Computer Systems and Networks

ECPE 170 – Jeff Shafer – University of the Pacific

Networking Fundamentals

Lab Schedule

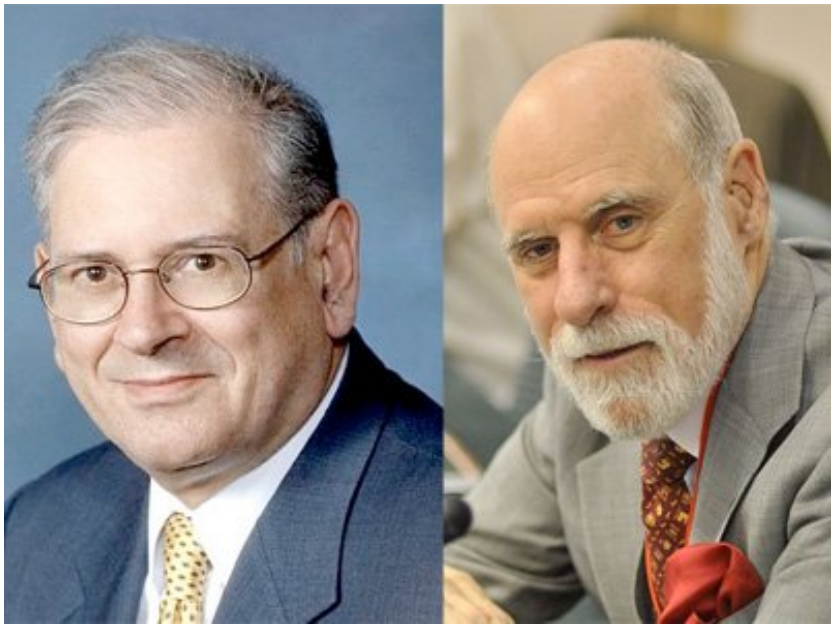
Activities

- **This Week**
  - Network programming
  - Endianness
  - **Lab 8 – Network Programming**

Assignments Due

- **Lab 8**
  - **Due by Mar 27th 5:00am**
- **Lab 9**
  - **Due by Apr 3rd 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

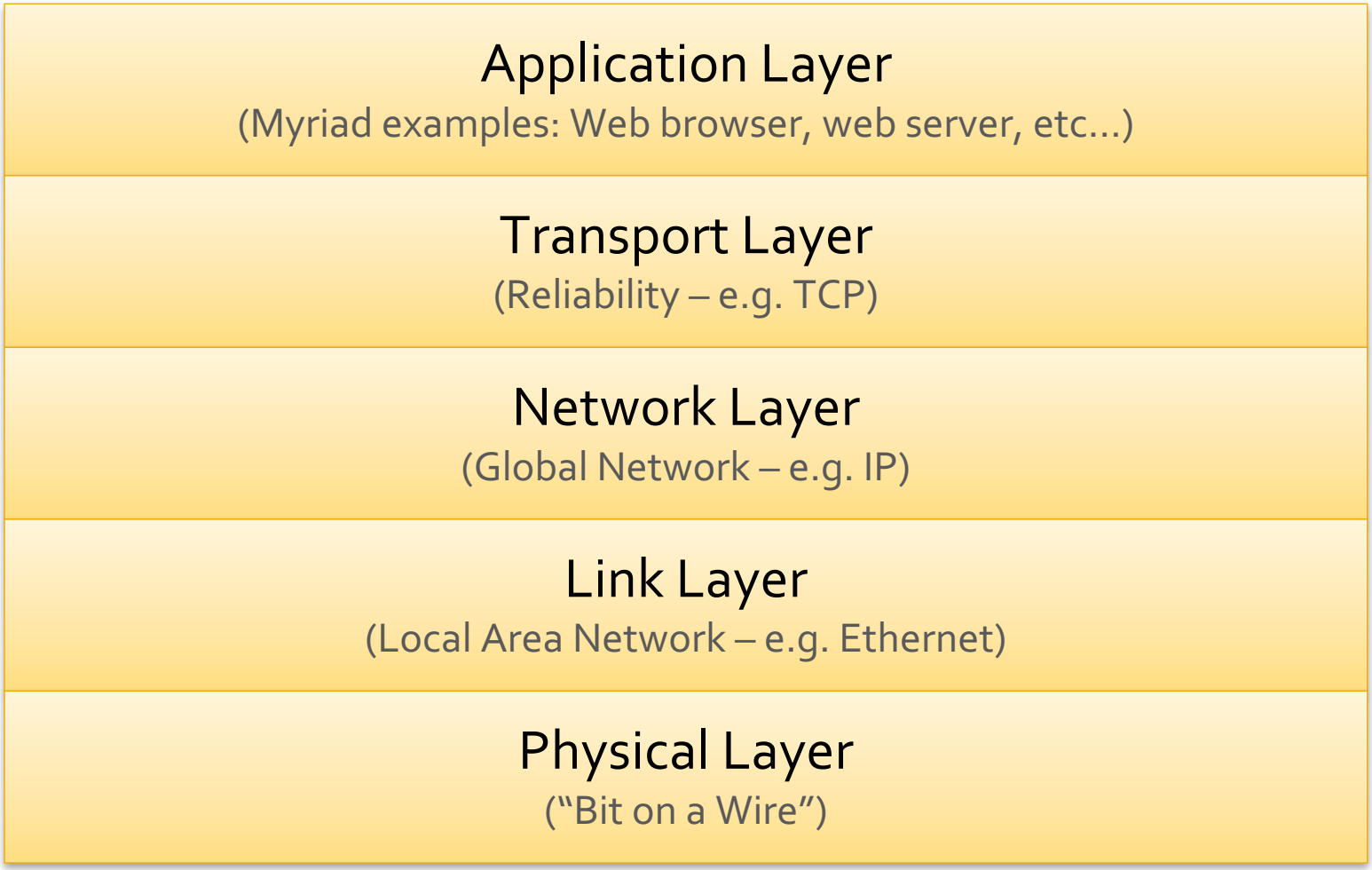
- Inventor of "World Wide Web"
  - First implementation of **HTTP** (HyperText Transfer Protocol) to communicate between client and server
- Knighted by Queen Elizabeth II in 2004

