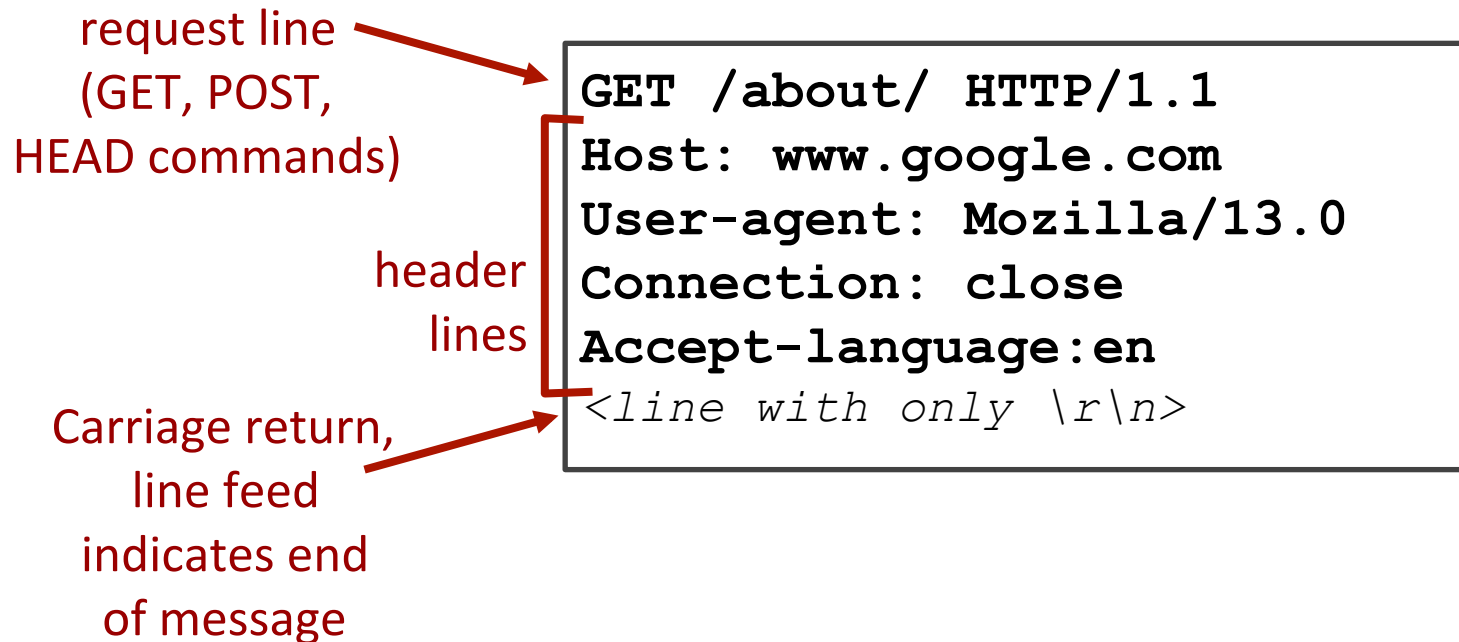
Web and HTTP

- Web **page** consists of base HTML file and (potentially) many referenced **objects**
 - HTML file, PNG image, Flash video, ...
- Each object is addressable by a **URL**
- Example URL:

`www.somecompany.com/someDept/image.png`

host name path name

HTTP Request Message (Client->Server)



HTTP is a text-based protocol. The client sends ASCII bytes in the request, and the server responds with ASCII bytes in the reply.

HTTP Response Message (Server -> Client)

status line
(protocol
status code,
status phrase)

header
lines

data, e.g.,
requested
HTML file

```
HTTP/1.1 200 OK
Vary: Accept-Encoding
Content-Type: text/html
Last-Modified: Tue, 10 Apr 2012 09:33:47
Date: Tue, 10 Apr 2012 17:50:51 GMT
Expires: Tue, 10 Apr 2012 17:50:51 GMT
Cache-Control: private, max-age=0
X-Content-Type-Options: nosniff
Server: sffe
X-XSS-Protection: 1; mode=block
Transfer-Encoding: chunked
<line with only \r\n>
<Data begins here...>
```

HTTP Response Status Codes

*A few
examples
out of
many!*

200 OK

➤ Request succeeded, requested object later in this message

301 Moved Permanently

➤ Requested object moved, new location specified later in this message (Location:)

