Computer Systems and Networks

ECPE 170 – University of the Pacific

Networking Fundamentals

Lab Schedule

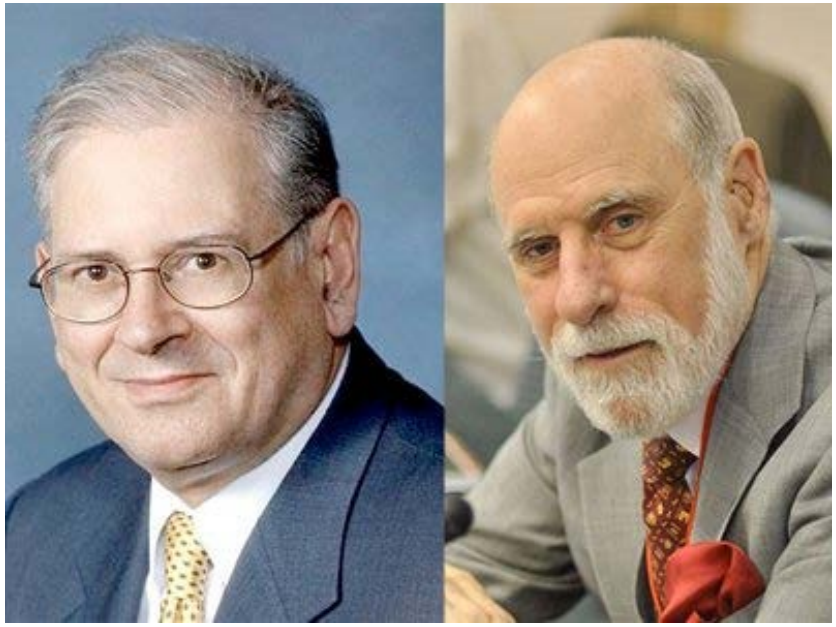
Activities

- **Today**
  - Networking Fundamentals
  - **Lab 11 & 12**
- **Next Tuesday**
  - **Lab 11 & 12**
- **Last 2 days of class**
  - **Lab 12 – Network Programming**

Assignments Due

- **Sun Dec 1st**
  - **Lab 11 due by 11:59pm**
- **Tues Dec 10th**
  - **Lab 12 due by 11:59pm**

Persons of the Day: Vint Cerf / Bob Kahn



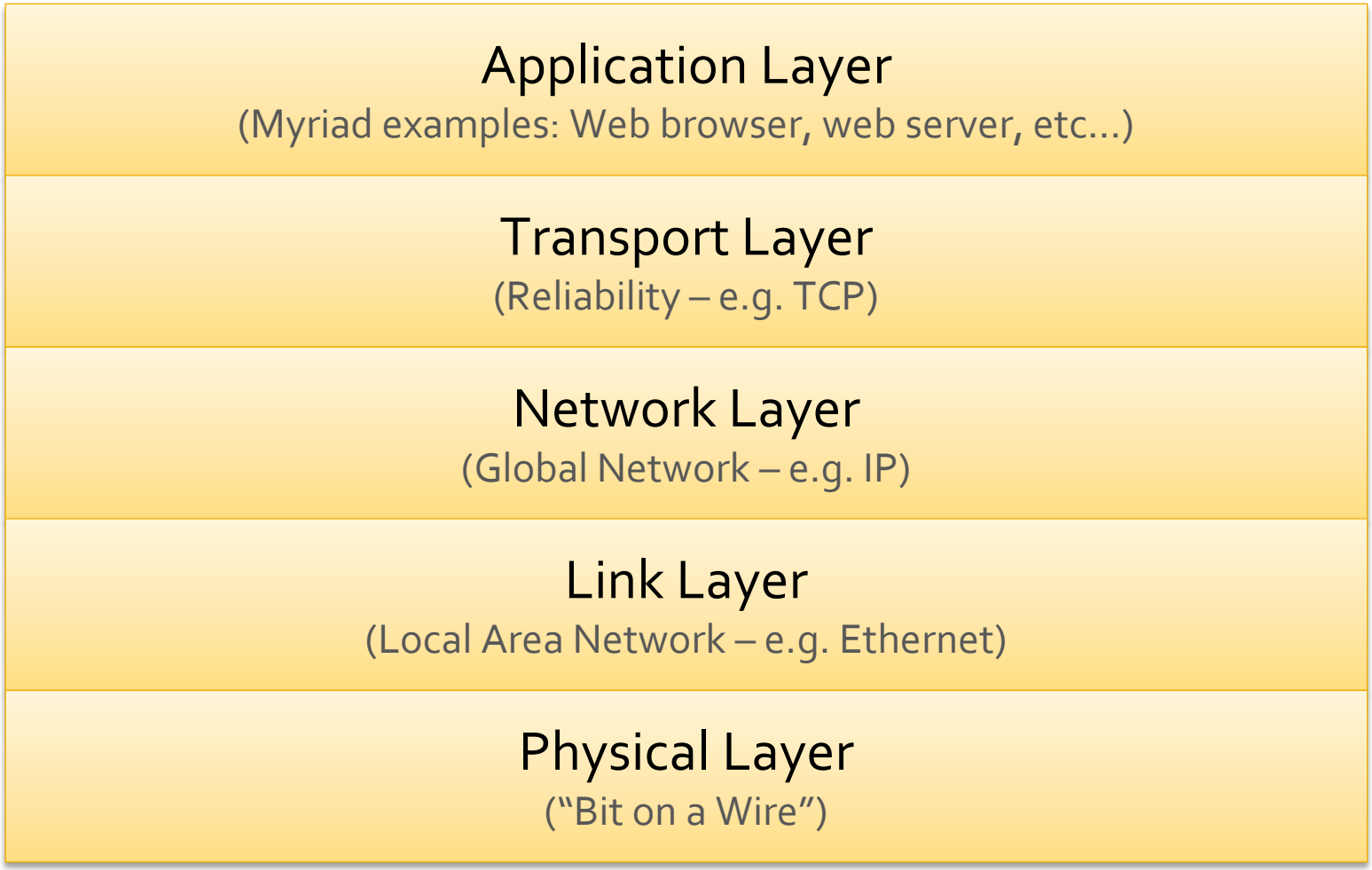
- Co-designers of TCP/IP protocol suite
  - Enables reliable communication across unreliable network
  - **Foundation of Internet**
- 2004 *ACM Turing Award* winners (shared)
- 2005 *Presidential Medal of Freedom winners* (shared)