Computer Networks

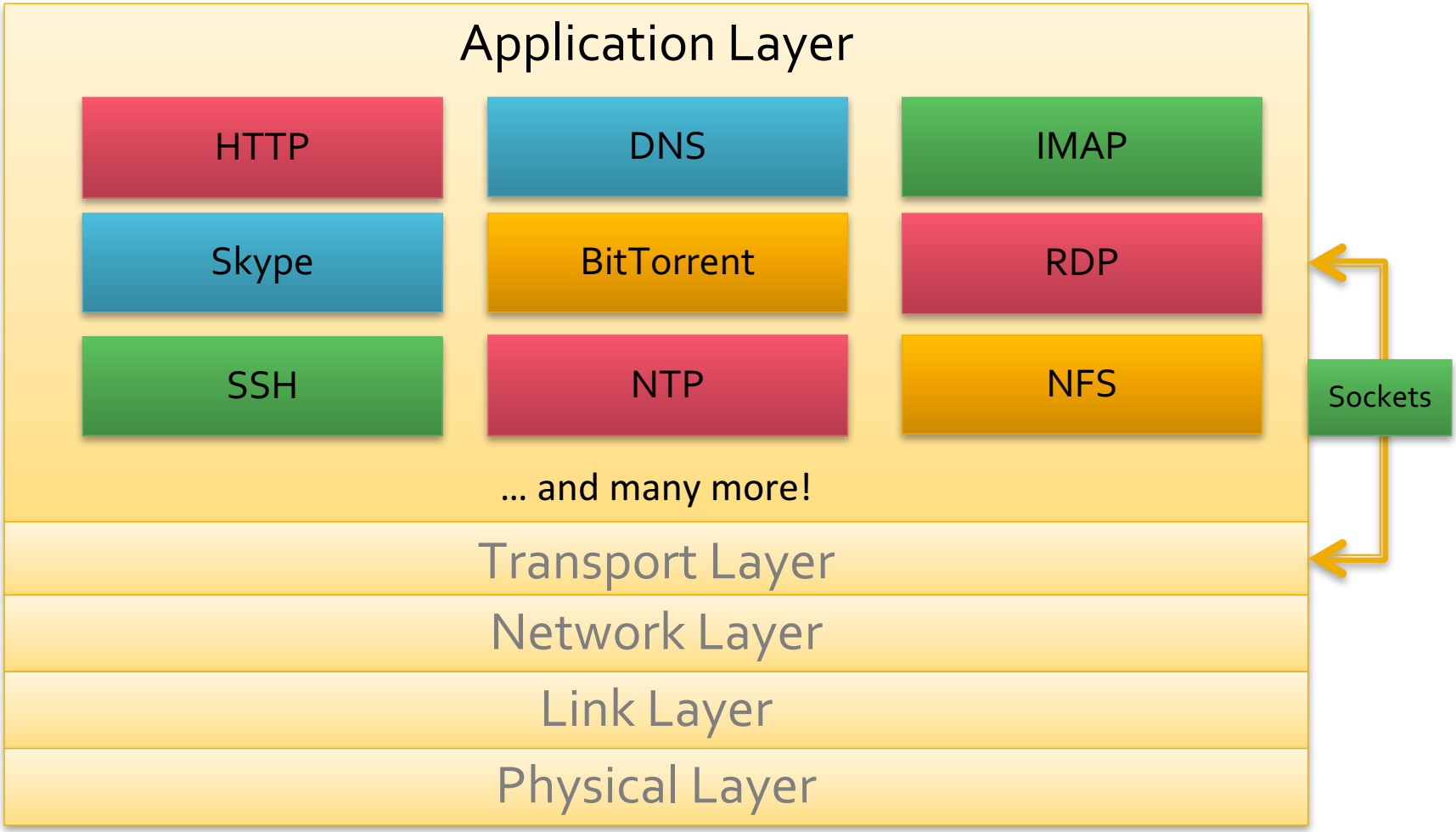
Disclaimer

- **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



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?

