CS 260:
Seminar in Computer Science: Multimedia Networking

Jiasi Chen
Lectures: MWF 4:10-5pm in Chass South 2130

http://www.cs.ucr.edu/~jiasi/teaching/cs260_winter17/ (soon)
Why Networks?

Supports the applications that we use today...

Social media

Number of Internet users
- 97% of Americans between 18-29
- 40% of the world population → scope for more users

Why Networks?

But also a source of conflict.

Cyber security

A Look Back at the Target Breach

Network neutrality


By CECILIA KANG  NOV. 11, 2015

A new plan from T-Mobile USA to allow unlimited streaming of some video services may become the first test of the federal government’s rules to prevent favoritism on the Internet.

On Tuesday, T-Mobile, the nation’s third-largest wireless carrier, said customers could stream as many videos as they want — regardless of their data plan limits — from more than two dozen video providers, including Hulu and Netflix.

http://www.huffingtonpost.com/eric-dezenhall/a-look-back-at-the-target_b_7000816.html
What is networking?

• Bunch of acronyms?
What is networking?

• Bunch of headers?

Source: https://nmap.org/book/tcpip-ref.html
Networking is...

The search for general principles to guide communication
What is Multimedia?
What is Multimedia?
Multimedia is...

- Content creation
- Compression
- Storage
- Distribution
- Internet
- End users
  - Audio
  - On-demand video
  - Live video
  - Virtual/augmented reality
What You Will Learn in this Course

• Knowledge
  • 50%: device-centric
  • 50%: network-centric

• Skills
  • How to read
  • How to present
  • How to discuss
  • Whirlwind sample of networking problems
Course Structure

• Mondays
  • Overview by instructor
  • Student presentation on an important paper in the area
  • Discussion

• Wednesdays
  • Divide class into 2 groups and each group reads 1 paper
  • Discussion

• Fridays
  • Mini-lab: taste of implementation based on the week’s topic
  • For example: install and play with VR apps, run provided network simulation

• Project
  • Proposal, presentation, and final report
  • Can work individually in or in groups
<table>
<thead>
<tr>
<th>Week</th>
<th>Topic</th>
<th>Mini-lab</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Introduction + review</td>
<td>DASH adaptive video player</td>
</tr>
<tr>
<td>2</td>
<td>On-demand video</td>
<td>Wowza/Skype live streaming</td>
</tr>
<tr>
<td>3</td>
<td>Live video/gaming</td>
<td>Wowza/Skype live streaming</td>
</tr>
<tr>
<td>4</td>
<td>Virtual reality</td>
<td>Virtual reality on mobile phones</td>
</tr>
<tr>
<td>5</td>
<td>Augmented reality</td>
<td>Oculus Rift</td>
</tr>
<tr>
<td>6</td>
<td>Content distribution</td>
<td>Networking simulation</td>
</tr>
<tr>
<td>7</td>
<td>Wireless</td>
<td>Wireless simulation</td>
</tr>
<tr>
<td>8</td>
<td>Other delivery mechanisms</td>
<td>Simultaneous WiFi+LTE</td>
</tr>
<tr>
<td>9</td>
<td>Net neutrality, pricing</td>
<td>Data tracking mobile app</td>
</tr>
<tr>
<td>10</td>
<td>Project presentations</td>
<td></td>
</tr>
</tbody>
</table>
Grading

• Paper presentation (20%)
  • 1 presentation per student

• Class participation (20%)
  • Speak up!

• Mini-labs (10%)
  • ~8 mini-labs in class

• Project (50%)
  • Presentation
  • Report
Review

1.1 what is the Internet?
1.2 network edge
   - end systems, access networks, links
1.3 network core
   - packet switching, circuit switching, network structure
1.4 protocol layers, service models

Adapted from *Computer Networking: A Top-Down Approach*, Kurose & Ross
What’s the Internet: “nuts and bolts” view

- Millions of connected computing devices:
  - Hosts = end systems
  - Running network apps

- Communication links
  - Fiber, copper, radio, satellite
  - Transmission rate: bandwidth

- Packet switches: forward packets (chunks of data)
  - Routers and switches
What’s the Internet: “nuts and bolts” view

- **Internet**: “network of networks”
  - Interconnected ISPs
- **Protocols** control sending, receiving of msgs
  - e.g., TCP, IP, HTTP, Skype, 802.11
- **Internet standards**
  - IETF: Internet Engineering Task Force
What’s the Internet: a service view

• Infrastructure that provides services to applications:
  • Web, VoIP, email, games, e-commerce, social nets, ...

• provides programming interface to apps
  • hooks that allow sending and receiving app programs to “connect” to Internet
  • provides service options, analogous to postal service
What’s a protocol?

**human protocols:**
- “what’s the time?”
- “I have a question”
- introductions

... specific msgs sent
... specific actions taken when msgs received, or other events

**network protocols:**
- machines rather than humans
- all communication activity in Internet governed by protocols

*protocols define format, order of msgs sent and received among network entities, and actions taken on msg transmission, receipt*
What’s a protocol?

A human protocol and a computer network protocol:

Hi

Hi

Got the time?

2:00

TCP connection request

TCP connection response

Get http://www.awl.com/kurose-ross

<file>
Roadmap

1.1 what is the Internet?
1.2 network edge
  - end systems, access networks, links
1.3 network core
  - packet switching, circuit switching, network structure
1.4 protocol layers, service models
A closer look at network structure:

- **network edge:**
  - hosts: clients and servers
  - servers often in data centers

- **access networks, physical media:** wired, wireless communication links

- **network core:**
  - interconnected routers
  - network of networks
Access networks and physical media

Q: How to connect end systems to edge router?