Computer Networks

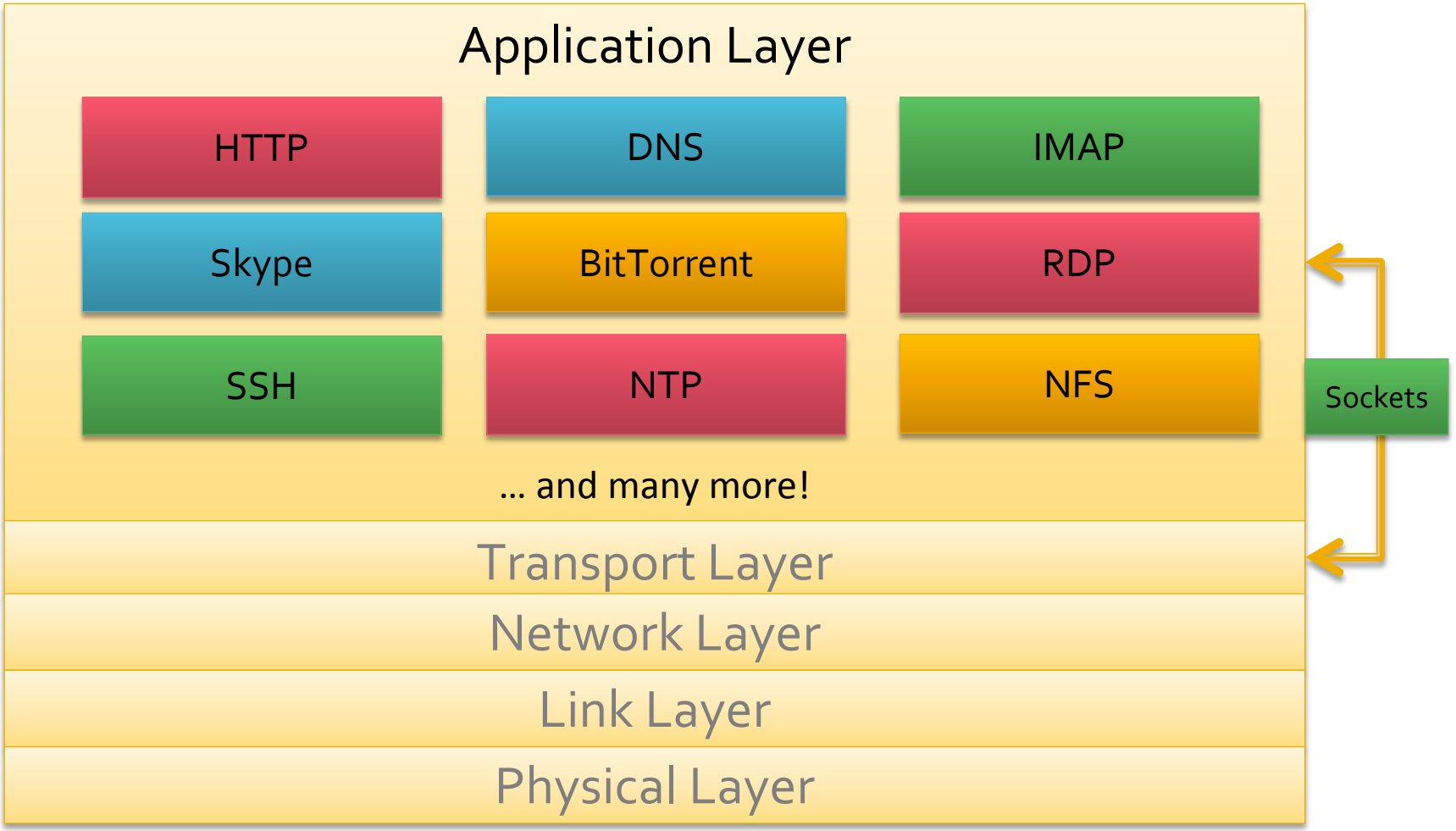
Disclaimer

- **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, etc.) 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?

