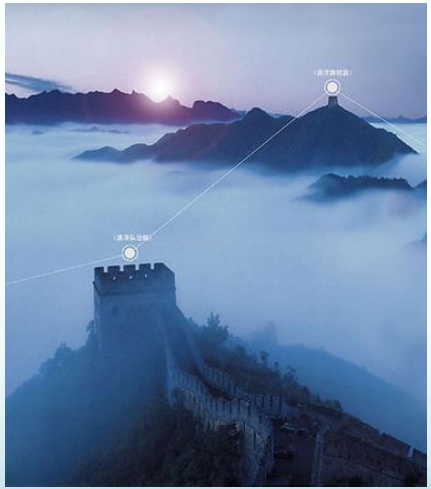
Network Protocols

What is a Network?

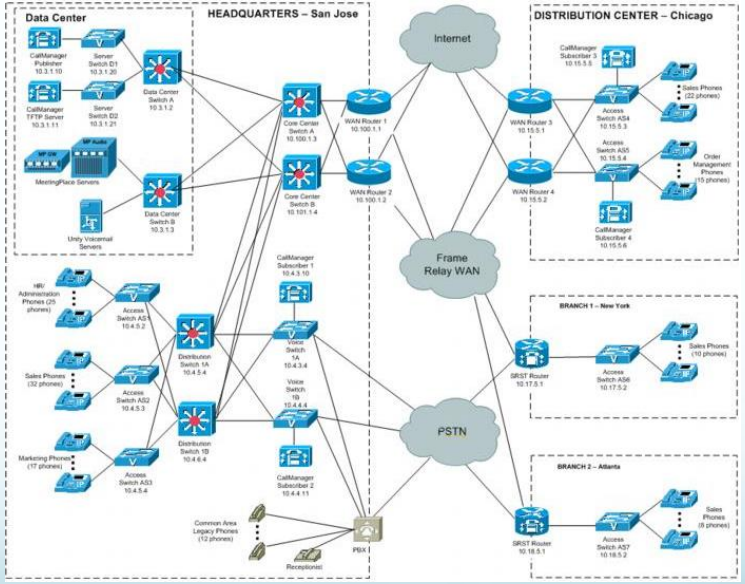
- A network is a way to transfer information or goods between people, places, or things.



1

Computer Networking

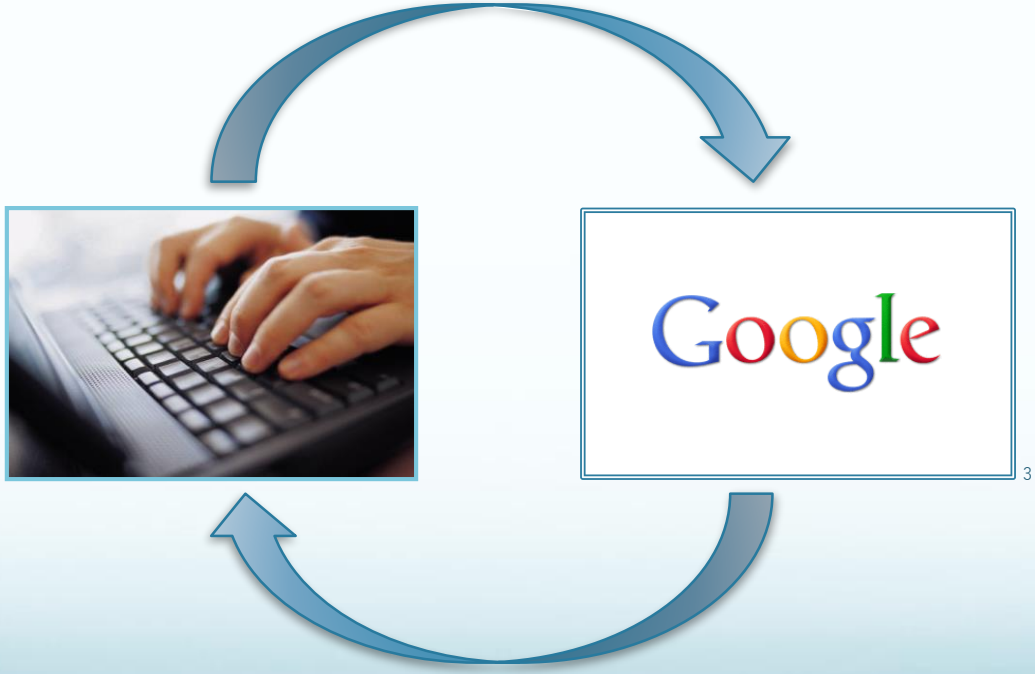
- Connecting devices together to share data
  - **Switch:** links devices together to form a network
  - **Router:** connects networks together and acts as a dispatcher
  - Some devices act as both switch and router (many of the consumer-grade routers, for example)



[2]

