COMP 204 – Principles of Computer Networks

Week 2

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Agenda

- Review this week's learning outcomes
- Presentation of this week's material
- Introduce homework problems
- Q & A session

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This Week's Outcomes

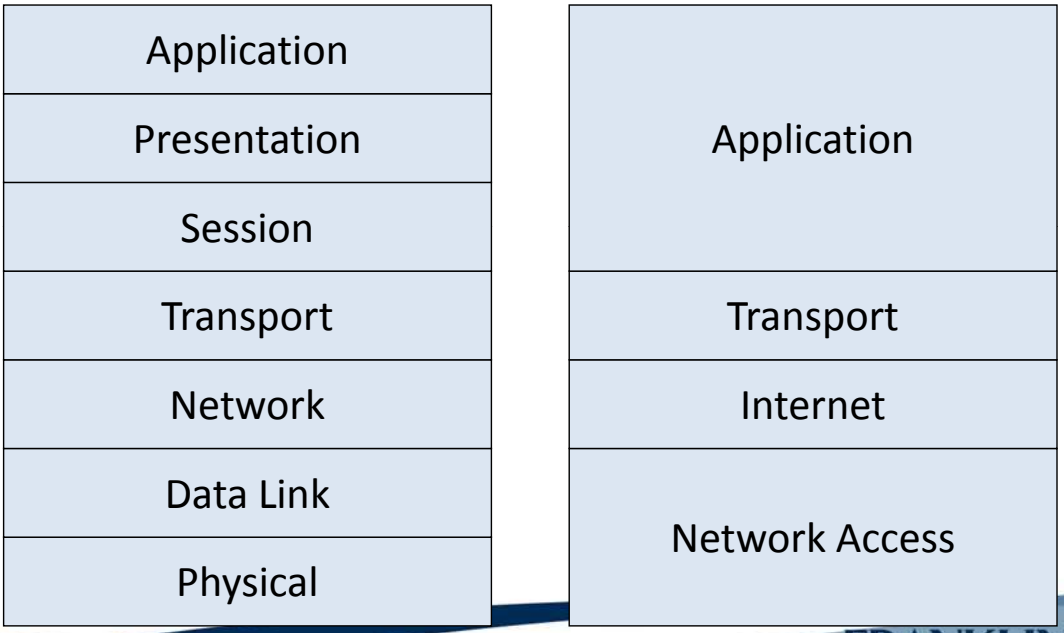
- Explain the functions of common TCP/IP application layer programs.
- Explain how protocols ensure a common language among communications endpoints.
- Compare and contrast TCP and UDP transport layer protocols.
- Simulate the key TCP functions of initiation, termination, acknowledgement, and re-transmission.

Review – OSI model

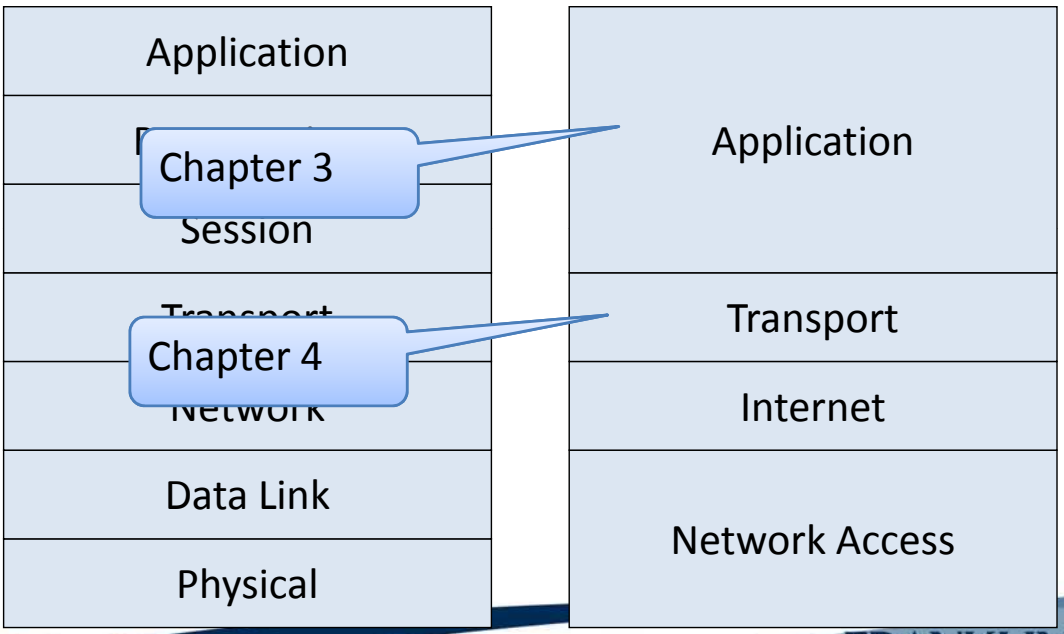
Application
Presentation
Session
Transport
Network
Data Link
Physical

- All People Seem To Need Data Processing (they really do – for exam purposes)
- Each layer provides a different level of abstraction
- Each layer has a well-defined function
- Layer boundaries are chosen to minimize the information flow between layer boundaries
- The number of layers is kept small enough to be feasible

Review - OSI versus TCP/IP



Review - OSI versus TCP/IP



Chapter 3

- Application layer (7 on OSI model)

Application Layer

- Applications vs. Services vs. Protocols
  - User applications – programs that someone runs.
  - Services – processes that the operating system runs to provide services to applications or other parts of the OS.
  - Application protocols – the language defined by an application for exchanging data with other applications or services.