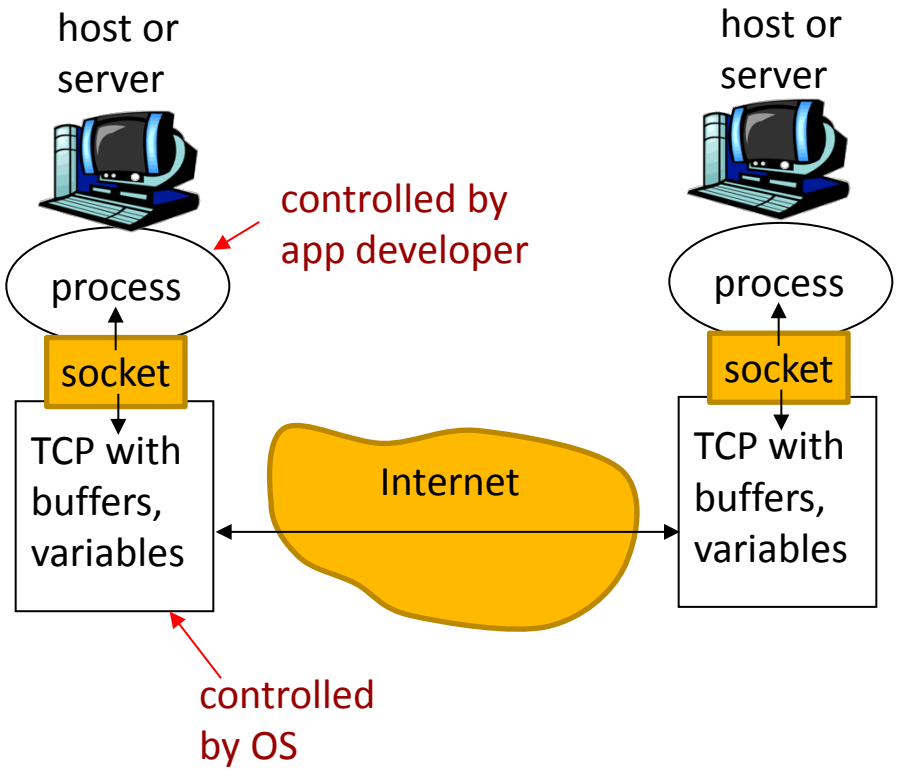
- Challenge – **Inter-process communication**
- A **process** is an independent program running on a host
  - Separate memory space
- How do processes communicate with other processes
  - On the same host?
  - On different hosts?
- Send **messages** between each other

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

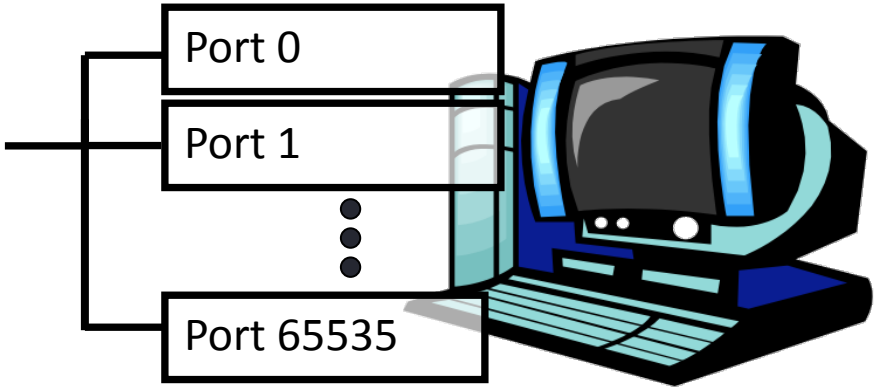


Addressing Processes

- 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 **connectionless (UDP)** or **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