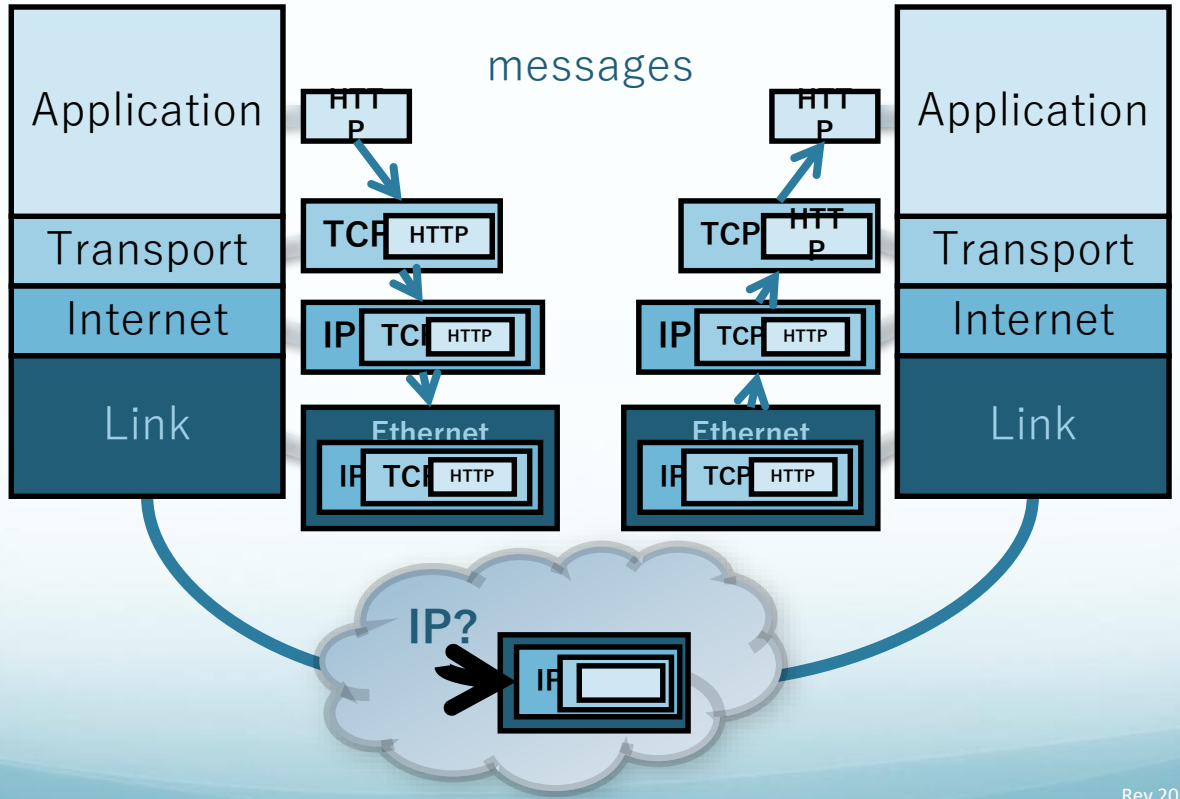
IP Telephony Network Topology Diagram Example (Cisco)

How does it work?

