Welcome to:

Computer Science 457
Networking and the Internet

Fall 2016
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Website: http://www.cs.colostate.edu/~cs457
- For both local and remote students
- Syllabus, Outline, Grading Policies
- Homework and Projects
  - Available on CANVAS
  - Submit on CANVAS

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Recitation Sections (WF@ CSB 315)
- Unix/C/Makefile tutorials, Socket programming
- Homework/Project discussion/solutions
Grading and Policies

• Grading
  – 10% Homework
  – 5% Project 1
  – 10% Project 2
  – 25% Project 3
  – 20% Midterm 1
  – 20% Midterm 2

• Grading Policy
  – See grading policy for late homeworks and projects on the website
  – No make-up exams. It is your responsibility to check for conflicts and make arrangements
Workload

- Weekly Reading Assignments
- Frequent Homework Assignments
  - Some from the book
  - Pen & paper problems, small programming exercises
  - Submissions **MUST** be typed! Be nice to the TA
- Exams
  - 2 midterms
- Course Projects
  - Language: **C/C++ ONLY!** (no Java or Python or other languages)
  - Projects can be developed on your laptop, but **MUST** run on Linux Lab machines in the CS department.
What About the Book?

• All the material you need for the exams will be on the slides

• However, the book is very valuable to clarify concepts and help you with the homework

• Don’t care what edition of the book you have, but make sure you solve the correct homework! It is your responsibility to identify correct homework
How to Do Well in this Class

• Review your C/C++ now! Projects 2 and 3 are not trivial

• Do all the homework

• Understand the high-level picture during the lecture. You can review details later on your own, or ask me or the TA

• After each lecture, ask what you have learned and how it fits with the big picture
Cheating Policy

• Simple cheating policy
  – Anyone caught cheating will FAIL the CLASS!
  – Regardless of what you cheated on, so don’t cheat.
  – We know that solutions to the book exercises are on the web – don’t use those solutions!

• Plagiarism – see definition
  – http://writing.colostate.edu/guides/teaching/plagiarism/
  – Rule of thumb: if you didn’t write it, it’s not yours
  – Cut and paste from the Web is plagiarism 99% of the time
Questions?
Our Focus: the Internet

• There ARE other networks!
  – Cable, satellite, POTS, sensor nets, etc.

• Interested in Protocols and Mechanisms
  – Protocol rules and algorithms
  – Investigate mechanism tradeoffs
    • Why this way and not another?

• First high-level picture, then the details
By the End of the Class..

• You will have a good understanding of networking concepts
• You will know UDP/TCP/IP
• You will understand how key applications of the Internet work
Chapter 1: Foundations

• Networking is a very broad topic
  – How does a wireless card talk to a base station?
  – How does a message get from CSU to Amazon.com?
  – How does an application (web browser, IM, P2P) work?
  – How to do deal with loss, delay, congestion, security?

• First Goal: Learn Big Picture and Terminology
  – What are network layers?
  – What is a protocol?
  – What are the basic network components?
What is a Network?

Point-to-Point

Multiple Access

Wireless
Definition of a Network

- A network can be defined recursively as...
  Two or more nodes connected by a link, or
  two or more networks connected via two or more nodes

Internet: network of networks
Simplest Network
Local Area Network (LAN)
Network of LANs

argon.tcpipe-lab.edu
"Argon"
128.143.137.144

neon.tcpipe-lab.edu
"Neon"
128.143.71.21

router137.tcpipe-lab.edu
"Router137"
128.143.137.1

router71.tcpipe-lab.edu
"Router71"
128.143.71.1

Ethernet Network

Router
Internetworking

- Internetwork = Collection of networks connected via routers
Internet = Virtual Network
Network Components

• The network is composed of:
• Hosts or endpoints (PCs, PDAs, cell-phones, laptops, etc.)
• Routers (specialized machines that route packets)
• The distinction is often blurred (caches, content servers, etc.)
Network

• Network needs:
  – wires (from the phone or cable company) and maybe some wireless equipment
  – Router(s)
  – a firewall?
  – an ISP to connect to the Internet
  – a network address block (e.g., 192.168.1.xxx)
  – servers
An ISP

- ISP needs:
  - a (big?) block of addresses
  - connections to one or more other ISPs, *peerings*
  - multiple routers, some at *exchange points*
  - servers for your users: mail, web, etc.
  - servers for you: monitoring, billing, etc.
  - competent network admins (recommended)
  - an AUP (Acceptable Use Policy)
  - a lawyer
Idealized Network Structure

Backbones, Tier 1
(national, global)