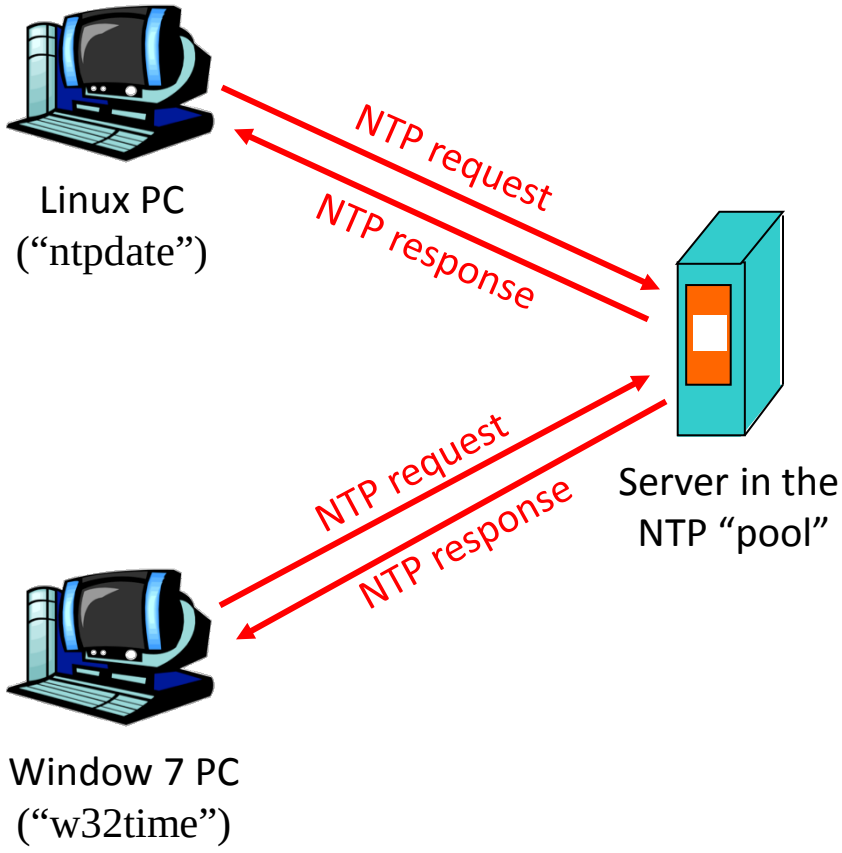
- Sockets just allow us to send raw messages between processes on different hosts
  - Transport service takes care of moving the data
- **What** exactly is sent is up to the application
  - An **application-layer** protocol
  - NTP, HTTP, IMAP, SFTP, Skype, etc…

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

Network Time Protocol Overview

- **NTP** is the *application layer protocol* for syncing computer's clock
- It is how the client and server communicate
- Client/server model
  - **Client**: requests "current time"
  - **Server**: server sends time responses



Clock Strata

- NTP servers are arranged in a hierarchy called **stratums**
  1. Synchronized directly to atomic. GPS or radio clocks
  2. Synchronized to one or more stratum 1 sources
  3. Synchronized to one or more stratum 2 sources
  4. …..
- This layering allows the workload to be distributed

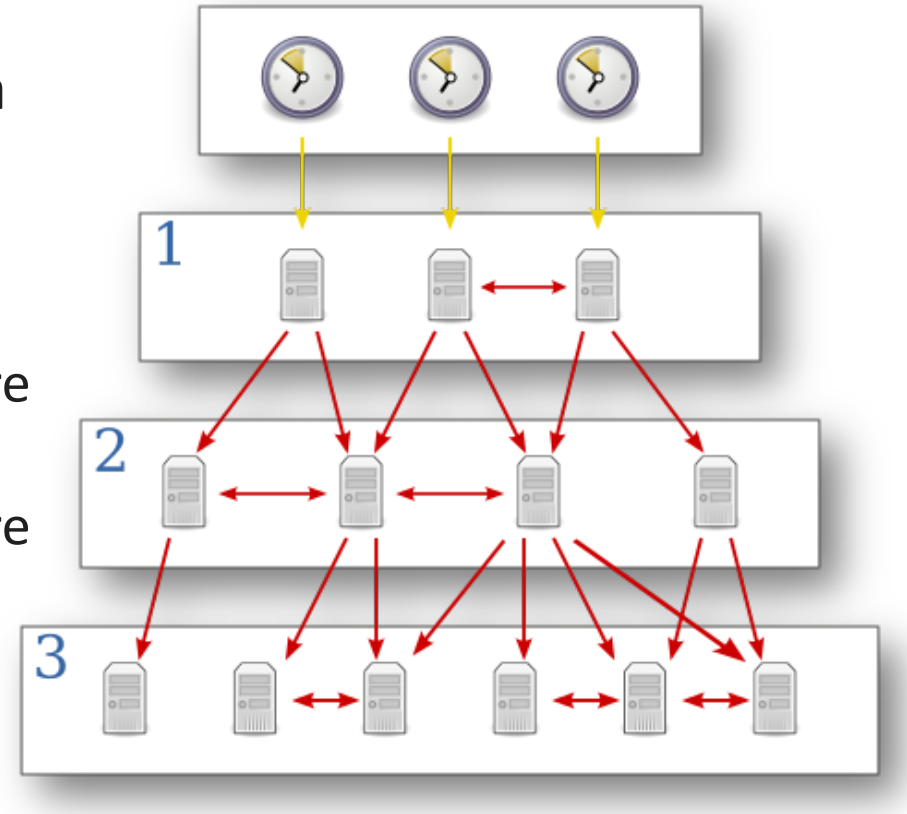
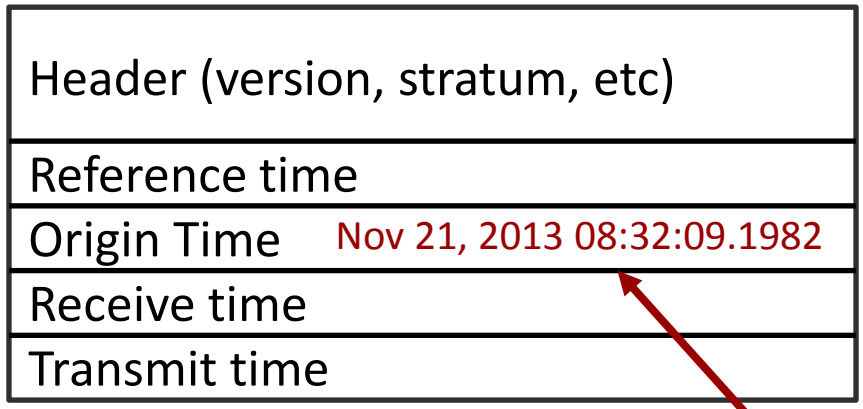