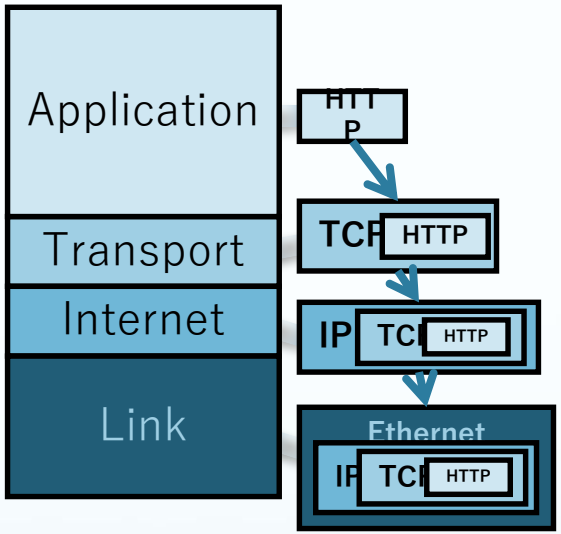


3

A Simple View



Messages



message, data

segment, datagram

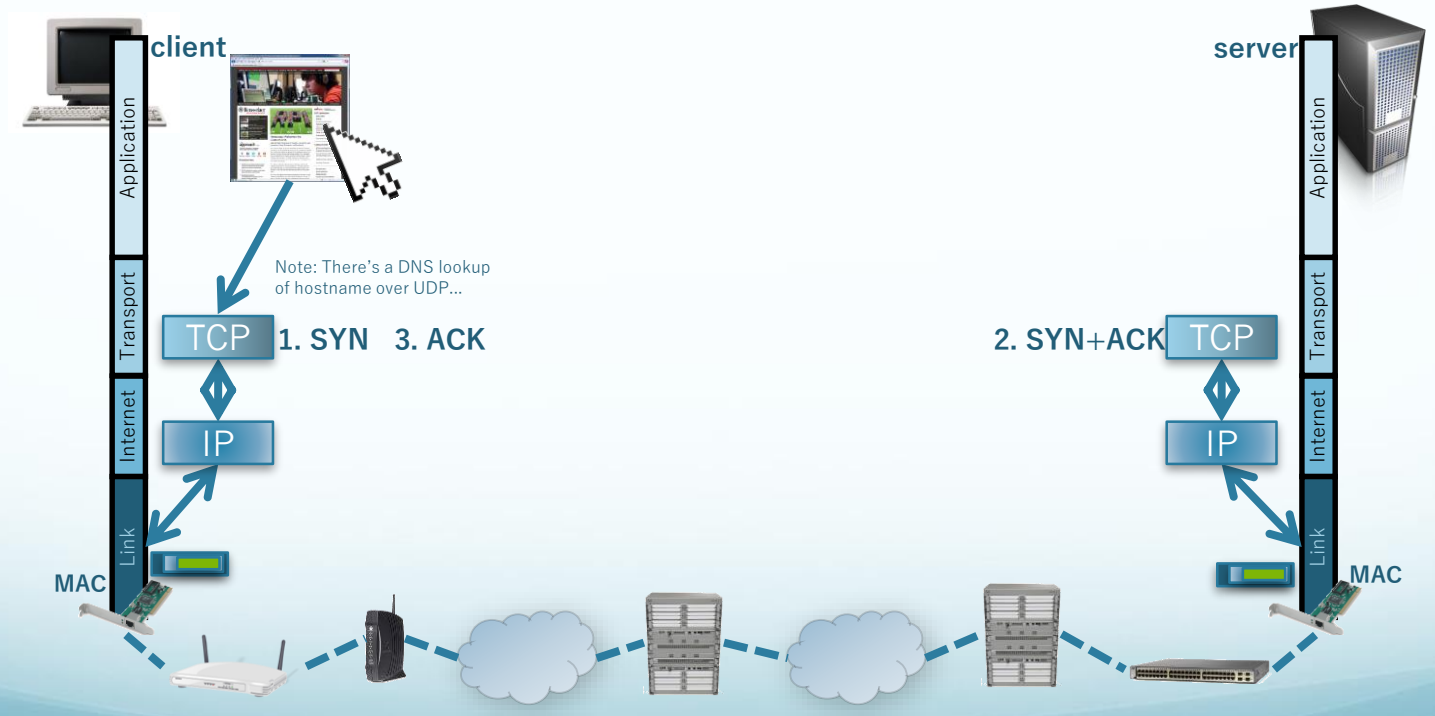
packet

frame

All are "messages".
All are frequently referred to as "packets"
(and for the purposes of this class, that's ok).