Application Layer

- Applications vs. Services vs. Protocols
  - User applications – programs that someone runs.
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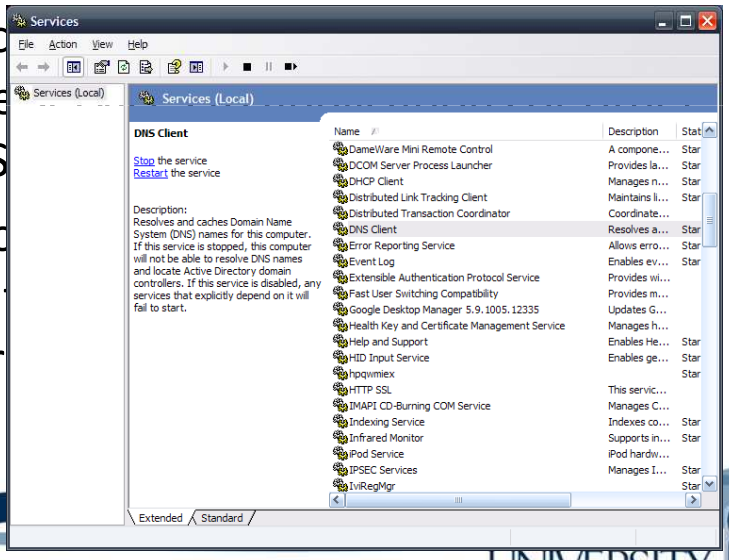
Chrome web browser

Application Layer

- Appli ocols
  - User ap ations – programs that someone runs.
  - Services – proc runs to provide parts of the OS
  - Application pro an application applications or

DNS client – resolves names. Also, httpd or IIS for the web server.



Application Layer

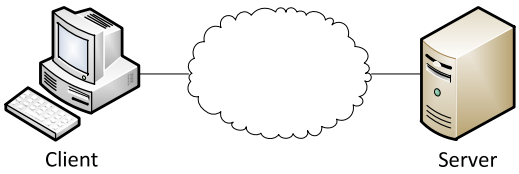
- Applications vs. Services vs. Protocols
  - User applic… someone runs.
  - Services – p… rating system runs to pro… tions or other parts of the O…
  - Application protocols – the language defined by an application for exchanging data with other applications or services.

HTTP – client/server protocol for sending requests and receiving responses.

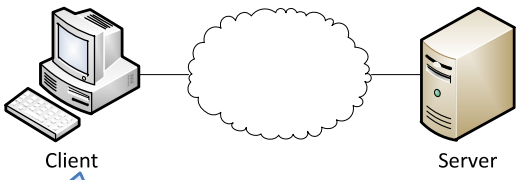
Application Layer Protocols

- Rules for exchanging data between applications.
- How is data structured in the messages?
- What kind of messages (errors, requests, responses, etc.)?

Applications and Services



Applications and Services

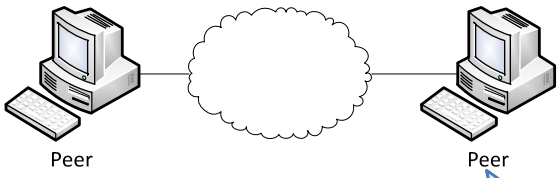


Runs the application

Runs the service

It's still "client-server" even if the application and the service run on the same machine.

Applications and Services



Runs the application and the service

Runs the application and the service

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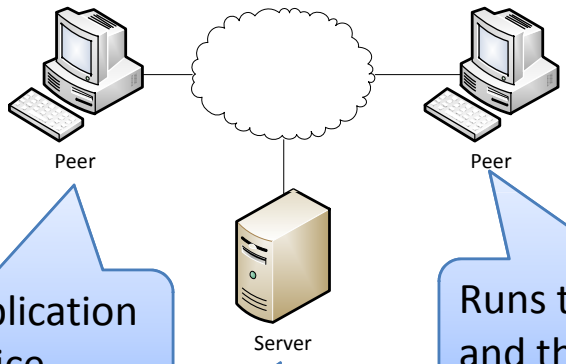
Applications and Services



Runs the application and the service

Runs the application and the service

Often employs a “centralized” service for naming or tracking purposes.

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Book examples

- DNS (domain name system) resolution
- Web servers and HTTP
- E-mail servers and SMTP (simple mail transfer protocol), POP (post office protocol), IMAP (internet message access protocol)
- DHCP (dynamic host configuration protocol) clients and servers

DNS – Background

- Original Internet had flat namespace
- INTERNIC approved names which has the following shortcomings:
  - Central authority
    - Big workload
    - Cannot delegate
  - Does not accommodate large sets
    - Name conflict
    - Difficult to maintain translation file

DNS – Design Goals

- Decentralized naming mechanism
- Ability to delegate the authority
- Distributing translation responsibility
- Similar to organizational structure

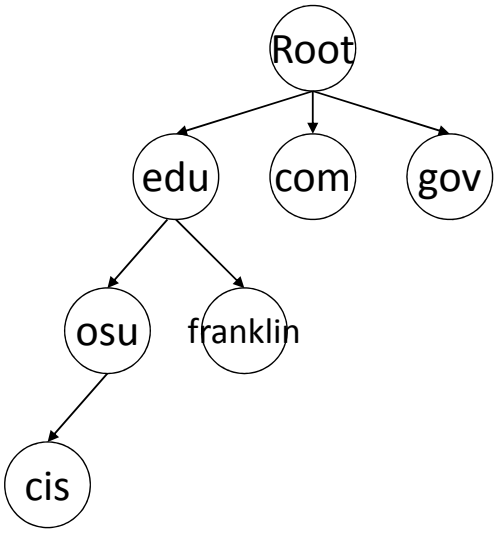
DNS – Features

- Distributed system
- Efficient – most names resolve locally
- Reliable – no single point of failure
- Servers are called **name servers**
- Clients are called **name resolver**