Image by Ben D. Esham, from Wikipedia

NTP Request Message (Client->Server)

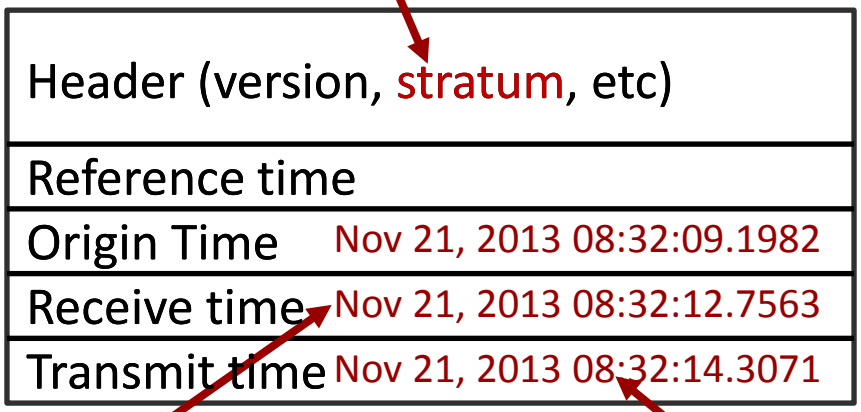
Data packet format is the same for clients and servers



Client sends request with the current local time

NTP Request Message (Server -> Client)

It also updates the header with the stratum and IP address



Server records the time when the packet was received…

and the time when it sends its reply

NTP Request Message (Client result)

The client notes the time when it receives the reply…
then calculates the differences between the transmit and receive delays.

→ Nov 21, 2013 08:32:15.4853

Header (version, stratum, etc)	
Reference time	
Origin Time	Nov 21, 2013 08:32:09.1982
Receive time	Nov 21, 2013 08:32:12.7563
Transmit time	Nov 21, 2013 08:32:14.3071

Local time is 1.1904 sec fast!