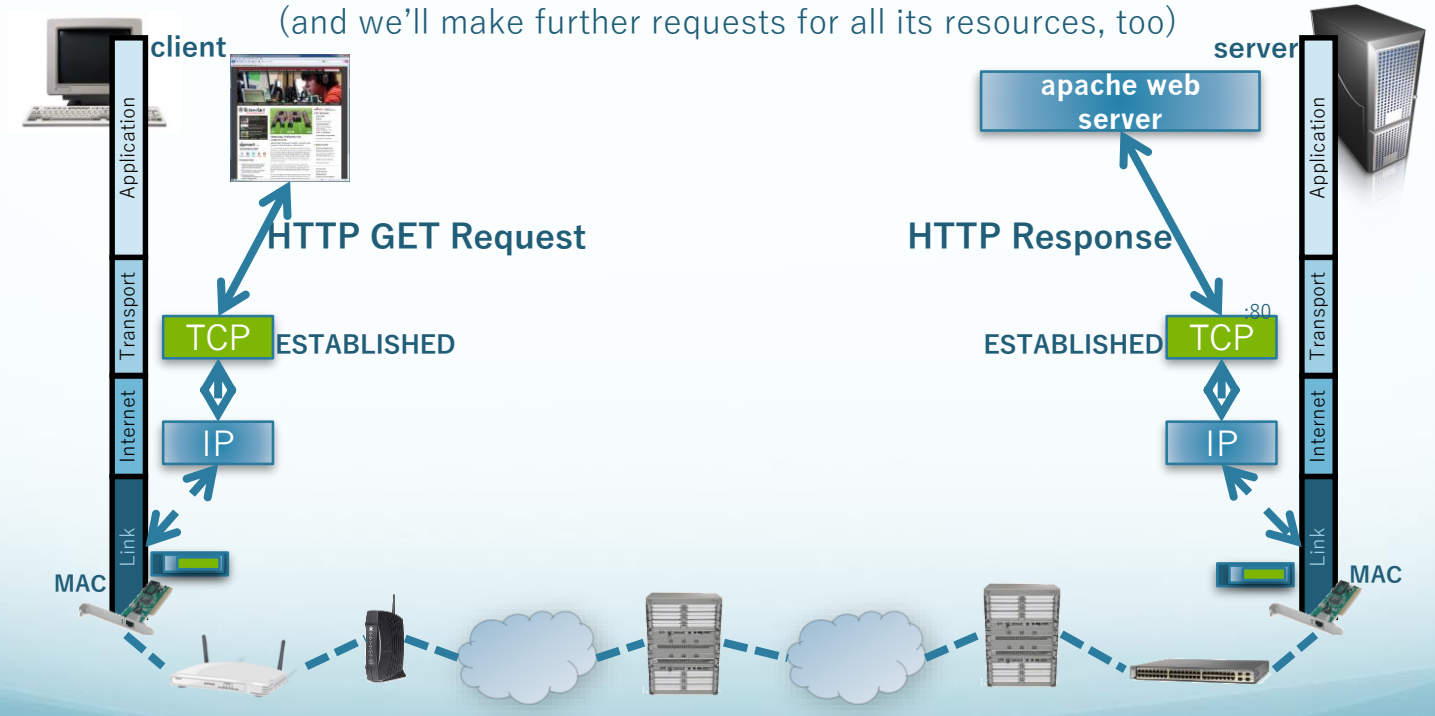
Web Browsing

1. TCP three-way-handshake: *establish a connection*



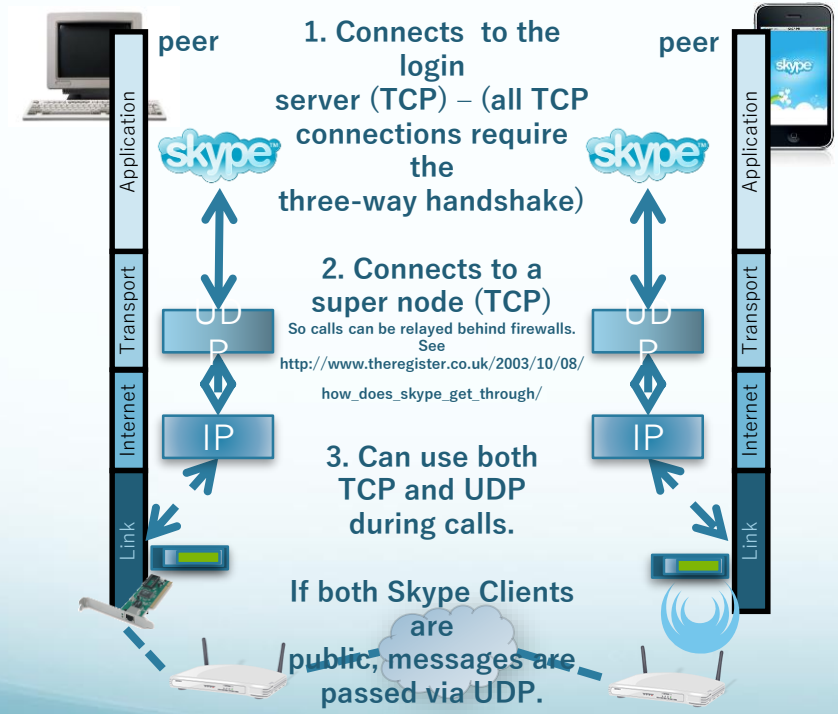
Web Browsing

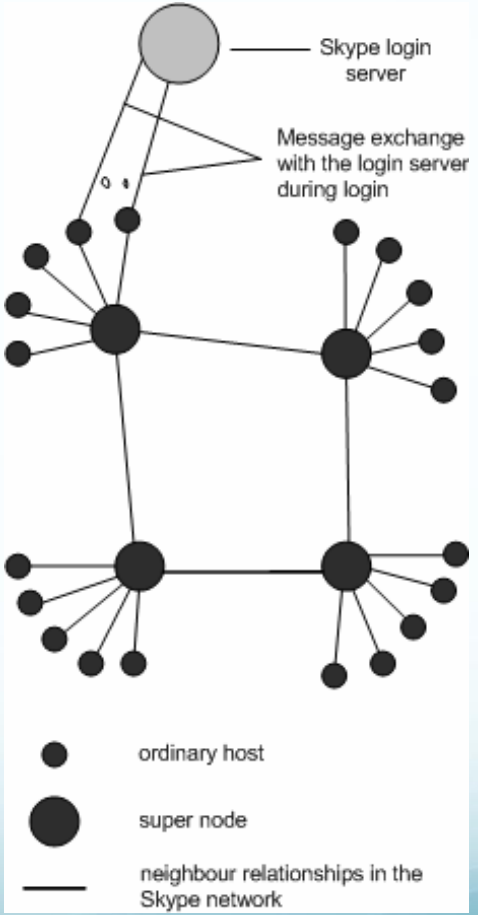
2. Use the HTTP protocol to get a web page
(and we'll make further requests for all its resources, too)



Skype

P2P VOIP





5

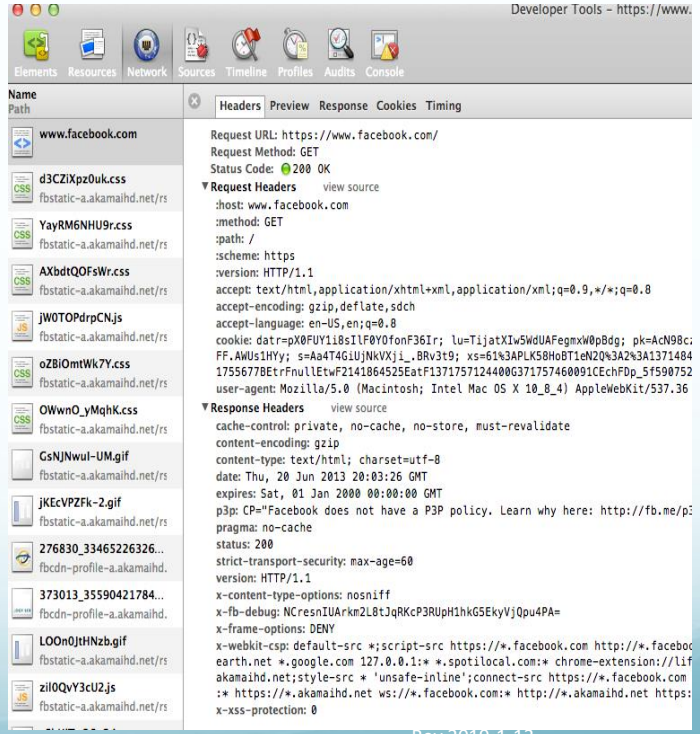
What is a Protocol?

- A protocol is a set of rules
- “A set of conventions governing the treatment and especially the formatting of data in an electronic communications system.” Merriam-Webster Dictionary