400 Bad Request

➤ Request message not understood by server

404 Not Found

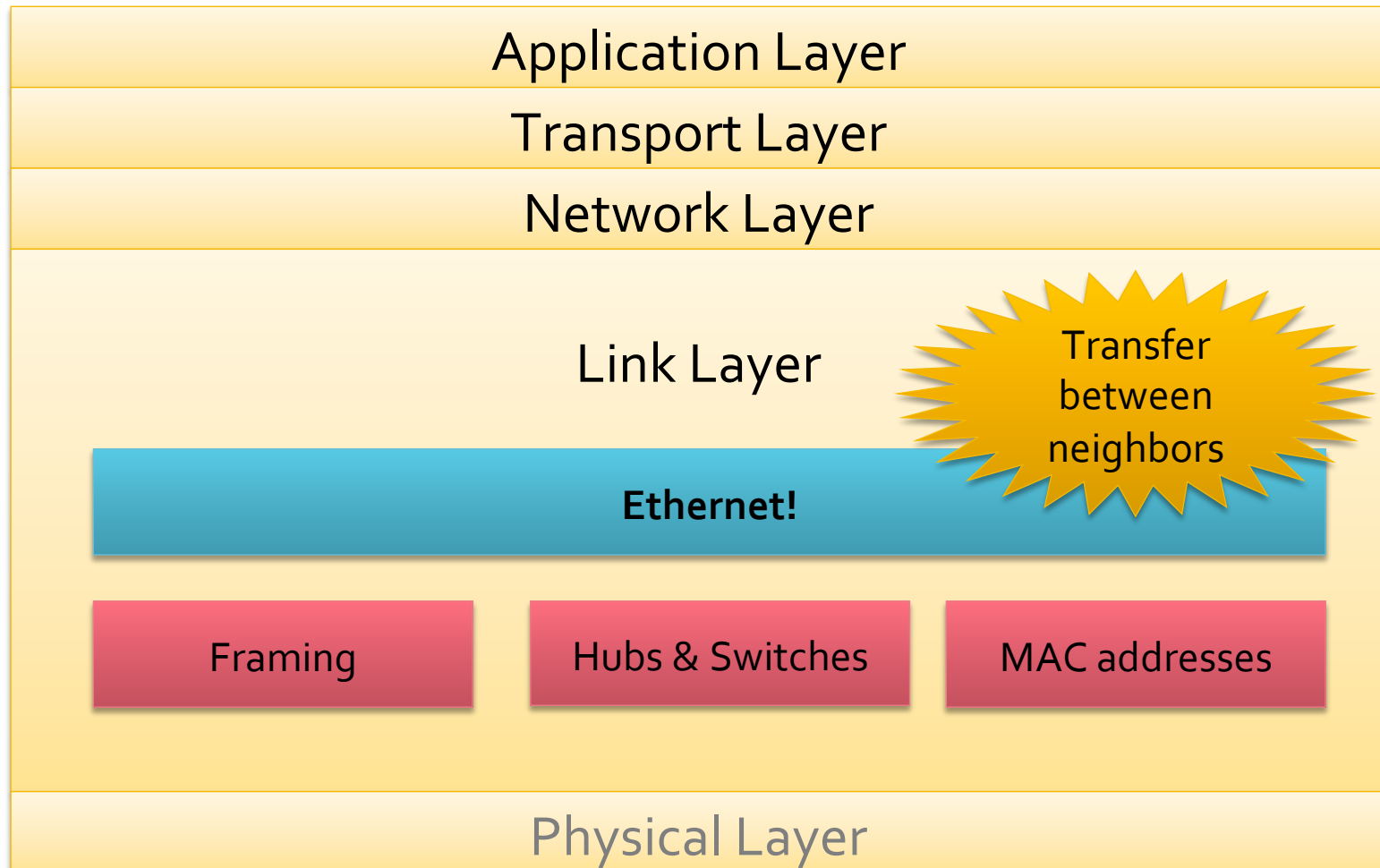
➤ Requested document not found on this server