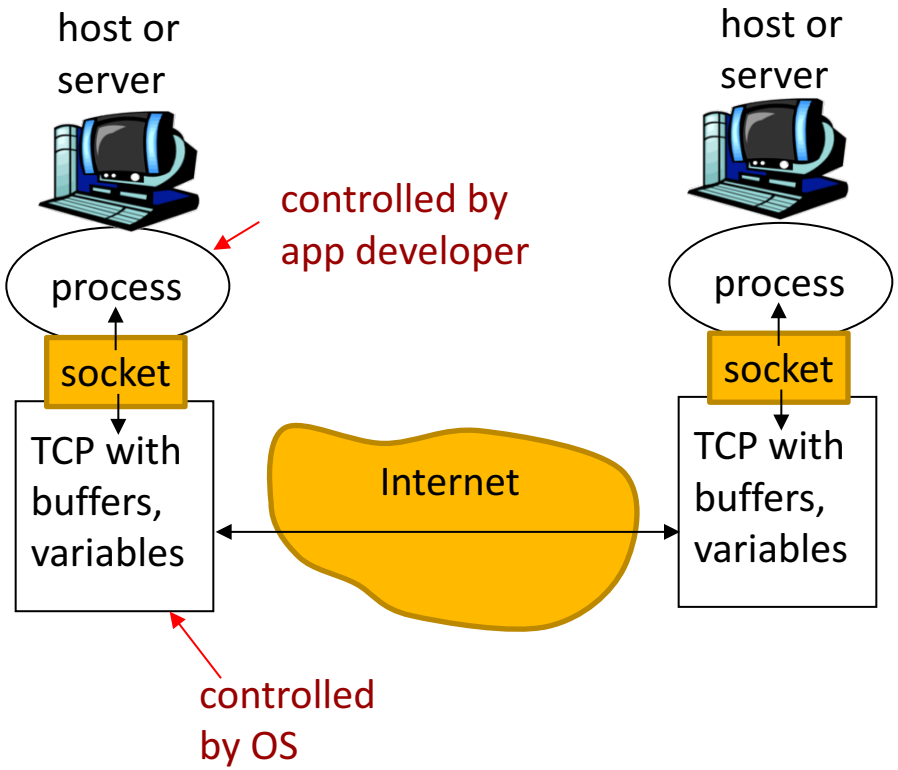
- Challenge – **Inter-process communication**
- A **process** is an independent program running on a host
  - Separate memory space
- How do processes communicate with other processes
  - On the same host?
  - On different hosts?
- Send **messages** between each other