Regional, Tier 2

Campus LANs,
Business

The Internet today looks nothing like this!
Some Basic Terms

Simple Example: Use web browser to lookup www.cnn.com

My laptop and the web server are both **End Systems = Hosts**

End systems can also include PDAs, sensors, cell phones, and generally any device using the network to communicate

End systems are located at the **network edge** and connected to the network using **communication links (wired or wireless)**
End systems may be classified as **client**, a **server**, both, or neither.  
**Client** - runs *some program* that requests services:  
web browser requests a page, email reader requests messages,  
ftp program requests files, etc.  
**Server** - runs *some program* that listens for requests and provides services.  
web server, email server, ftp server, etc.  
Client vs. server depends on what programs the end system is running.
What is a Packet?

• Self-contained set of bits
• Includes a header and (in most cases) user data or payload
• **Header**: needed by the network - contains control information needed to deliver the packet to the destination
• **Payload**: can be anything – network does not care
**Example: IP Packet**

<table>
<thead>
<tr>
<th>4-bit Version</th>
<th>4-bit Header Length</th>
<th>8-bit Type of Service (TOS)</th>
<th>16-bit Total Length (Bytes)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16-bit Identification</td>
<td>3-bit Flags</td>
<td>13-bit Fragment Offset</td>
<td></td>
</tr>
<tr>
<td>8-bit Time to Live (TTL)</td>
<td>8-bit Protocol</td>
<td>16-bit Header Checksum</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>32-bit Source IP Address</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>32-bit Destination IP Address</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Options (if any)</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Payload</th>
</tr>
</thead>
</table>
Circuit vs. Packet Switching

- **Circuit switching:**
  - Reserve the circuit ahead of time, exclusive use by one connection
  - Like reserving your own lane in the highway, so your lane cannot be used by others. But with networks, the highway has hundreds or thousands of lanes!!
  - Example: Telephone network (POTS)

- **Packet switching:**
  - Nothing gets reserved, share the lanes with everyone else
  - Leads to **Statistical Multiplexing!!** (remember this term)
  - Example: Internet

- **What are the advantages/disadvantages of each?**
Packet Switching Illustration

Interleave packets from different sources

- Efficient: resources used on demand
  - Accommodates multiple applications, bursty traffic
  - Statistical multiplexing
Statistical Multiplexing Gain

Problem: Link is 1 Mbps; users require 0.1 mbps when transmitting; users active only 10% of the time. How many users can we support?

Answer:

• Circuit switching: can support 10 users.
• Packet switching: with 35 users, probability that >=10 are transmitting at the same time = 0.0004.
Host Configuration

Host configuration needs:
1. a physical network cable or wireless card
2. an IP address
3. a network mask
4. a gateway
5. a DNS server (and other servers)

2-5 often obtained using DHCP (dynamic host configuration protocol)
How Do Computers Find Each Other?
What Are the Different Kinds of Names and Addresses?

- Have domain name (e.g., www.colostate.edu)
  - Global, human readable name
- DNS translates name to IP address (e.g. 128.82.103.106)
  - Global, understood by all IP networks
- Finally, we need local net address
  - e.g., Ethernet (08-00-2c-19-dc-45)
  - Local, works only on a particular type of link
Sending a packet from Argon to Neon

argon.tcpip-lab.edu
"Argon"
128.143.137.144

router137.tcpip-lab.edu
"Router137"
128.143.137.1

router71.tcpip-lab.edu
"Router71"
128.143.71.1

neon.tcpip-lab.edu
"Neon"
128.143.71.21
Sending a packet from Argon to Neon

**DNS:** What is the IP address of "neon.tcpip-lab.edu"?

128.143.71.21 is not on my local network. Therefore, I need to send the packet to my default gateway with address 128.143.137.1.

**ARP:** What is the MAC address of 128.143.71.21?

128.143.71.21 is on my local network. Therefore, I can send the packet directly.

**ARP:** The MAC address of 128.143.137.1 is 00:e0:f9:23:a8:20.

128.143.137.1 is not on my local network. Therefore, I need to send the packet to my default gateway with address 128.143.137.1.

**ARP:** The MAC address of 128.143.137.1 is 00:20:af:03:98:28.
DHCP Simplified

Computer 1

Broadcast: I need an IP address/mask

Here you go: 129.82.138.196/24

Here’s your gateway: 129.82.138.254/24

Here’s your DNS server: 129.82.103.106
Finding Ether Address: Address Resolution (ARP)

Broadcast: who knows the Ethernet address for 129.82.138.254? (gateway address)

Broadcast: I do, it is 08-00-2c-19-dc-45
Domain Naming System (DNS)

What’s the IP address for www.colostate.edu?