- Already we've named:
  - HTTP, DNS, TCP, UDP, IP, and Ethernet protocols

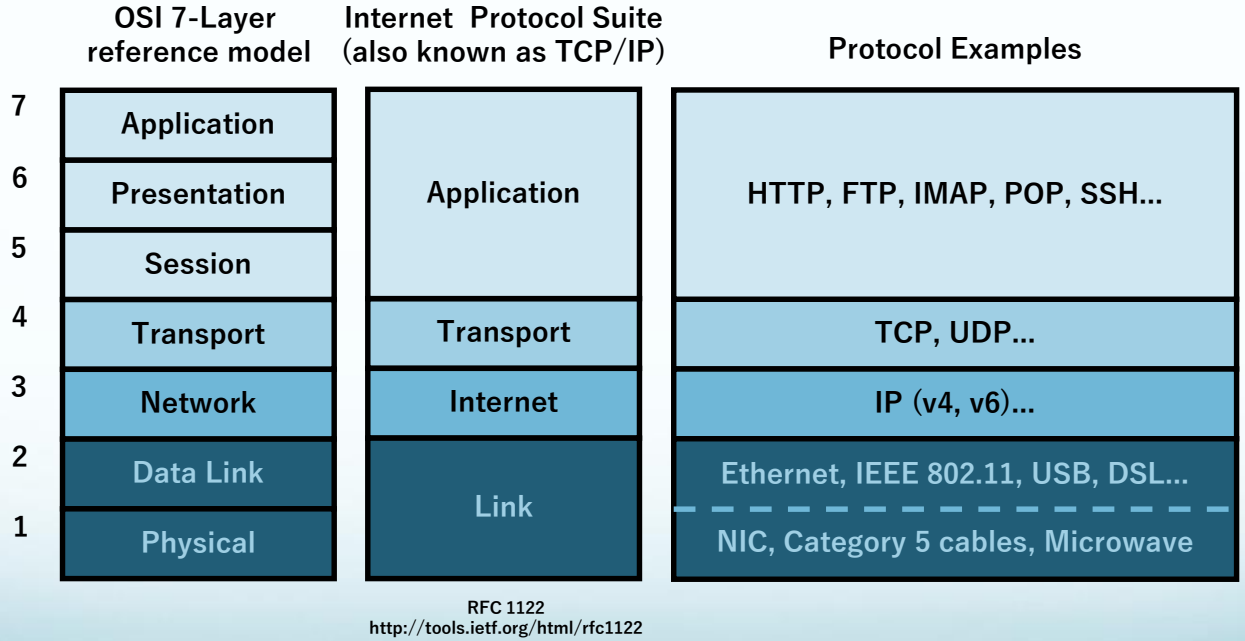
HTTP Protocol

- Let's look at an HTTP request / response cycle:
  - Open Chrome, and visit http://www.facebook.com (or any site of your choosing)
  - Select (Hotdog menu) → Tools → Developer Tools
  - Select Network and then select a page (in this case www.facebook.com)
  - Select "Headers" to see the Request and Response headers



Network Models
and the
Internet Protocol Suite (TCP/IP)

Network Models

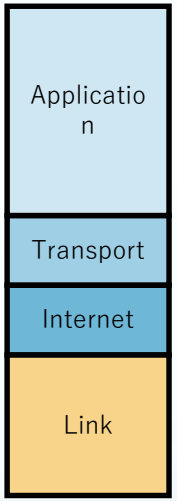


RFC 1122
http://tools.ietf.org/html/rfc1122

Web Browsing

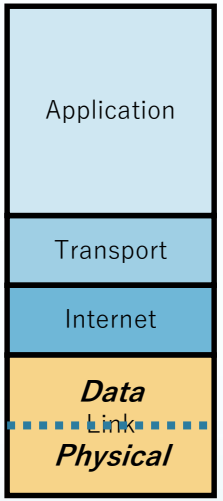
Revisited

The Link Layer



Link Layer

- Physical layer
  - Primarily Cat 5 (wired) and Microwave (wireless)
  - Transmits and receives signals in the form of electrical current, light pulses, microwaves, etc.
- Data link layer
  - The Data layer converts the signal from the Physical layer into 1s and 0s that can be used by the Network layer (and vice versa)
  - *Ethernet* is the most common data layer protocol
  - Data layer messages (called *frames)* can only send messages on the local network

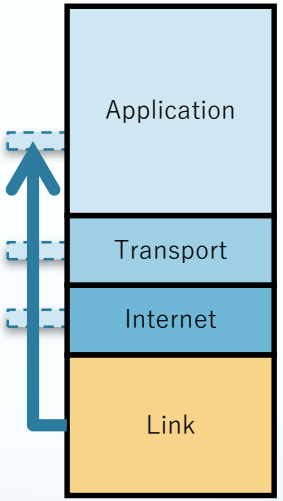


Ethernet: Addressing

- Every Ethernet adapter must have a unique address:
  - Media Access Control (MAC) address
    - aka physical address, Ethernet address, adaptor address, or hardware address (Saunders)
    - is unique to a specific Ethernet adapter
    - 12-digit (48 bit) hexadecimal address
      - e.g. `00-13-CE-BE-8B-9F`
      - Note: 64 bit MAC addresses will supersede 48 bit addresses due to address exhaustion
    - The first 6 digits are the Vendor code, (0013CE belongs to Intel), the last 6 are the individual interface's own. (Saunders)
      - See http://coffer.com/mac_find/ to look up some vendor codes.

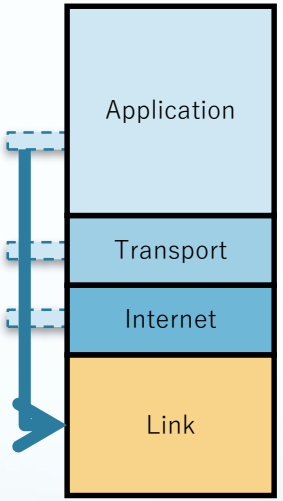
Ethernet Communication 1 of 2

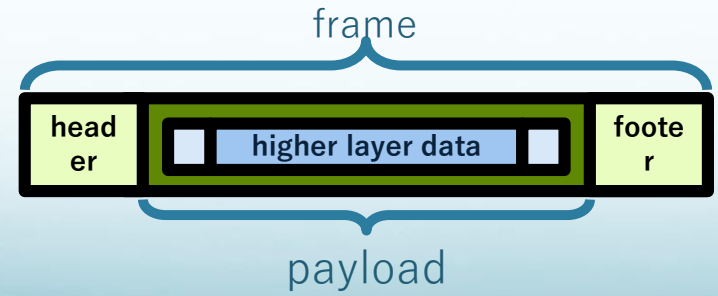
- If one machine on an Ethernet Local Area Network wants to communicate with another, it sends a “broadcast” frame
- All machines on the wire see the frame
  - Check the destination address - is it me?
    - yes - hand data up the stack
    - no - ignore (or so we hope…)
  - When the recipient responds, it will include it’s MAC address in the frame headers
  - From this point, sender and receiver know each other by MAC address (no more broadcasts until a set period of time has passed)



Ethernet Communication 2 of 2

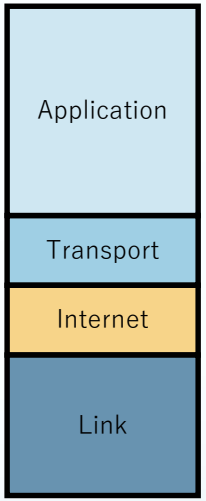
- Sender constructs a frame
  - header includes source and destination address
  - payload (data) comes from higher layer
- Sender puts the frame on “the wire”
  - asks physical layer to send it