505 HTTP Version Not Supported

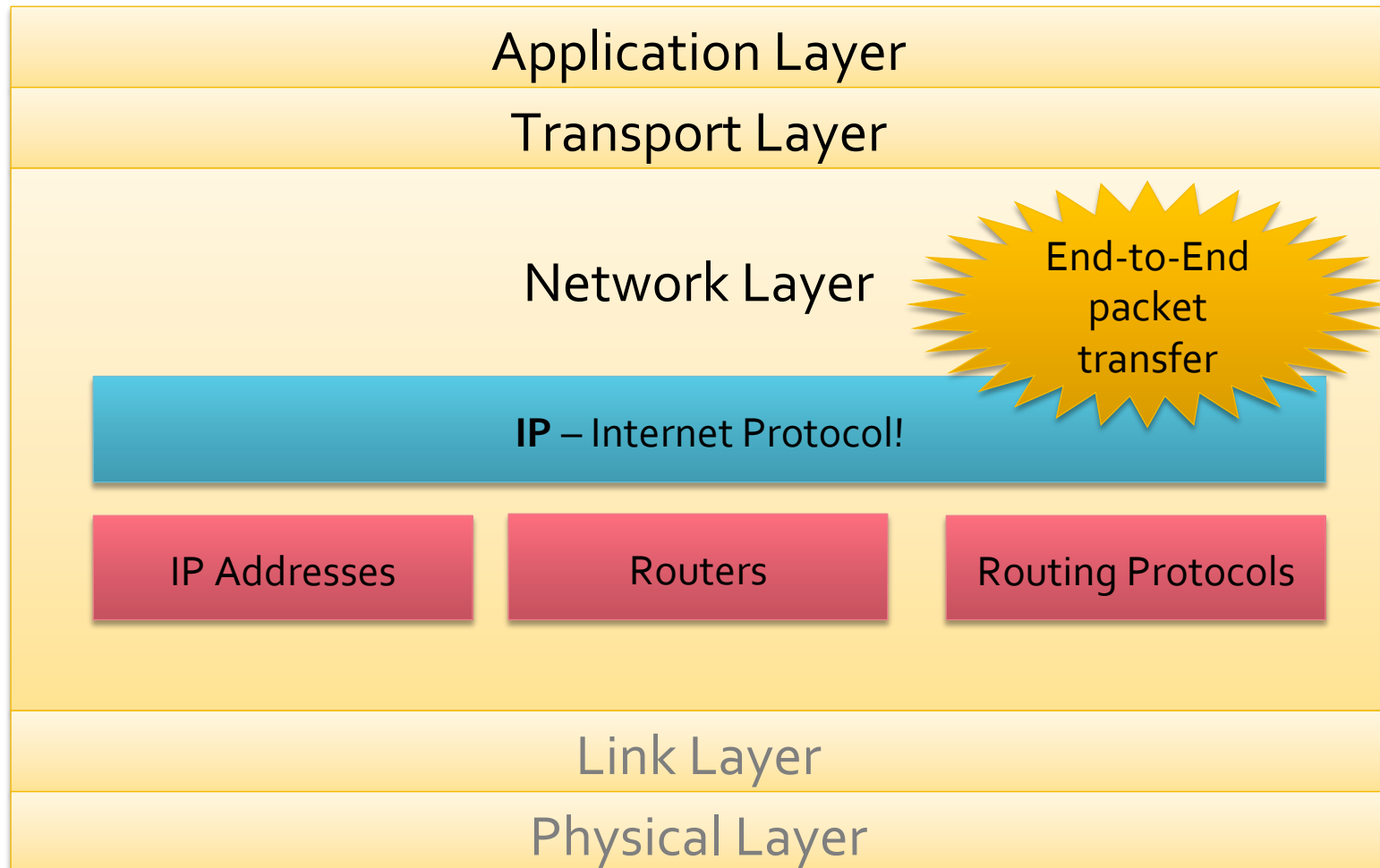
Other Layers



Link Layer



Network Layer



IP Properties

➤ **Datagram**

- Each packet is **individually routed**
- Packets may be **fragmented** or **duplicated** by underlying networks