\- = 1.1872 sec

\- = 3.5581 sec

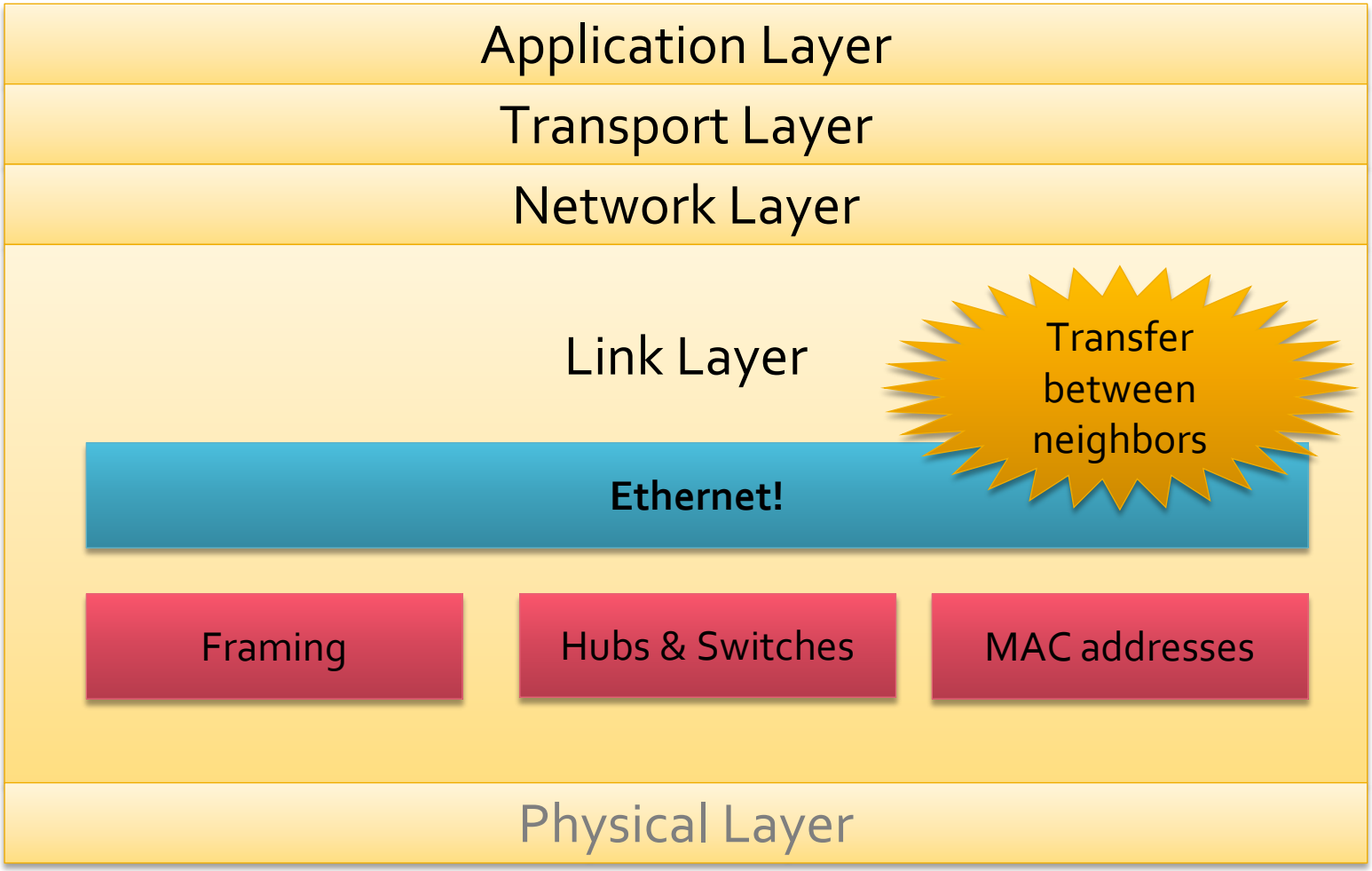
Assuming each delay *should* be identical, it calculates the difference between the local time and the "true" time.