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

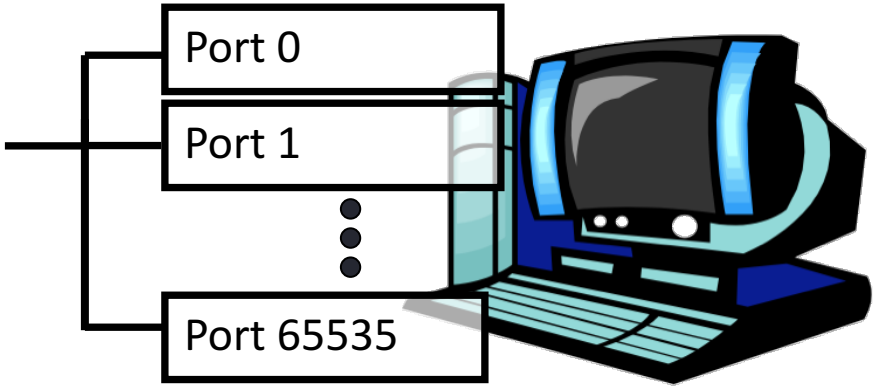


Addressing Processes

- 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

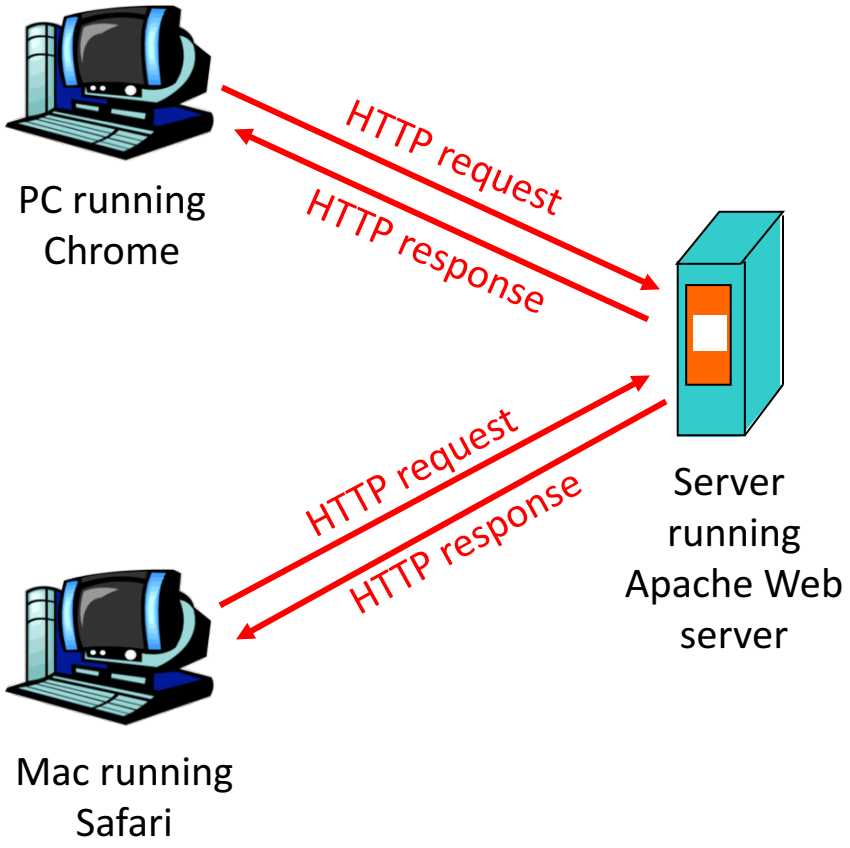
- Sockets just allow us to send raw messages between processes on different hosts
  - Transport service takes care of moving the data
- **What** exactly is sent is up to the application
  - An **application-layer** protocol
  - HTTP, NTP, IMAP, SFTP, Skype, etc…