DNS – Features

- Conceptually each level knows next level down
- Each server has naming authority
- Each subdomain would need its own server
- In reality multiple levels are served by single server

Mapping Domain Names



DNS – Hierarchical Design

- Hierarchical naming scheme
- Partitioned at the top
- Authority for names in subdivisions is delegated
- Similar to phone numbers
  - Area code, exchange, subscriber number
- Names in partition do not conflict

DNS – Hierarchical Design

- Hierarchical naming does not imply physical location
- DNS allows computers to be named by logical association, not physical
- Each sub-tree of the name space is called **domain**
- Part that the name server is responsible for is called **a zone**
- If the name server does not delegate the responsibility for managing its domain, then **domain** is the same as the **zone**
- Mapping information is stored in a **zone file**

DNS – Name Servers

- **Primary server** stores, maintains and updates the zone file on its own
- **Secondary server** downloads the **zone file** from the **primary server** during the process called **zone transfer**
- Both servers are **authoritative** for that zone
- Done for redundancy purposes

DNS – Basics

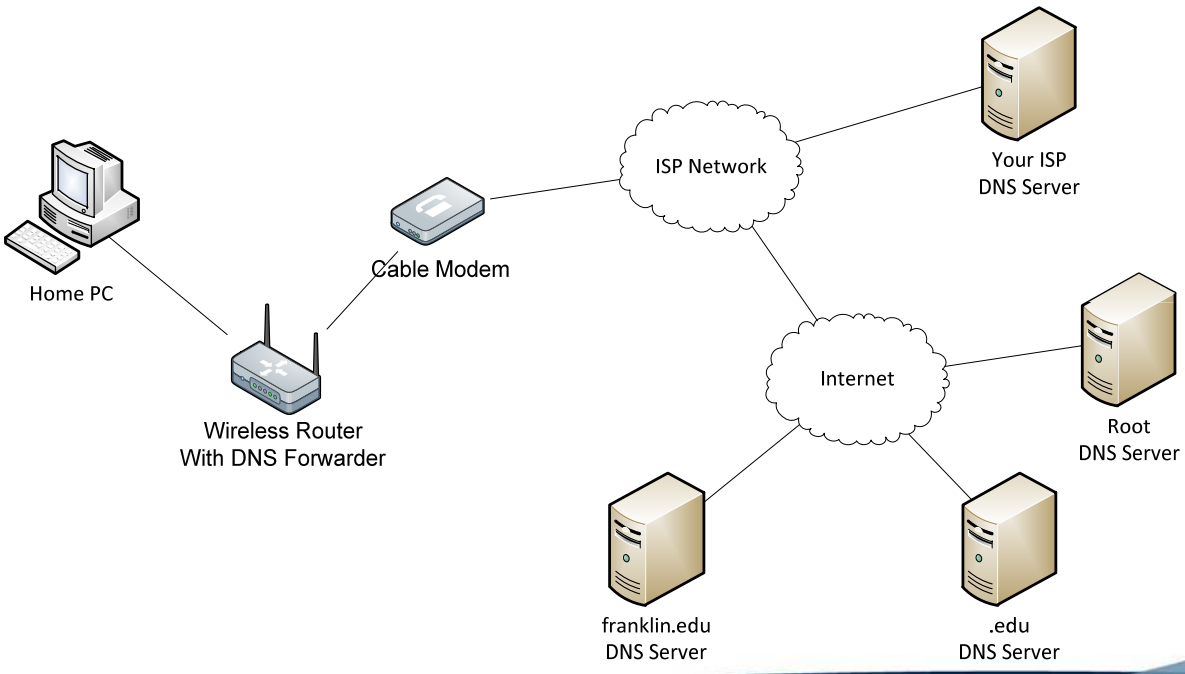
- Two major concepts
  - Name syntax and rules for delegation
  - Implementation of distributed mapping system
- Each level is a label
- Labels are separated by dots

DNS – Example

- Highest level is last

  cs.franklin.edu
- Three labels
  - cs
  - franklin
  - edu
- Three domains
  - cs.franklin.edu
  - franklin.edu
  - edu

DNS – Example



DNS – Syntax

- Standard only specifies syntax
- Any organization could choose own values for labels
- Usually follow official Internet domain system
- Organizational or Geographical

DNS – Top Level Domains

- Top level organizational domains
  - COM – commercial organizations
  - EDU – educational institutions
  - GOV – federal government institutions
  - MIL – United States military
  - NET – major network support centers
  - ORG – other organizations
  - INT – international organizations

DNS – Top Level Domains

- Geographical domains
- Two letter country codes (ISO 3166)
- 239 official country codes (as of 2/26/01)
    - US – United States
    - CA – Canada
    - DE – Germany
    - JP – Japan
    - LI – Liechtenstein
    - TW – Taiwan, Province of China

DNS – US Domain Names

- US Domain subdivided
    - FED – Federal government agencies
    - DNI – Distributed national institutes
    - 50 state codes
        - CI.<city>.<state>.US
        - CO.<county>.<state>.US
        - <school>.K12.<state>.US
        - <school>.CC.<state>.US

DNS – Examples

- City of Columbus
  - `WWW.CI.Columbus.OH.US`
- Dublin City Schools
  - `WWW.Dublin.K12.OH.US`
- Franklin County
  - `WWW.CO.Franklin.OH.US`
- Delaware County
  - `WWW.CO.Delaware.OH.US`