➤ **Connectionless**

- No guarantee of delivery in sequence

➤ **Unreliable**

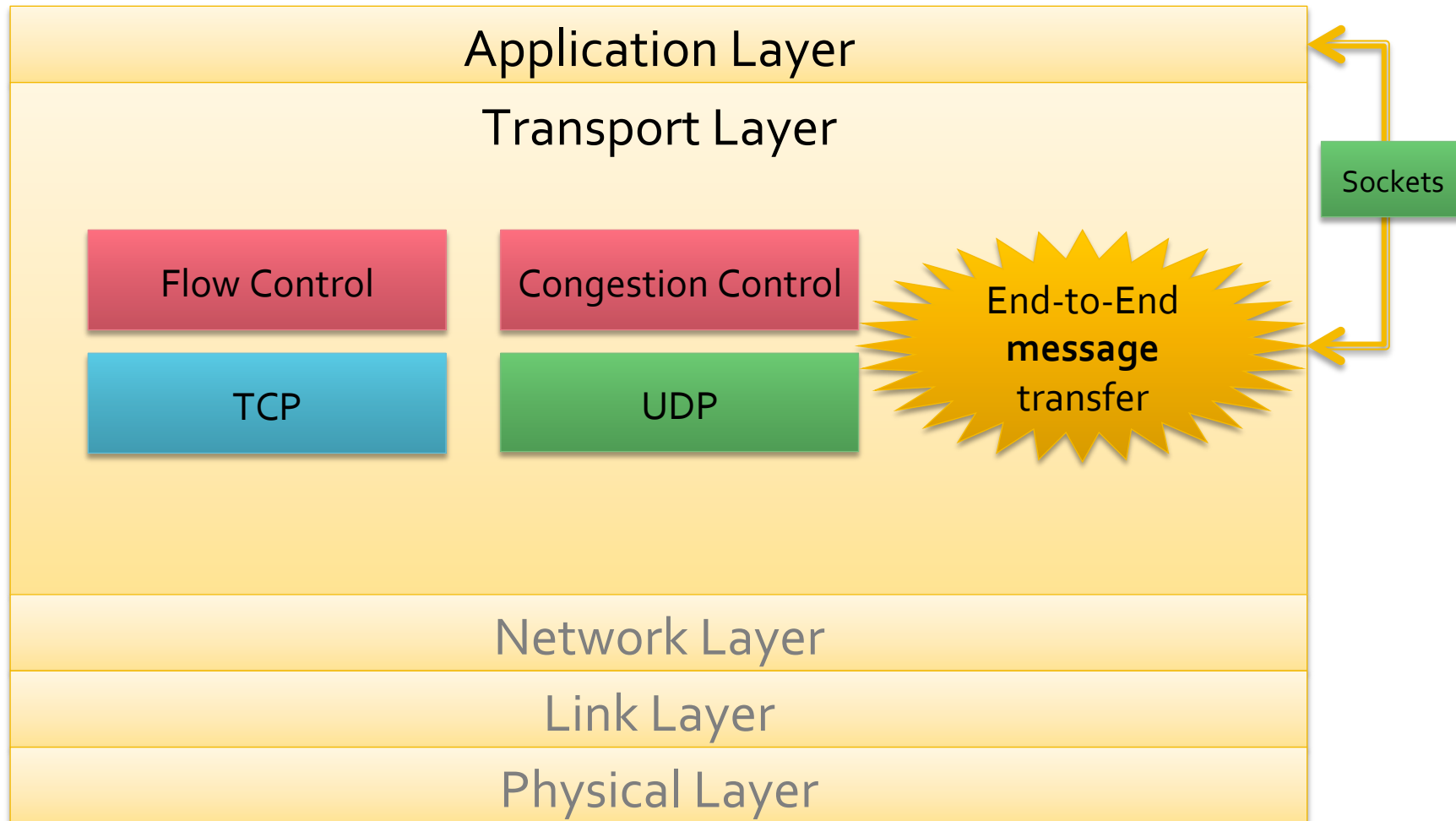
- No guarantee of delivery
- No guarantee of integrity of data

➤ **Best effort**

- Only drop packets when necessary
- No time guarantee for delivery

Ethernet networks provide the same “guarantees”

Transport Layer



“Magic” of the Internet

- **IP**: Un-reliable, order not guaranteed, delivery of **individual messages**
- **TCP**: Reliable, in-order delivery of data **stream**
- Magic
 - TCP is built on top of IP!
- Great clown analogy by Joel Spolsky
<http://www.joelonsoftware.com/articles/LeakyAbstractions.html>

Clown Delivery



Need to move clowns from Broadway to Hollywood for a new job



Broadway, NYC



Clown Delivery – Problems?



Many cars, many clowns
Bad things are guaranteed to
happen to at least *some* of them

Car crash / lost



Shaved head / too
ugly to work!



Different routes



Clown Delivery – Problems?

People in Hollywood get frustrated –
It's hard to make movies with clowns in this condition!



Clown Delivery - Solution

- New company
 - **Hollywood Express**
- Guarantees that all clowns
 - (1) Arrive
 - (2) In Order
 - (3) In Perfect Condition

- Mishap? Call and request clown's twin brother be sent immediately



- UFO crash in Nevada blocks highway?



- Clowns re-routed via Arizona
 - Director never even *hears* about the UFO crash
 - Clowns arrive a little more slowly

Networking Abstraction

- TCP provides a similar reliable delivery service for IP
- Abstraction has its limits
 - Ethernet cable chewed through by cat?
 - No useful error message for that problem!
 - The abstraction is “leaky” – it couldn’t save the user from learning about the chewed cable



Demos



Demos

1. Impersonate web browser via Telnet
2. Walkthrough of `client.py` and `server.py` demo programs
3. Run `display.py` with example image
4. Monitor `display.py` with *Wireshark* and examine packet trace