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

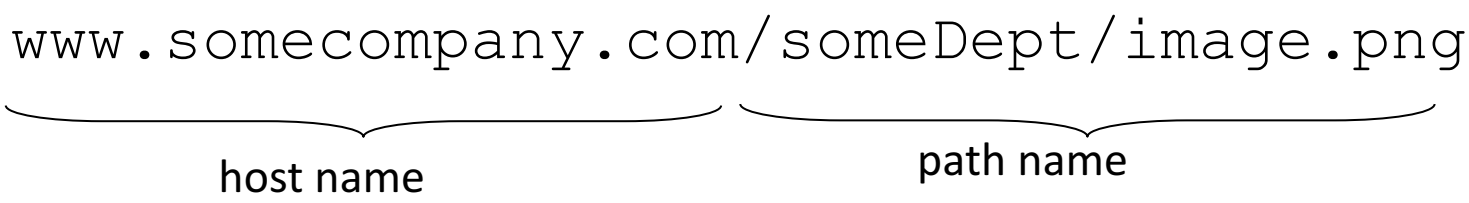
Hypertext Transfer Protocol Overview

- **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

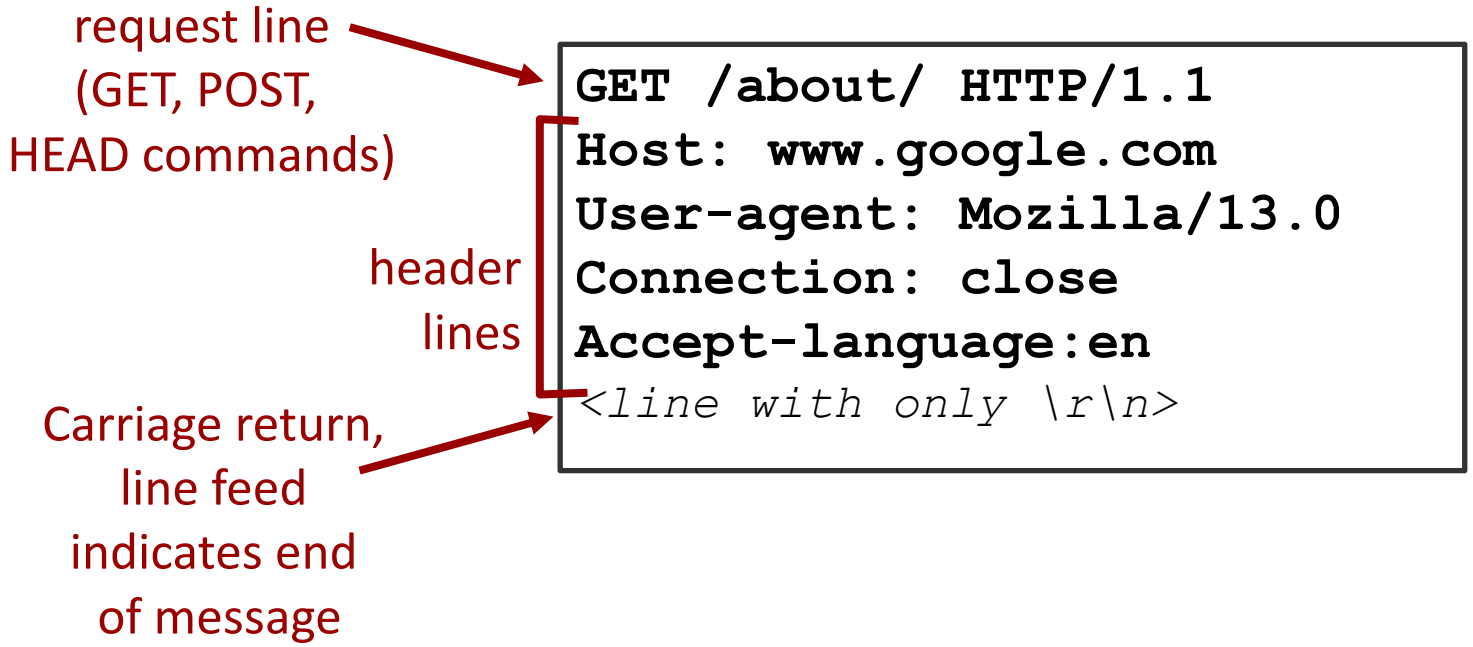