DNS – Protocol

- A given name may map to more than one item in the domain system.
- Must specify what type of resolution is desired
- May need IP address or mail exchanger

DNS – Query Types

- Queries and Resource records contain type

Type	Meaning
A	Host address to IP
MX	Mail Exchanger
NS	Name of authoritative server for domain
CNAME	An alias in case multiple services are running on a single server

DNS – Resolution

- Two methods of resolving names
  - Recursive – Asking name server for complete resolution. The client asks the name server for resolution, if the server has the necessary information its returned. Otherwise, the server queries other servers to find out the answer.
  - Iterative – Contacting names servers one at a time. The client asks the name server for resolution, if the server has the necessary information it is returned. Otherwise, the name of the server that might have the information is returned, so the client can re-query it.

DNS – Resolution

- Must be efficient
- What if always start at root
  - Most translations are local
  - Root would be overloaded
  - Root failure would cause system failure
  - Generate lots of network traffic

DNS – Caching

- Name servers use name caching
  - Contains recently used names and where mapping was obtained
- Server checks cache
  - Sends **non-authoritative** response
  - Includes server and its IP address
- Client decides whether to use or revalidate

DNS – Caching

- Each cache entry has a time limit
- Entry is deleted when expires and mapping is requested again
- Time limit is set by original server
- Long time limits can be sent for static binding, short for dynamic bindings

DNS – Caching

- Some OS download local name server database (including time limits)
- Name resolution requires no traffic
- Must check with name server for updates, expired entries

DNS – Utilities

- nslookup
  - Used to lookup a translation from name to address
- named
  - Unix name server

Chapter 4

- Transport layer (4 on OSI model)

Transport layer

- Tracks communication between apps on sender and receiver.
- Segments data for multiplexing and flow control (sender).
- Reassembles segments into streams (receiver).
- Error recovery, open and close sessions.

Conversations

- One computer can simultaneously be sending/receiving data on many applications.
- How is this done?
  - Ports
  - Segmentation

Ports

- Each application is assigned a *port* for communication. Just a number.

Port	Keyword	Unix Keyword	Description
7	Echo	echo	Echo
20	FTP-DATA	ftp-data	File Transfer Protocol (data)
21	FTP	ftp	File Transfer Protocol
43	NICNAME	whois	Who is
53	DOMAIN	nameserver	Domain Name Server
80	HTTP	http	Web servers

Ports

- Each application is assigned a *port* for communication. Just a number.

Port	Keyword	Unix Keyword	Description
		echo	Echo
		ftp-data	a)
21	FTP	ft	
43	NICNAME	whois	Who is
53	DOMAIN	nameserver	Domain Name Server
80	HTTP	http	Web servers

This program…

…is tied to this port.

Ports

- "Well known" ports are 0 – 1023
- "Registered" ports are 1024 – 49151
- "Dynamic" ports are 49152 – 65535
- Where the heck do these weird numbers come from?

Ports

- Binary (base 2 number system).
  - Fixed width field consisting of all 1's and 0's.

Bin	Dec	Hex
0000	0	0
0001	1	1
0010	2	2
0011	3	3
0100	4	4
0101	5	5
0110	6	6
0111	7	7

Bin	Dec	Hex
1000	8	8
1001	9	9
1010	10	A
1011	11	B
1100	12	C
1101	13	D
1110	14	E
1111	15	F

Ports

- Binary (base 2 number system).
  - What is this 10101011_2 in decimal? Hex?
    - $1*2^7 + 0*2^6 + 1*2^5 + 0*2^4 + 1*2^3 + 0*2^2 + 1*2^1 + 1*2^0 = 171_{10} = AB_{16}$.

Ports

- 0000 0100 0000 0000 ts are 0 – 1023
- 1011 1111 1111 1111
- "Registered" ports are 1024 – 49151
- "Dynamic" ports are 49152 – 65535
- Where the heck do th se weird umbers come from?

1100 0000 0000 0000

1111 1111 1111 1111

Socket

- Combination of an internet name or number and a port is called a *socket*.
  - Ex: www.franklin.edu:80
  - Ex: cs.franklin.edu:22
  - Ex: 127.0.0.1:7

Socket

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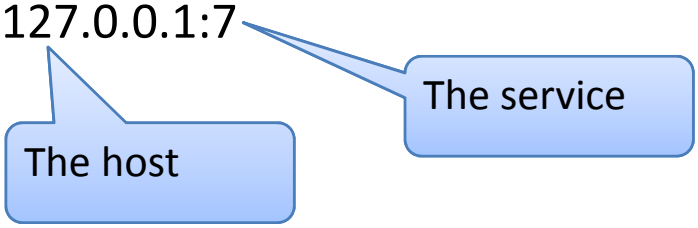
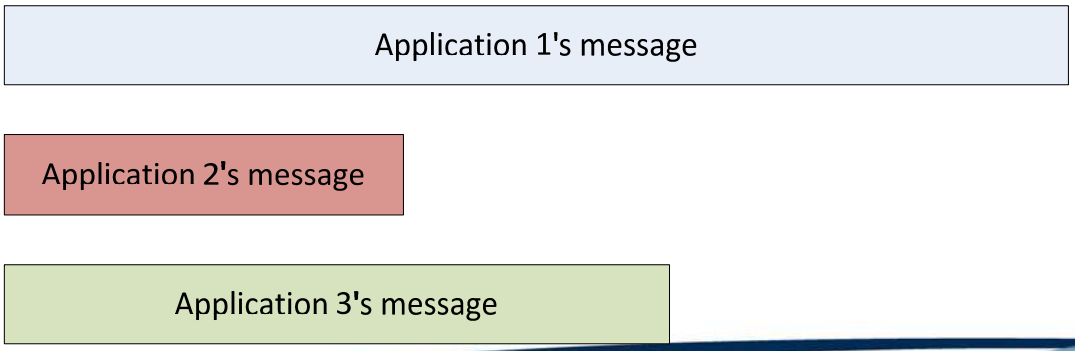