It is 129.82.103.106
How Do the Routers Know Where to Send Data?

• Each router has a **forwarding table**, which is populated by **routing protocols**

• Original Internet: forwarding table was manually updated! Network was small enough

• Routing protocols update tables based on “cost” (typically hop count)
  – Exchange tables with neighbors or everyone to build a shortest path tree, then
  – Use neighbor leading to shortest path
Programming with Layers

- Sub-divide the problem
  - Each layer relies on services from layer below
  - Each layer exports services to layer above
- Interface between layers defines interaction
  - Hides implementation details
  - Layers can change without disturbing other layers

![Layer Diagram]

Application

Application-to-application channels

Host-to-host connectivity

Link hardware
Network Layering

Layering: technique to simplify complex systems
IP Suite: End Hosts vs. Routers

HTTP message
TCP segment
IP packet

host

HTTP
TCP
IP
Ethernet interface

router

IP packet
IP packet
IP packet

host

HTTP
TCP
IP
Ethernet interface
SONET interface
Ethernet interface

IPv4: End Hosts vs. Routers

HTTP message
TCP segment
IP packet

host

HTTP
TCP
IP
Ethernet interface

router

IP packet
IP packet
IP packet

host

HTTP
TCP
IP
Ethernet interface
SONET interface
Ethernet interface
Layer Encapsulation

User A
- Get index.html
- Connection ID
- Source/Destination
- Link Address

User B
- Get index.html
- Connection ID
- Source/Destination
- Link Address
The Internet Hourglass Design

Remember this one!
Why the narrow waist?

Applications
Application protocols
Transport protocols
Network protocol
Link layer protocols
(framing, access ctl..)
Physical layer (hardware)

[Deering98]
Designing Protocols

• What factors should be taken into account when designing protocols?
• Application requirements – can vary widely
• Network characteristics – bandwidth, delay, loss, etc.
• Link characteristics – wired, wireless, copper, optical, etc.
Application Requirements vs. Network Service

• Application may provide input to network
  – Traffic data rate
  – Traffic pattern (bursty or constant bit rate)
  – Traffic target (multipoint or single destination, mobile or fixed)
  – Internet does not accept any of this!

• Network service delivered to application
  – Delay characteristics
  – Loss characteristics
  – In the Internet applications measure and adapt
Email, Reliable File Transfer

- Loss sensitive
- Not delay sensitive relative to round trip times
- Point-to-point
- Bursty
Remote Login

• Loss sensitive
• Delay sensitive
  – Subject to interactive constraints
  – Can tolerate up to several hundreds of milliseconds
• Bursty
• Point to point
Network Audio

- Relatively low bandwidth
  - Digitized samples, packetized
- Delay *variance* sensitive
- Loss tolerant
- Possibly multipoint, long duration sessions
  - Natural limit to number of simultaneous senders
Network Video

- High bandwidth
- Compressed video, bursty
- Loss tolerance function of compression
- Delay tolerance a function of interactivity
- Possibly multipoint
- Larger number of simultaneous sources
Web

- Transactional traffic
  - Short requests, possibly large responses
- Loss (bug?) tolerant (hit refresh)
- Delay sensitive
  - Human interactivity
- Point-to-point (multipoint is asynchronous)
Bandwidth-Delay Product

• Very important consideration in network design
• Determines how much data is in transit (and thus cannot be stopped)
## Examples

<table>
<thead>
<tr>
<th>Link Type</th>
<th>Bandwidth</th>
<th>Distance</th>
<th>RTT</th>
<th>BW x Delay</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dial-up</td>
<td>56Kb/s</td>
<td>10Km</td>
<td>87 µs</td>
<td>5 bits</td>
</tr>
<tr>
<td>Wireless Lan</td>
<td>54Mb/s</td>
<td>50m</td>
<td>0.33µs</td>
<td>18 bits</td>
</tr>
<tr>
<td>Satellite</td>
<td>45 Mb/s</td>
<td>33,000 Km</td>
<td>230 ms</td>
<td>10 Mb</td>
</tr>
<tr>
<td>Cross-country fiber</td>
<td>10Gb/s</td>
<td>4,000 Km</td>
<td>40 ms</td>
<td>400 Mb</td>
</tr>
</tbody>
</table>
What Next?

• Read Chapter 1
• Project 1 will be posted on the web – the TA will cover it in recitation along with intro to socket programming and makefiles
• Homework 1 will be posted on the web