Web and HTTP

- 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:

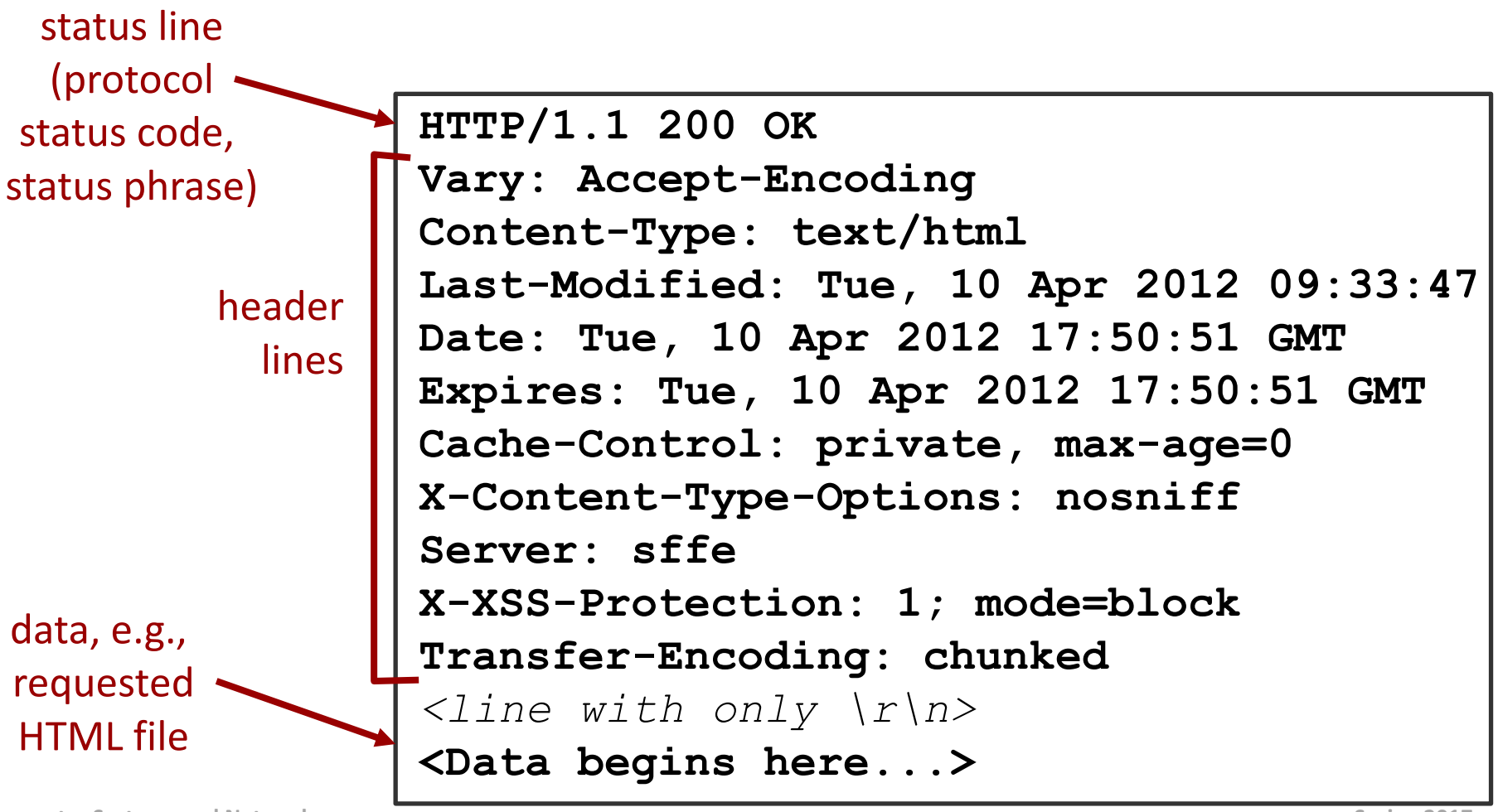


HTTP Request Message (Client->Server)



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)