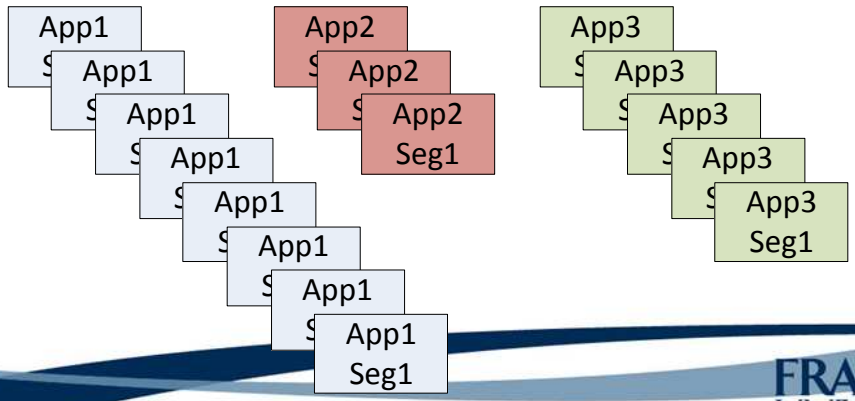
Segmentation

- How do we share the network, especially when sending long messages?
  - Long messages tie up the network for a very long time – and other problems…



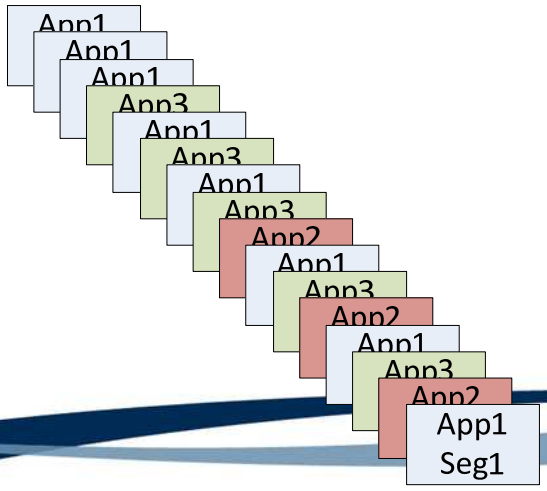
Segmentation

- How do we share the network, especially when sending long messages?
  - Multiplex the network by breaking up long messages into multiple *segments*.



Segmentation

- How do we share the network, especially when sending long messages?
  - Interleave the sending of the segments



Segmentation

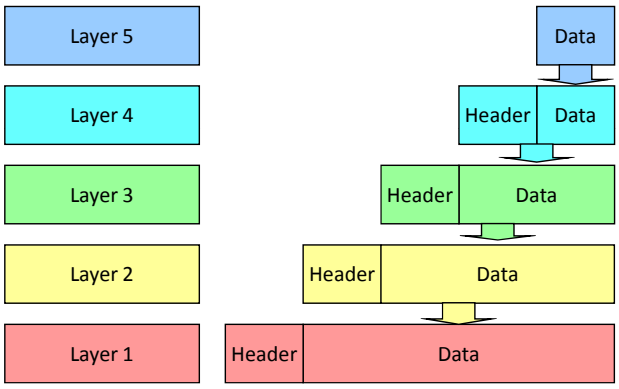
- How do we share the network, especially when sending long messages?
  - What has to happen on the other end?

Flow and error control

- Flow control determines the speed of transmission such that the network isn't flooded.
- Error control is resending segments that are lost or corrupted in transmission.

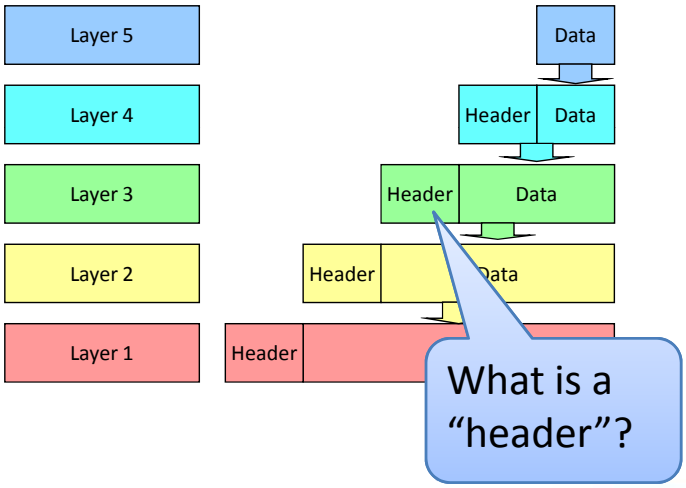
UDP

- Remember this diagram?



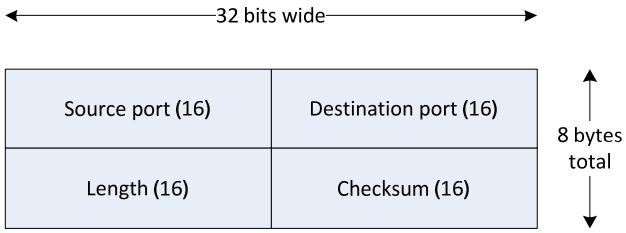
UDP

- Remember this diagram?