The Internet Layer

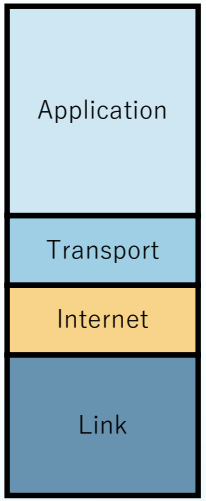
Called the “Network Layer” in the OSI Reference Model



Internet Layer

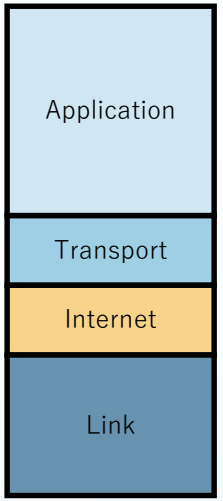
- When you link computers up via the Link Layer you get a network.
- When you link networks up, you get an internetwork.
- You need the Network layer to get data between all the little networks (often called subnets) of your internetwork.

(Saunders)



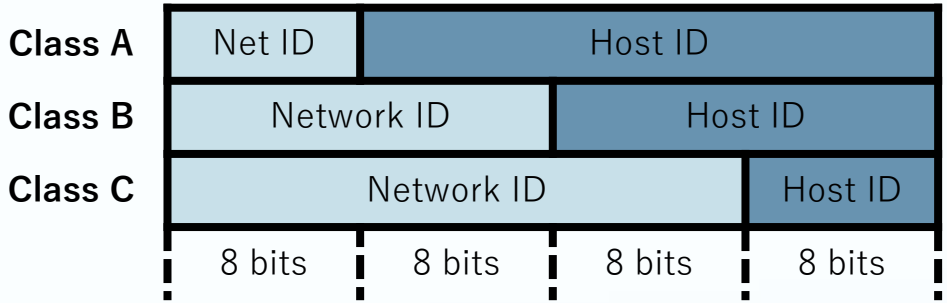
Internet Protocol (IP)

- The Internet Protocol (IP) is the Network layer protocol used on the Internet! It's so handy that most everyone uses it on all their networks big and small.
- Designed for huge, ever-expanding networks of networks. Works pretty well with unreliable links, routes can be re-built when links go down.



Saunders, Drew. *Introduction to Networking* [PDF Document]. Retrieved from http://www.stanford.edu/dept/its/support/techtraining/techbriefing-media/Intro_Net_91407.ppt
Used with permission of the author.

IP Address (IPv4)



- IP Address:
  - First byte(s) identify the network
  - Last byte(s) identify the machine
- RPI is a Class B network
  - 128.113.*subnet.host*
- Every host must have a unique IP address
- Examples:
  - 128.113.91.241
  - 173.194.33.104

Dotted Decimal Notation

- IPv4 addresses are typically displayed by showing the value of each byte (in decimal).

Binary	Dotted Decimal
00000001 00000010 00000011 00000100	1.2.3.4
10000000 11010101 00000001 00000001	128.213.1.1
01111111 00000000 00000000 00000001	127.0.0.1 (localhost)

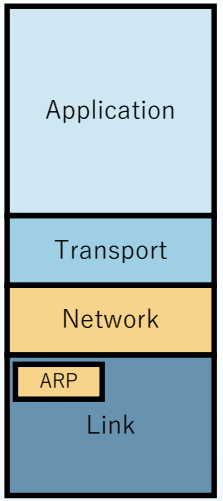
IPv6

- IPv4 addresses are 4 bytes (32 bits)
  - Supports 2^{32} (approximately 4.3 billion) addresses
  - These are becoming exhausted
- IPv6 addresses are 16 bytes (128 bits)
  - Supports 2^{128} (approximately 340 undecillion) addresses
  - Notation uses hexadecimal representing pairs of bytes separated by a colon. For example:
    2620:0:2820:2:3c7f:8f2:389a:b053
- How big is 340 undecillion?
  - If you were to line up 340 undecillion soccer balls back-to-back on a string, the strand would wrap around our known universe 200 billion times.

IPv6 *.340 Undecillion Soccer Balls.* [Web log posting].
Retrieved August 31, 2011 from http://www.ipv6resource.com/340-undecillion-soccer-balls.html

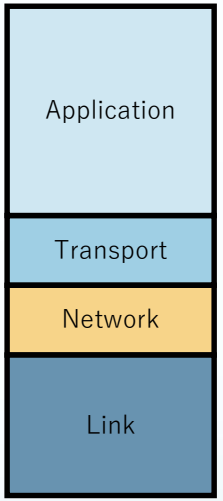
IP Routing 1of 3

- How do we communicate between machines when all we may have is an IP address??
- ARP: Address Resolution Protocol
  - Turns an IP address into a MAC address. You ask “Who’s 172.19.4.15” and if you get a reply, associate the MAC address with the IP address in your ARP table, and now you can keep sending your data to the intended recipient via the correct MAC address. (Saunders)
- Every IP number not on your local network will “belong” to your router in your ARP table.



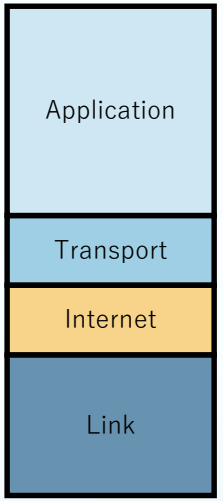
IP Routing 2 of 3

- Routers keep a table of *networks* attainable by the router, called a “routing table”
- A routing table keeps track of
  - the topology of the network immediately around it,
  - measurements to determine best paths to destination networks it knows about,
  - and contains a “default route” for everything else.