• residential access nets
• institutional access networks (school, company)
• mobile access networks

keep in mind:

• bandwidth (bits per second) of access network?
• shared or dedicated?
Access net: home network

- wireless devices
- often combined in single box
- wireless access point (54 Mbps)
- cable or DSL modem
- router, firewall, NAT
- wired Ethernet (100 Mbps)
- to/from headend or central office
Enterprise access networks (Ethernet)

- typically used in companies, universities, etc
  - 10 Mbps, 100Mbps, 1Gbps, 10Gbps transmission rates
  - today, end systems typically connect into Ethernet switch

institutional mail, web servers

institutional link to ISP (Internet)

institutional router

Ethernet switch
Wireless access networks

- shared *wireless* access network connects end system to router
  - via base station aka “access point”

**wireless LANs:**
- within building (100 ft)
- 802.11b/g (WiFi): 11, 54 Mbps transmission rate

**wide-area wireless access**
- provided by telco (cellular) operator, 10’s km
- between 1 and 10 Mbps
- 3G, 4G: LTE
Host: sends *packets* of data

host sending function:

- takes application message
- breaks into smaller chunks, known as *packets*, of length $L$ bits
- transmits packet into access network at *transmission rate* $R$
  - link transmission rate, aka link *capacity*, aka link *bandwidth*

\[
\text{packet transmission delay} = \frac{L \text{ (bits)}}{R \text{ (bits/sec)}}
\]
Review

1.1 what is the Internet?
1.2 network edge
   - end systems, access networks, links
1.3 network core
   - packet switching, circuit switching, network structure
1.4 protocol layers, service models
The network core

• mesh of interconnected routers

• packet-switching: hosts break application-layer messages into packets
  • forward packets from one router to the next, across links on path from source to destination
  • each packet transmitted at full link capacity
Packet-switching: store-and-forward

- Takes $L/R$ seconds to transmit (push out) $L$-bit packet into link at $R$ bps
- **Store and forward**: entire packet must arrive at router before it can be transmitted on next link
  - End-end delay = $2L/R$ (assuming zero propagation delay)

**One-hop numerical example:**
- $L = 7.5$ Mbits
- $R = 1.5$ Mbps
- One-hop transmission delay = 5 sec
Packet Switching: queueing delay, loss

**queueing and loss:**

- If arrival rate (in bits) to link exceeds transmission rate of link for a period of time:
  - packets will queue, wait to be transmitted on link
  - packets can be dropped (lost) if memory (buffer) fills up
Two key network-core functions

**routing:** determines source-destination route taken by packets
  - **routing algorithms**

**forwarding:** move packets from router’s input to appropriate router output
Roadmap

1.1 what *is* the Internet?
1.2 network edge
  - end systems, access networks, links
1.3 network core
  - packet switching, circuit switching, network structure
1.4 protocol layers
Protocol “layers”

Networks are complex, with many “pieces”:

• hosts
• routers
• links of various media
• applications
• protocols
• hardware, software

Question:

is there any hope of organizing structure of network?

.... or at least our discussion of networks?
Internet protocol stack

- **application**: supporting network applications
  - FTP, SMTP, HTTP
- **transport**: process-process data transfer
  - TCP, UDP
- **network**: routing of datagrams from source to destination
  - IP, routing protocols
- **link**: data transfer between neighboring network elements
  - Ethernet, 802.111 (WiFi), PPP
- **physical**: bits “on the wire”
Why layering?

dealing with complex systems:

• explicit structure allows identification, relationship of complex system’s pieces
  • layered *reference model* for discussion

• modularization eases maintenance, updating of system
  • change of implementation of layer’s service transparent to rest of system
  • e.g., change in letter language doesn’t affect rest of system

• layering considered harmful?
Layering of post office functionality

<table>
<thead>
<tr>
<th>Sender writes letter</th>
<th>Recipient reads letter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sender drops off letter at post office</td>
<td>Mailman delivers from post office to sender’s home</td>
</tr>
<tr>
<td>Post office X sends mail to city Y</td>
<td>Post office Y receives mail from city X</td>
</tr>
</tbody>
</table>

**layers:** each layer implements a service
- via its own internal-layer actions
- relying on services provided by layer below
Layering of post office functionality

**layers**: each layer implements a service

- via its own internal-layer actions
- relying on services provided by layer below

Transport: Delivery via UPS (signature required) or USPS (no signature required)
Application: the contents of the letter, e.g. photo, video, novel
source

message

call

segment

H

H

Mesh

datagram

H

H

H

frame

H

H

H

H

H

source

message

call

segment

H

H

Mesh

datagram

H

H

H

frame

H

H

H

H

H

destination

application

transport

network

link

physical

application

transport

network

link

physical

network

link

physical

Encapsulation

switch

router
Internet structure: network of networks

Question: given millions of access ISPs, how to connect them together?
Internet structure: network of networks

Option: connect each access ISP to every other access ISP?

connecting each access ISP to each other directly doesn’t scale: $O(N^2)$ connections.
Internet structure: network of networks

Option: connect each access ISP to a global transit ISP? **Customer and provider ISPs have economic agreement.**
But if one global ISP is viable business, there will be competitors...
Internet structure: network of networks

But if one global ISP is viable business, there will be competitors … which must be interconnected
Internet structure: network of networks

... and regional networks may arise to connect access nets to ISPS
Internet structure: network of networks

- at center: small # of well-connected large networks
  - “tier-1” commercial ISPs (e.g., Level 3, Sprint, AT&T, NTT), national & international coverage
  - content provider network (e.g., Google): private network that connects it data centers to Internet, often bypassing tier-1, regional ISPs
Tier-1 ISP: e.g., Sprint