UDP

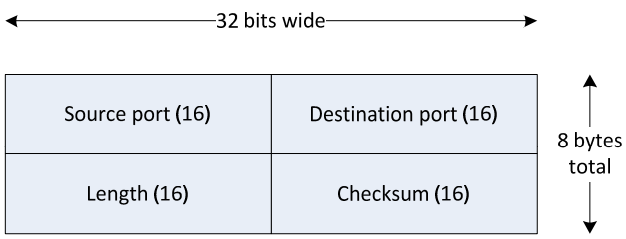
- UDP header



- 2^{16} is 65536, therefore max UDP segment is 64K (where "1K" is 1024)

UDP

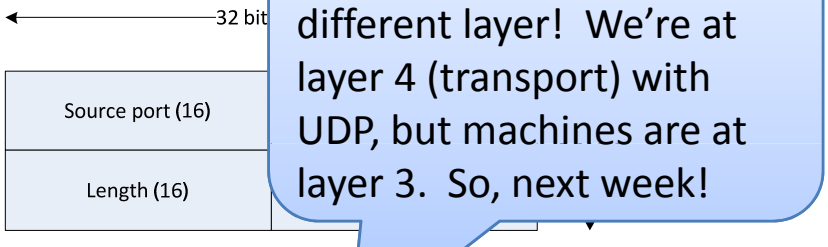
- UDP header



- If a port identifies a program on a machine, how does the segment get to the machine?

UDP

- UDP header



That's a problem for a different layer! We're at layer 4 (transport) with UDP, but machines are at layer 3. So, next week!

- If a port identifies a program on a machine, how does the segment get to the machine?

UDP

- UDP
  - Considered to be “unreliable” delivery.
    - Packets are just sent out on the network.
    - No acknowledgement of receipt, retransmissions.
    - Segments can arrive out of order.
  - Very low overhead
    - Only 8 bytes in the header.
    - No acknowledgement or retransmissions.

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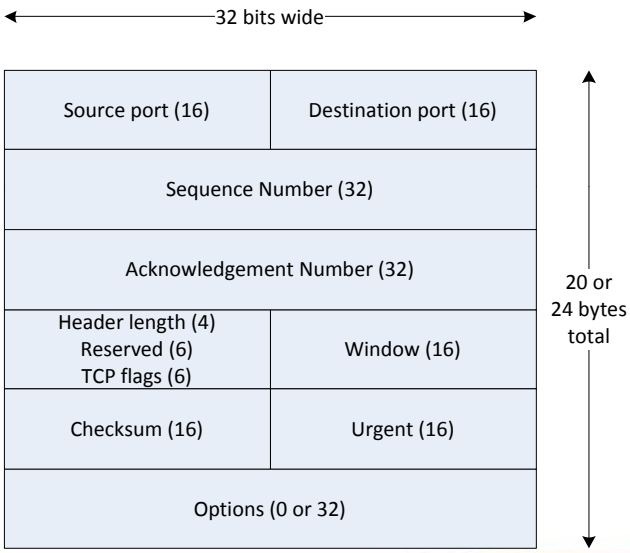
Very much like the standard US postal service!

TCP

- TCP header



TCP

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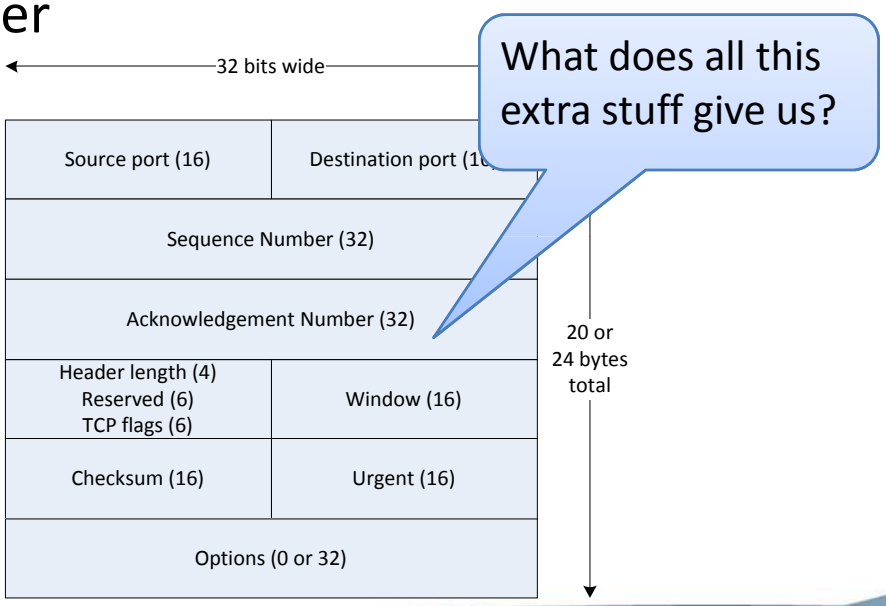
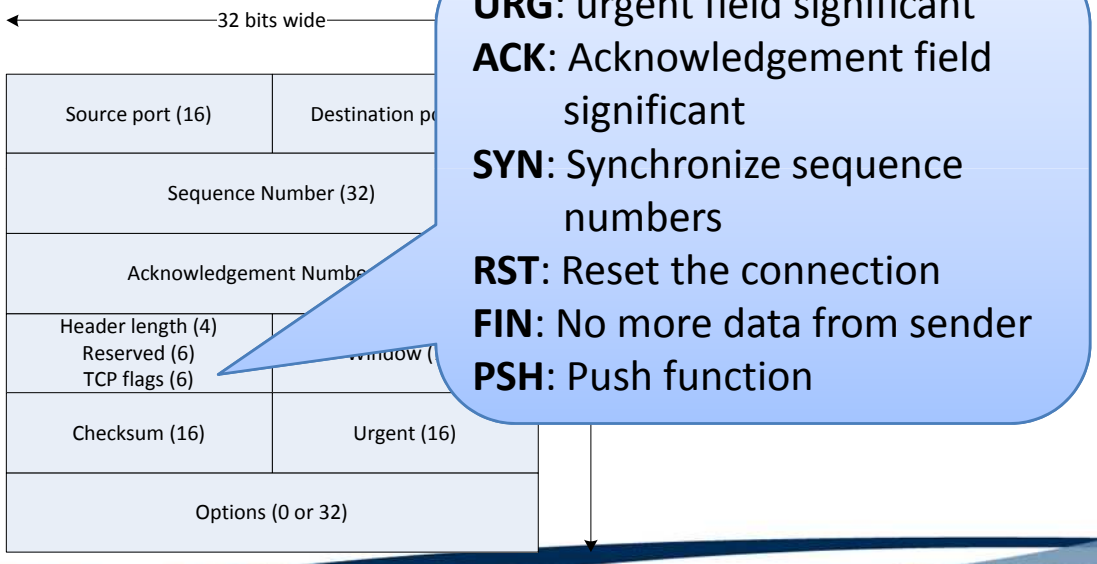