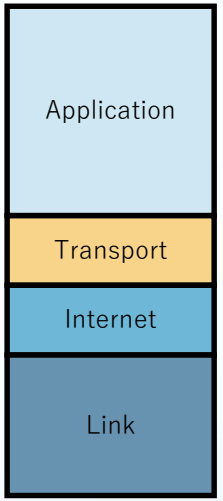


IP Routing 3 of 3

- When an Ethernet frame arrives at a router, it looks at the destination IP address inside the Internet packet and sends a new Ethernet (or other link layer) frame out the correct interface based on the routing tables.
- That frame may go to the final host if it's on one of the routers directly connected networks, or to another router, which does the same process, until your packet gets to the router responsible for that local network, who then sends your packet to the intended host.

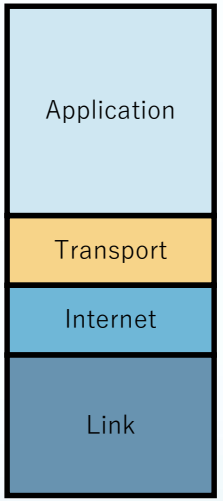


The Transport Layer



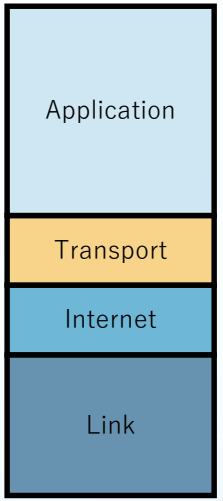
Transport Layer 1 of 2

- Responsible for delivering data to the application layer and for preparing application layer data for transport to other hosts
- Breaks the data up into packets - usually called segments
- Includes source and destination port numbers for application layer processes in its headers

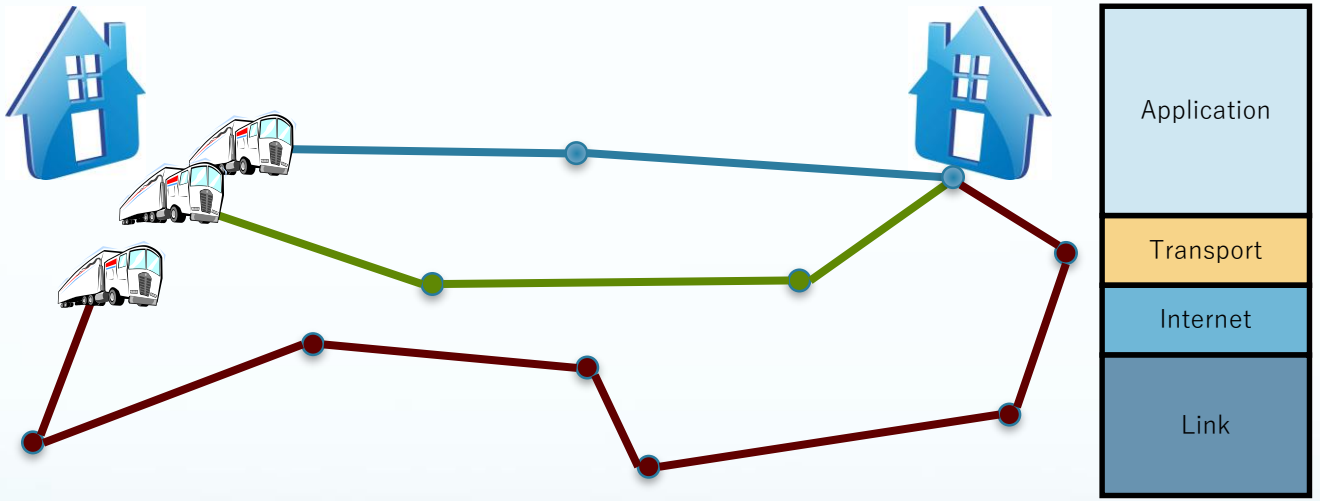


Transport Layer 2 of 2

- Transmission Control Protocol (TCP)
  - *Guarantees* reliability and sequencing
  - Connection-oriented transmission
  - Used by HTTP, FTP, SSH, Email
- User Datagram Protocol (UDP)
  - *Does not guarantee* reliability or sequencing
  - Connectionless, best-effort transmission
  - Used by VOIP, DNS, RTP where speed is more important than lost or damaged packets
- Both use port numbers to identify processes
  - e.g. http is often on port 80, https is often on port 443, mysql is often on port 3306, etc.



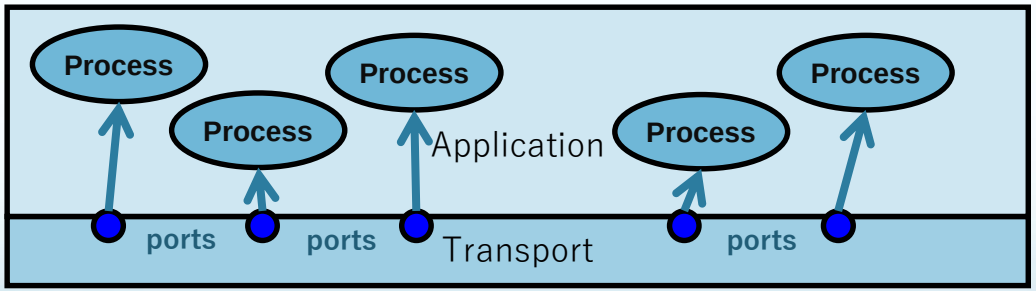
Sequencing

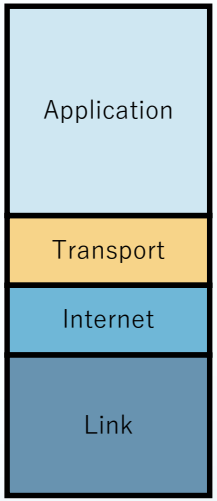


- Different packets may take different routes to get to their destination
- TCP has to put things back in order, UDP does not (though an application may try to do so, e.g. while buffering video)