ntpdate example

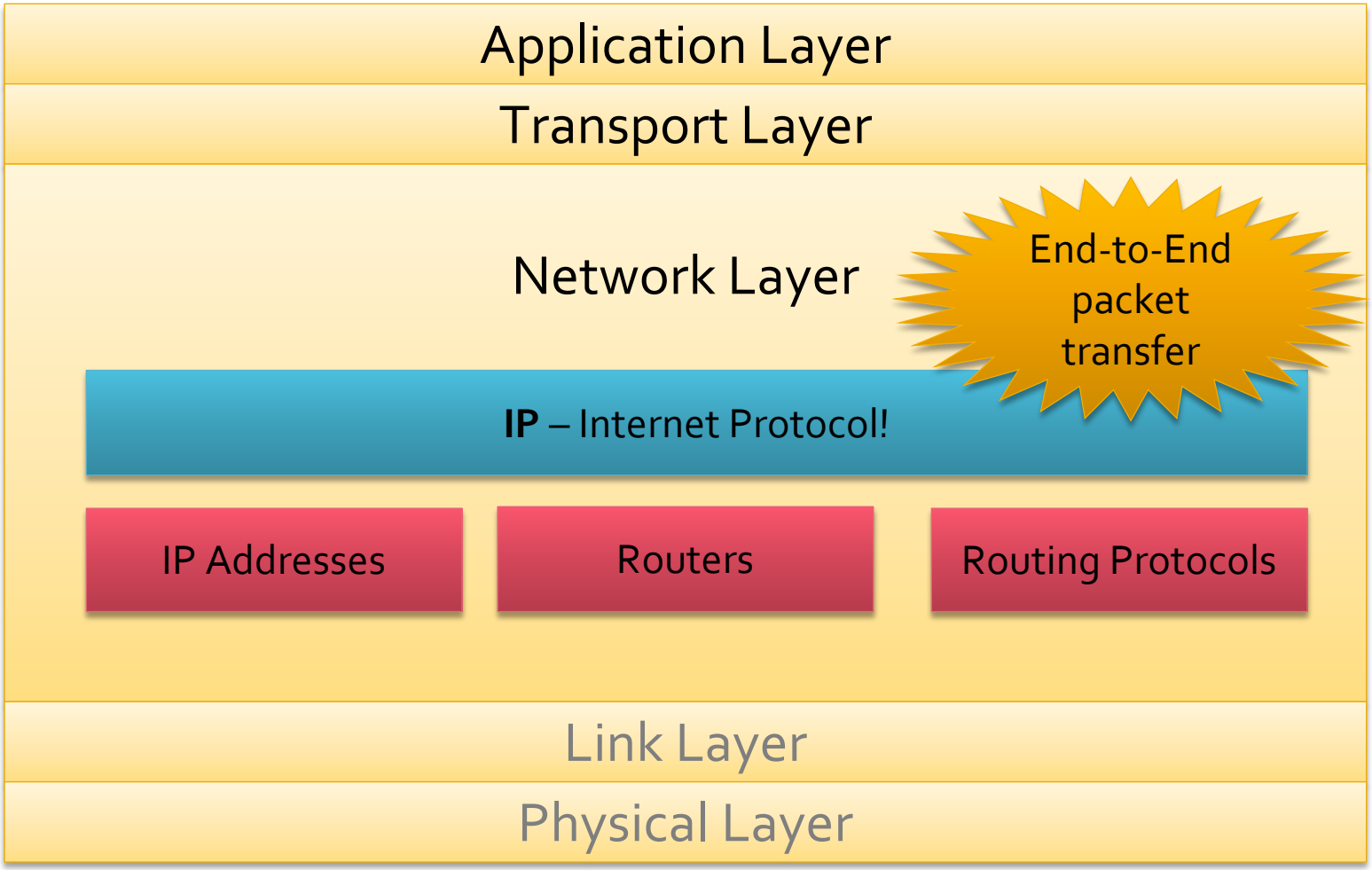
```
unix> ntpdate –vd 0.pool.ntp.org
Looking for host 0.pool.ntp.org and service ntp
host found : falcon.ca.us.slacked.org
transmit(173.230.158.30)
receive(173.230.158.30)
. . . .
stratum 2, precision -21, leap 00, trust 000
refid [108.61.56.35], delay 0.11089, dispersion 0.00169
transmitted 4, in filter 4
reference time:    d63643a8.54a20764  Tue, Nov 19 2013 12:08:08.330
originate timestamp: d63647e5.6f8ed6de  Tue, Nov 19 2013 12:26:13.435
transmit timestamp:  d63647e5.670059ac  Tue, Nov 19 2013 12:26:13.402
filter delay:  0.11162  0.11189  0.11134  0.11089
         0.00000  0.00000  0.00000  0.00000
filter offset: -0.00647 -0.00742 -0.00764 -0.00923
         0.000000 0.000000 0.000000 0.000000
delay 0.11089, dispersion 0.00169
offset -0.009232

19 Nov 12:23:52 ntpdate[1001]: adjust time server 198.60.22.240 offset 0.062573 sec
unix>
```