TCP

- Connection-oriented protocol
  - Reliable: lost or mangled packets are retransmitted.
  - Sequenced: messages can be reassembled into the same stream in the same order as was sent.
  - Flow and congestion control: window size can be changed to allow more or less data at a time.

TCP

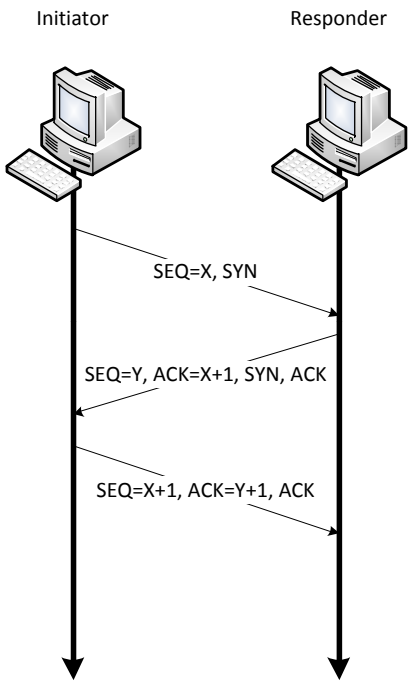
- Flags

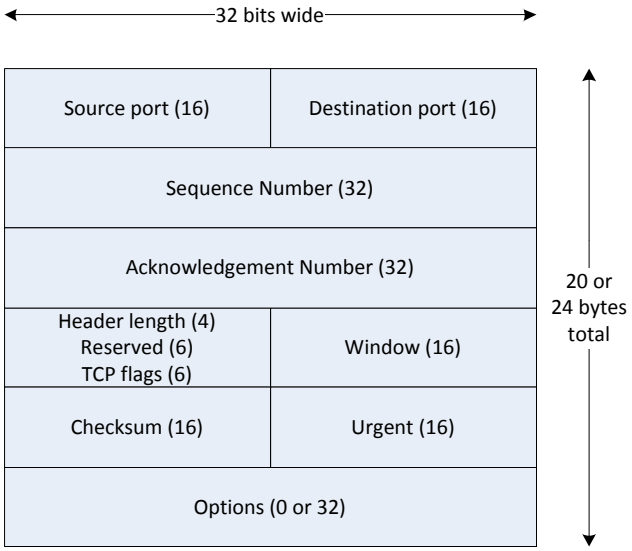


TCP

- Establishing a conversation
  - 3-way handshake required
    - Initiator opens the connection with SYN
    - Responder ACKs and sends own SYN
    - Initiator ACKs

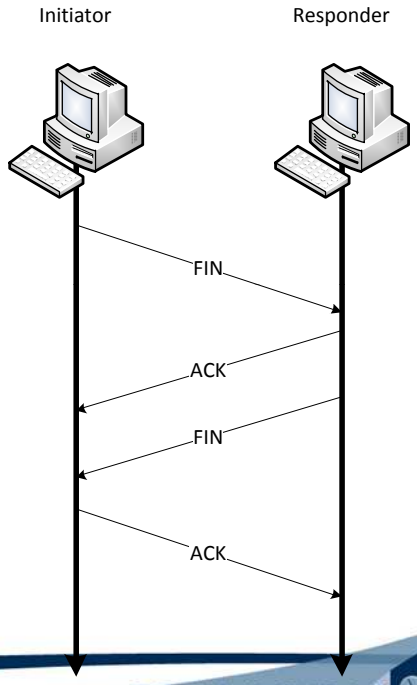
TCP





TCP

- Nicely ending a conversation
  - 3-way handshake required
    - Initiator sends FIN
    - Responder sends ACK
    - Responder sends FIN
    - Initiator sends ACK

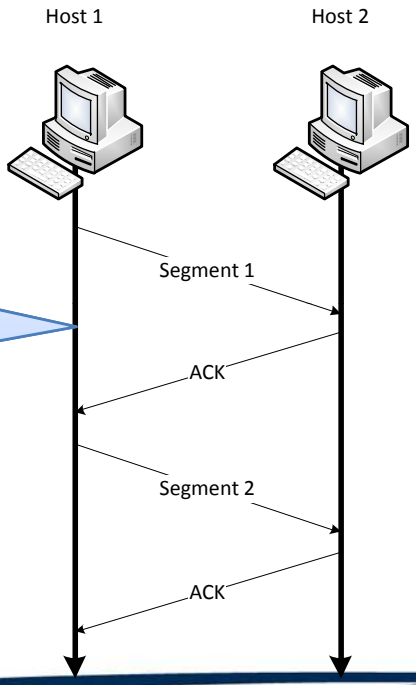


TCP

- Quickly ending a conversation
  - Send RST.
    - This is what Comcast did.
    - Net neutrality issue.