Ports 1 of 2

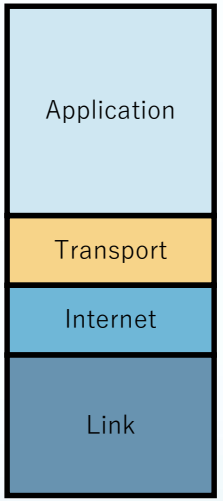
- Ports are application or process-specific endpoints for data communication
- Source and destination ports are included in the transport layer headers





Ports 2 of 2

- Port numbers less than 1024 are typically reserved for important network services
- Common well-known port numbers include 80 (HTTP), 443 (HTTP over TLS/SSL), 53 (DNS) etc.
- You'll sometimes see port numbers on URLs, e.g. "http://somesite:8080"



The Application Layer

Application Layer

HTTP

- Hypertext Transfer Protocol for the WWW

POP, IMAP

- Post Office Protocol and Internet Message Access Protocol for reading email

SMTP

- Simple Mail Transfer Protocol for sending email

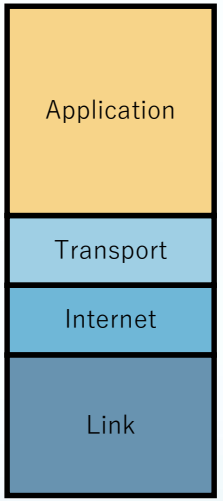
DNS

- Protocol for the Domain Name System (both are referred to as “DNS”)

RTP

- Real-time Transport Protocol for delivering audio and video (e.g. VOIP – uses RTP over UDP)

Many more…



Application Layer Example:

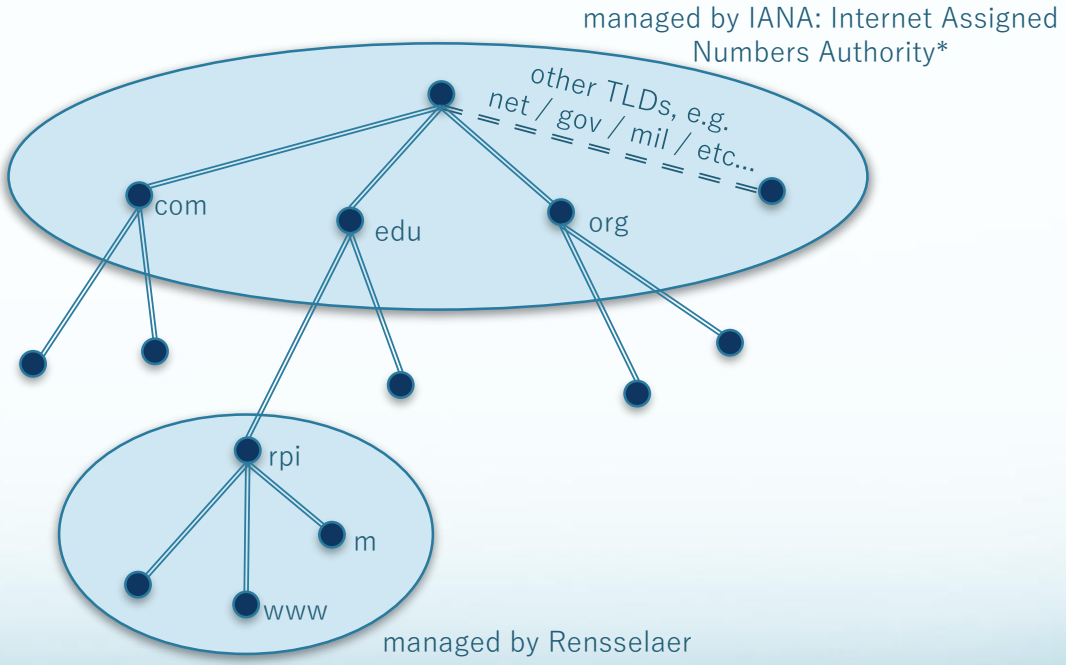
DNS

Domain Name System

Domain Name System

- Domain Name System (DNS)
  - It's hard to remember IP addresses
  - Since computers require numbers, DNS provides a lookup service to convert domain names to IP addresses
  - Example:
    - If you want the number for a host name within the rpi.edu domain, you'll ask one of our DNS servers to give it to you. If you need to go outside rpi.edu, you'll still ask our servers, but they'll figure out which other server(s) should get your request, send it to them (unless our server has already cached it), and will send the reply back to you.

Domain Name Hierarchy



*IANA is part of ICANN: the Internet Corporation For Assigned Names and Numbers

2011: TLDs for Sale

- June 2011: ICANN, the "Internet Corporation for Assigned Names and Numbers", approves a plan to allow groups to create new generic top level domains
  http://www.icann.org/en/announcements/announcement-20jun11-en.htm
- Becoming a registrar is somewhat expensive:
  - $185K evaluation fee
  - Can take up to 20 months to go through evaluation
  - $25K per year if approved (plus possible other fees)

Suggested Reading

- Designing for Cisco Internetwork Solutions, Chapter 1. Network Fundamentals Review.
  - http://opac.lib.rpi.edu/search/t?SEARCH=Designing%20for%20Cisco%20Internetwork%20Solutions&searchscope=1

Works Cited

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List of Figures

1. How were the messages sent along the wall? [Photograph, Great Wall of China]. Retrieved August 4, 2010 from http://www.visitourchina.com/china_great_wall/faq_02.htm
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   [Untitled photo of iPhone with Skype]. Retrieved September 5, 2010 from http://static.skattertech.com/media/2010/05/skype-mobile-for-iphone-3g-600x342.jpg