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

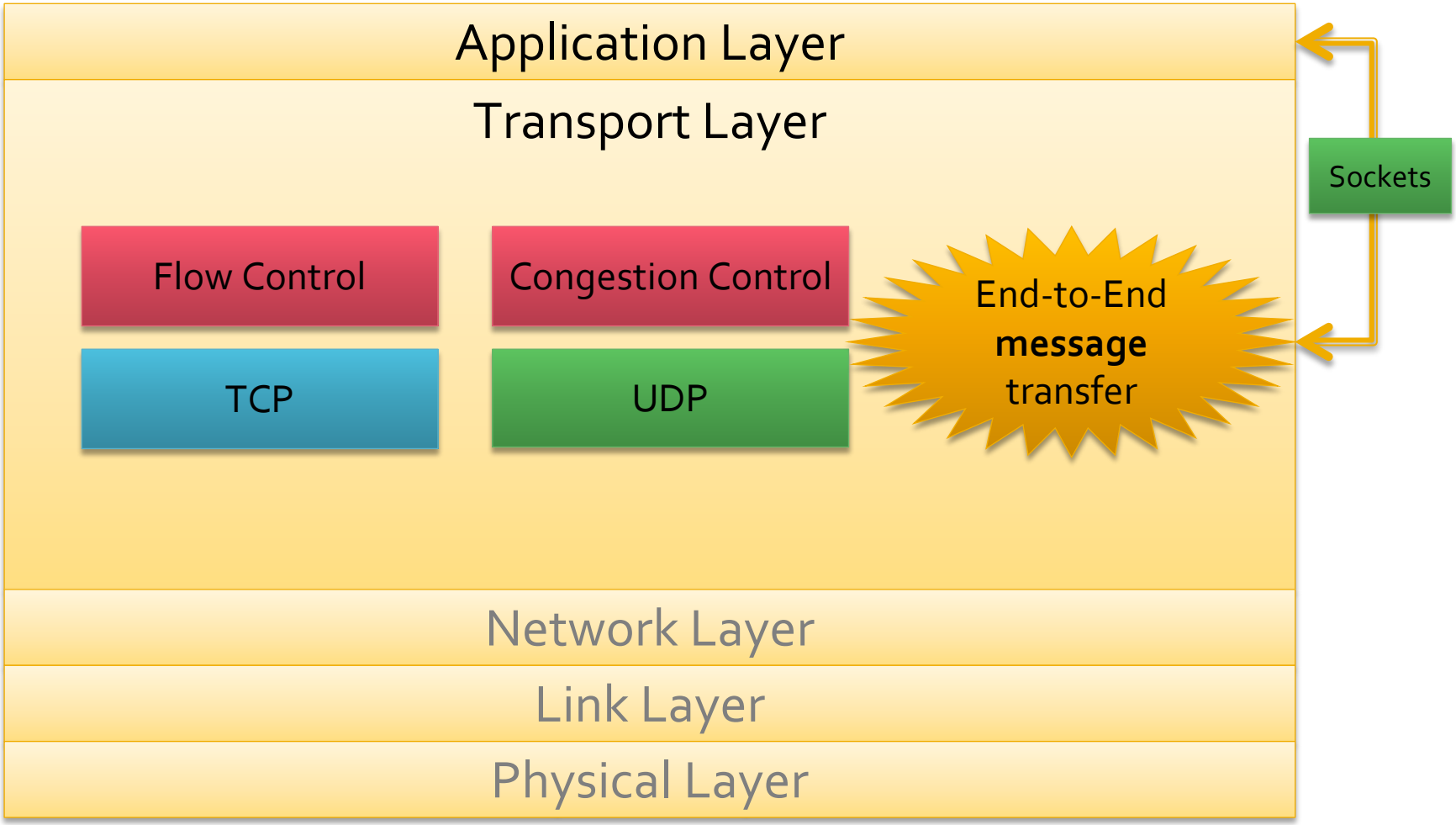


IP Properties

- **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

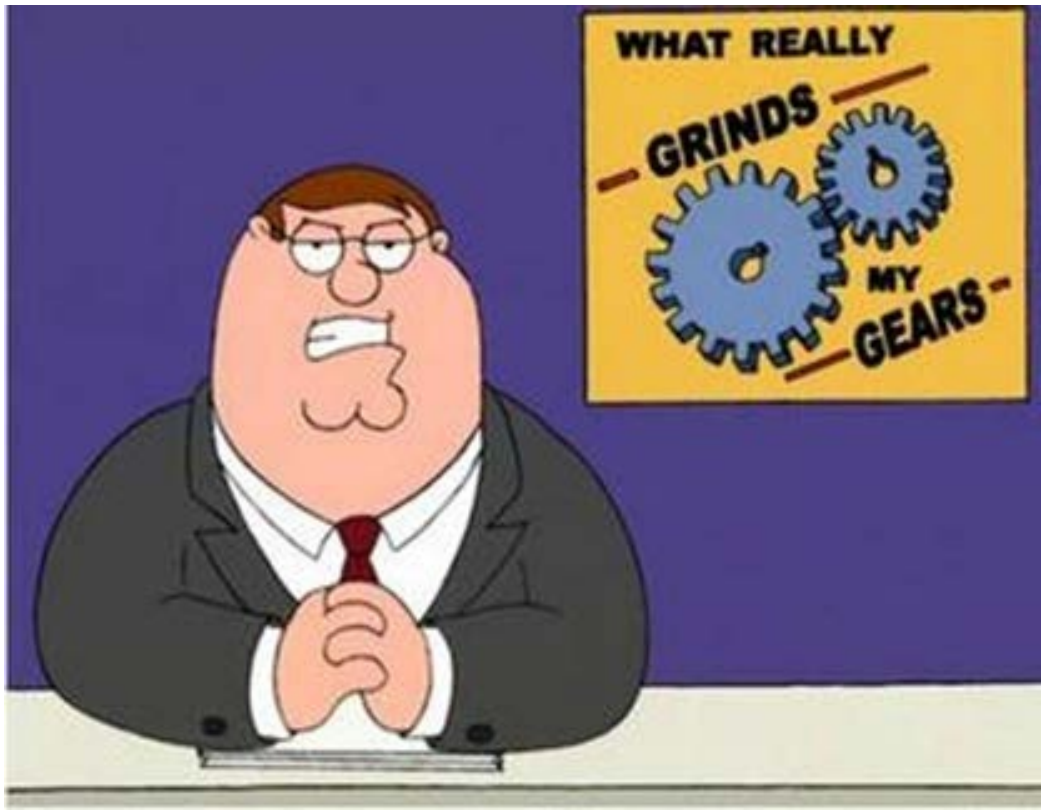
Shaved head / too ugly to work!

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. Run Linux *ntpdate* client
2. Impersonate NTP client via *netcat*
3. Run `ntpdate.py`
4. Monitor `ntpdate.py` with *Wireshark* and examine packet trace