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

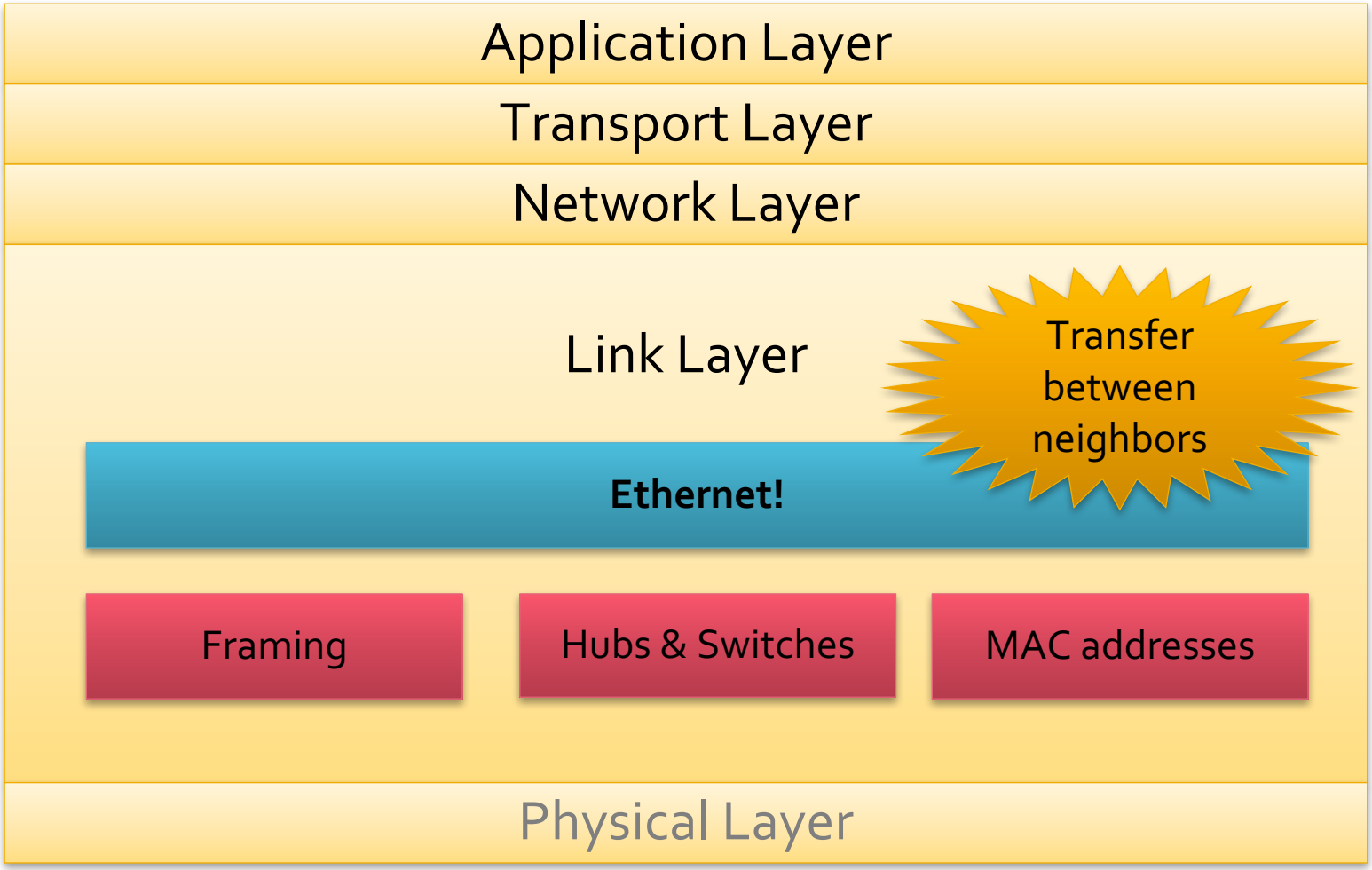
404 Not Found

- Requested document not found on this server

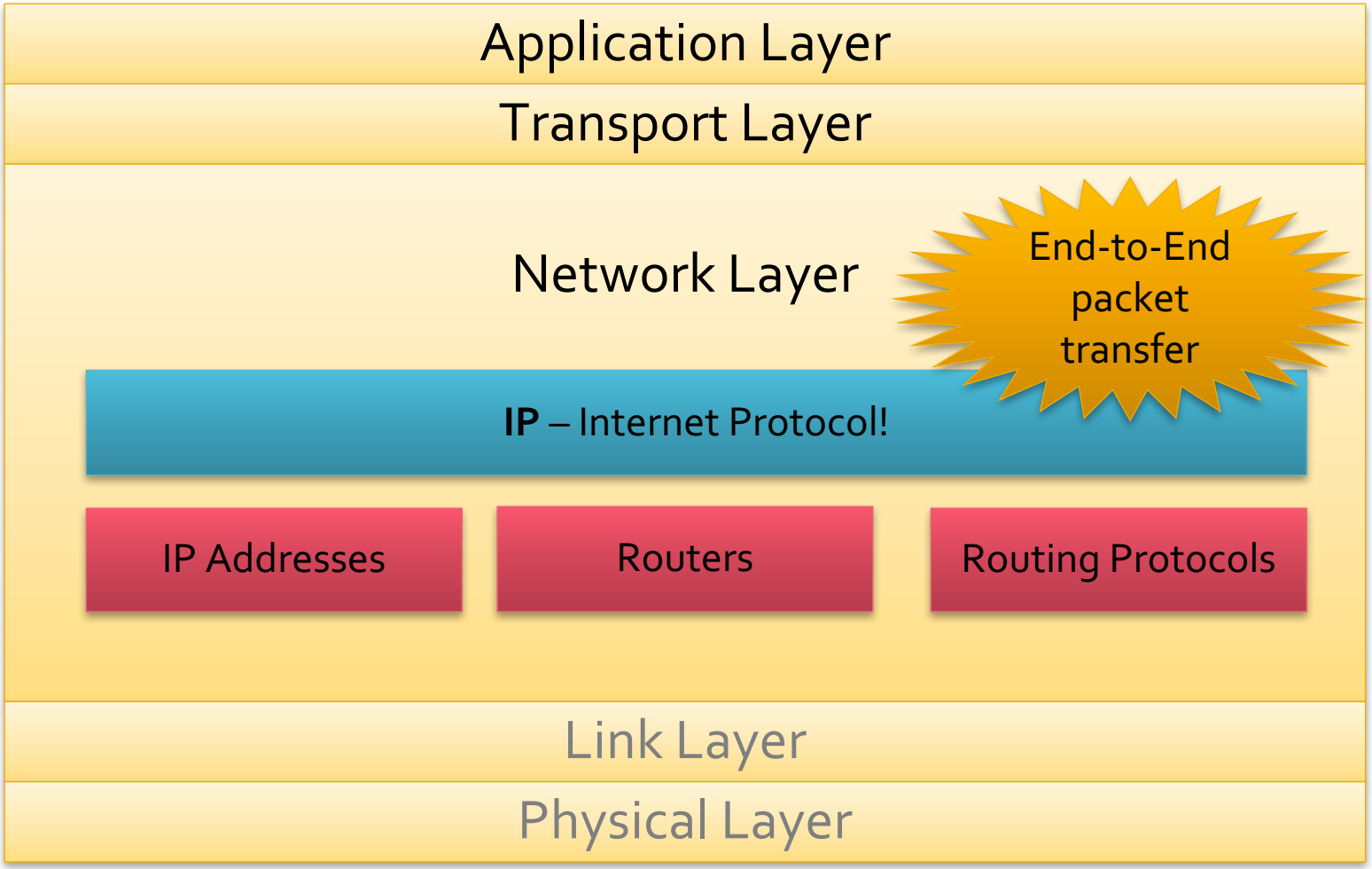
505 HTTP Version Not Supported

Other Layers

Link Layer


Application Layer
Transport Layer
Network Layer
Link Layer
Transfer between neighbors
Ethernet!
Framing
Hubs & Switches
MAC addresses
Physical Layer