TCP

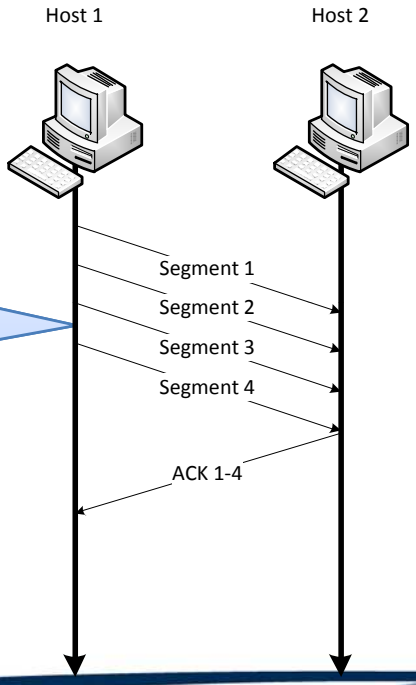
- Windowing



This gets very slow as we acknowledge every segment one at a time.

TCP

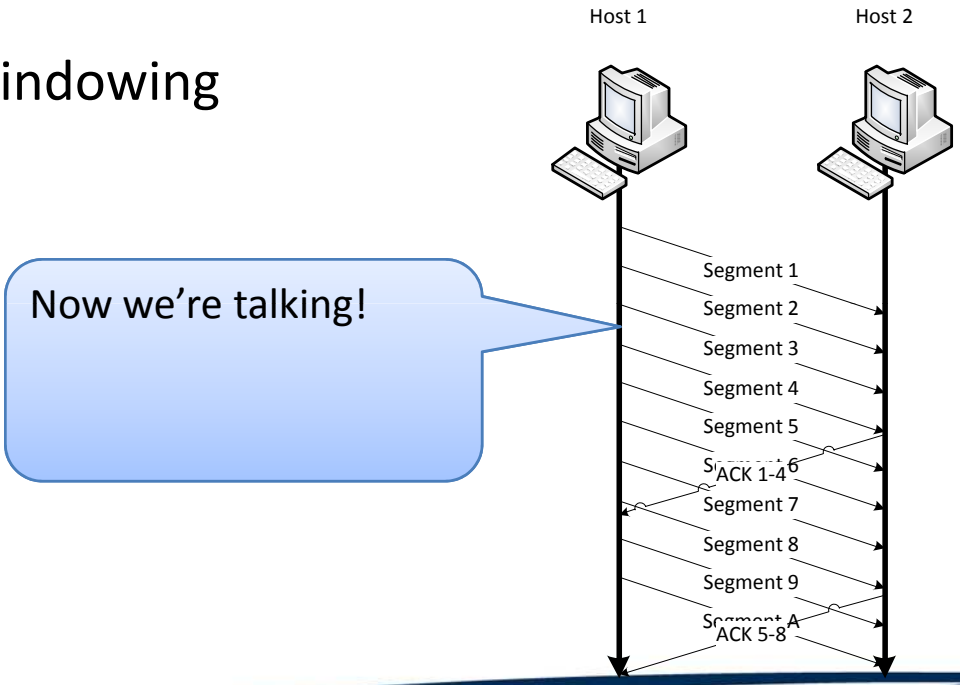
- Windowing



Getting better…

TCP

- Windowing



TCP

- Retransmission
  - When a segment is sent, the sender will also put it in a retransmit queue.
  - When an ACK is received, the sender will remove all ACKed segments from the queue.
  - If an ACK is not received after a set amount of time, or if the ACK numbers don't match, the sender will retransmit *all* segments in the queue.

TCP

- Windowing
  - The amount of data a host can receive before an ACK is the window size.
  - Window sizes can be adjusted on the fly in case packets get lost (smaller) or if the receiver can handle the data faster (larger)

This Week's Outcomes

- Explain the functions of common TCP/IP application layer programs. ✓
- Explain how protocols ensure a common language among communications endpoints. ✓
- Compare and contrast TCP and UDP transport layer protocols. ✓
- Simulate the key TCP functions of initiation, termination, acknowledgement, and re-transmission. ✓

Self Quiz

- Compare and contrast client/server and peer-to-peer architectures.
- What is the differences between a user application, a service, and an application protocol?
- TCP and UDP are at what layer in OSI?
- How is a network shared effectively?

Self Quiz

- How does TCP achieve connection oriented communications?
- Why is UDP considered “unreliable”? What makes it so?
- How are TCP sessions initiated? Closed?
- How does a sender know to retransmit in TCP? In UDP?

Due this week

- Proctor forms
- Homework 1
- Lab 1
- Participation 2

Due next week

- Homework 2
- Participation 3

Next week

- Chapter 5
- OSI Layer 3
- Internet Protocol (IP)
- Addressing and routing

Q & A

- Questions, comments, concerns?