Network Layer

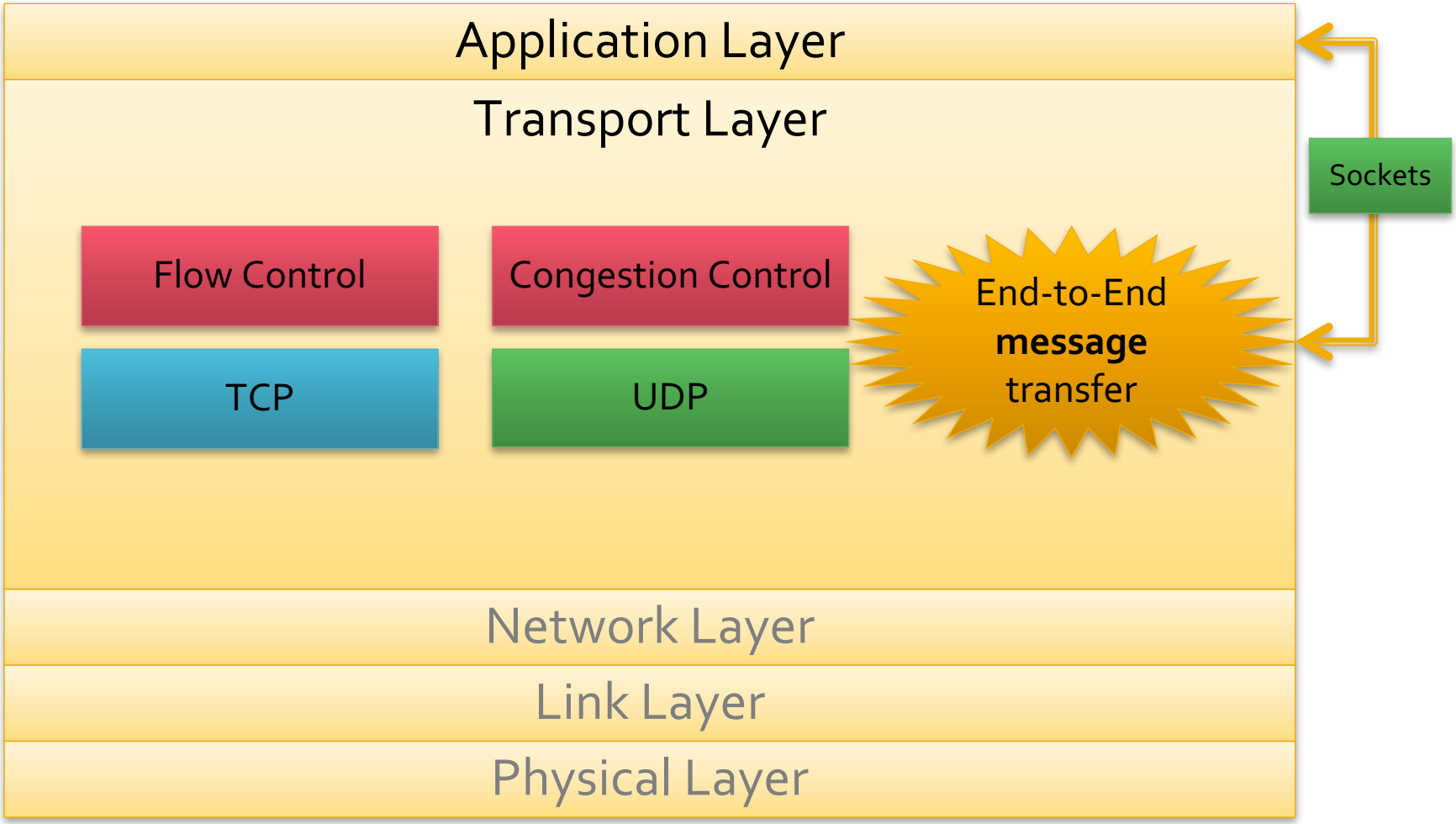


IP Properties

- **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



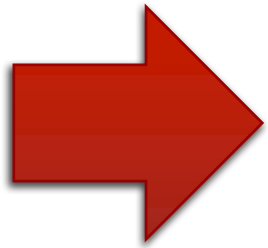
"Magic" of the Internet

- **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

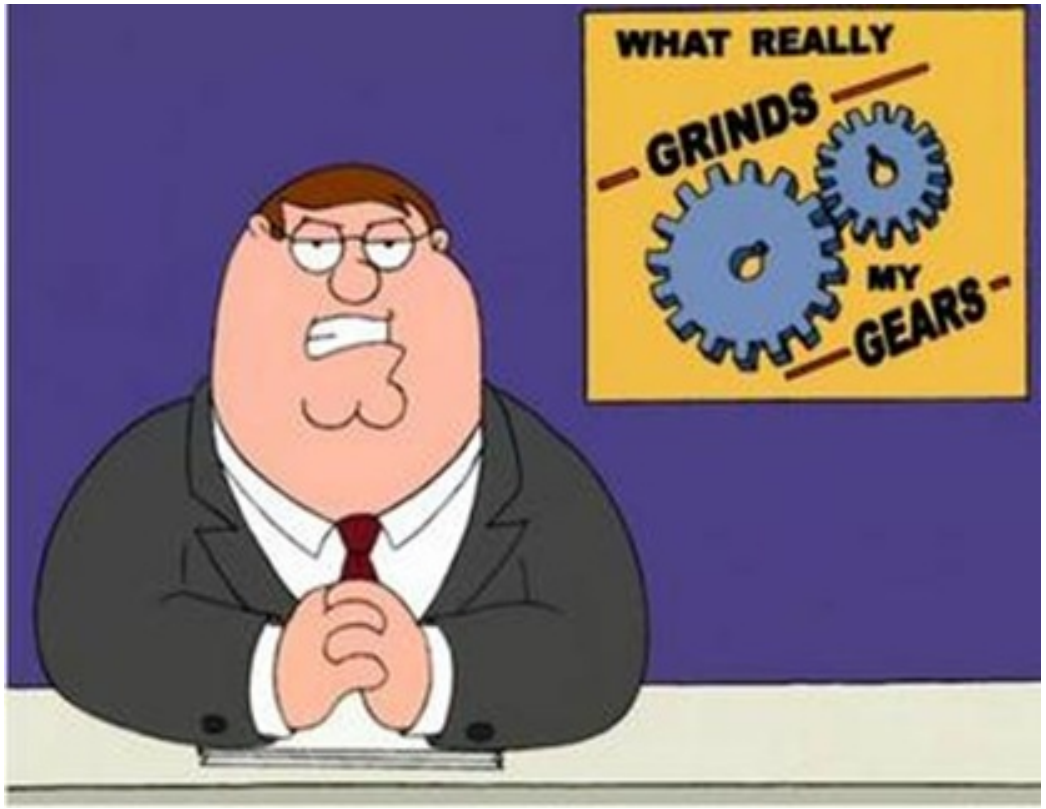
Shaved head / too ugly to work!

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