Course Logistics
Welcome to ECE/CS 438

- **Timing:** Tu/Th 3:30 – 4:50pm, UIUC time
- **Mode:** Online (Zoom)
- **Course URL:** [https://courses.grainger.illinois.edu/cs438/fa2020/](https://courses.grainger.illinois.edu/cs438/fa2020/)

- **Instructor:** Romit Roy Choudhury
  
  Faculty ECE and CS
  PhD from UIUC, 2006
  Research: Wireless/Mobile Networking, Sensing
  Webpage: croy.web.engr.illinois.edu

- **Office Hours:** Tu/Th after class
  Or email croy@illinois.edu for 1:1
Welcome to ECE/CS 438

Teaching Assistants (TAs) ... see URL for email IDs

Wally

Zhijian

Mingjia (ZJUI TA)
Welcome to ECE/CS 438

- Prerequisite:  - Probability
  - Programming

Further courses:
- Advanced Computer Networks
- Advanced Wireless Networking
- Hot Topics in Mobile Computing
- Advanced Distributed Systems
- IoT, Big Data, and CyberPhysical Systems
- ...

Welcome to ECE/CS 438

Information Dissemination:
URL: https://courses.grainger.illinois.edu/cs438/fa2020/
Most course related information will be posted on the website
When in doubt, check the webpage.

Some reminder/clarification emails may be sent out

Piazza:
- Just search for “ECE CS 438” on Piazza.
- Piazza meant entirely for students to communicate.
- Faculty and TAs may respond occasionally.
Welcome to ECE/CS 438

Grading:

- Homework (3 or 4): 15%
- Programming Assignments (3 or 4): 25%
- 1 mid-term exam: 25%
- Final exam: 35%

- Programming assignments may be in groups of 2. Each group makes single submission.

- 4 credit students need to complete a mini-project and submit a report at the end of semester (more later)
Finally

- Academic honesty
  
  1. I believe you won’t cheat. If you are anxious, or in great pressure ... talk to me. I understand, and some accommodations can be made. But don’t take the “wrong pill”.

  2. In the long run, GPA does not matter as much as you think it does. Tarnishing a long-term career not worth the 0.05 net GPA points.

  3. I am lenient and easy-going until someone is proven to be cheating.
Course Summary
(Very Briefly)
Course information

- **Course materials:**
  - **Text:**
    - *Computer Networking: A Top Down Approach*
    - J. Kurose & K. Ross,
    - Addison Wesley
  - **Class notes/slides**
    - Acknowledgment to Jim Kurose
  - **Some supplementary reading material**
What is this course about?

- *Introductory* (first) course in computer networking
  - Undergrads, early grad students

- learn **principles** of computer networking
- learn **practice** of computer networking
- Internet architecture/protocols as case study
- Real wireless networks as case studies
- Glimpses into the future of networking
Course information

- By the time you are finished ...
  - You understand variety of factoids and concepts
  - Propagation delay, transmit time, queeuing, ...
  - Internet layered architecture, HTTP, DNS, P2P, ...
  - Sockets, Ports, ...
  - Congestion Control, Flow Control, TCP, ...
  - Routing, Basic Graphs, Djikstra’s Algorithm, IP, BGP, OSPF, ...
  - DSL Vs Cable, Aloha, CSMA, TDMA, Token, ...
  - Cellular Network architecture, handoff, roaming, Mobile IP, ...
  - Wireless Networks (WiFi)
  - Security, RSA, Digital certificates, MIM attacks, ...
  - ...

If you understand 75% of these terms, you shouldn’t be here
What this Course Does Not Cover

- Does not cover
  - Device drivers, SDNs, cloud computing ...
  - Network theory, graph theory, proofs
  - Radio hardware, embedded systems, IoT, scheduling
  - Modulation schemes, transmitter/receiver design

- Not a “communications” course

This is course on

- Understanding, analyzing, and (perhaps) designing protocols and algorithms in networking systems (with case studies in wired and wireless networks)
What’s the difference between

Communications
And
Networking
Finally

- I cannot / will not / should not be speaking alone in class
  - Questions
  - Comments
  - Disagreements
  - Debates ... are highly encouraged

- This course can be real fun

- Whether it will be ...  
  - Is up to you and me
Hello!
I am ECE/CS 438
Computer Network Architecture

Past, Present, and Future
On the Shoulders of Giants

- 1961: Leonard Kleinrock published a work on packet switching
- 1962: J. Licklider described a worldwide network of computers called Galactic Network
- 1965: Larry Roberts designed the ARPANET that communicated over long distance links
- 1971: Ray Tomilson invents email at BBN
- 1972: Bob Kahn and Vint Cerf invented TCP for reliable packet transport
On the Shoulders of Giants ...

- 1973: David Clark, Bob Metcalfe implemented TCP and designed ethernet at Xerox PARC

- 1975: Paul Mockapetris developed DNS system for host lookup

- 1980: Radia Perlman invented spanning tree algorithm for bridging separate networks

- Things snowballed from there on ...
What we have today is beyond any of the inventors’ imagination ...
And YOU are here
And by “YOU” I mean ...
“Cool” internet appliances
"Cool" internet appliances

Web-enabled toaster + weather forecaster
And Of Course people ...
InterNetwork

- Millions of end points (you, me, and toasters) are connected over a network
  - Many end points can be addressed by numbers
  - Many others lie behind a virtual end point

- Many networks form a bigger network

- The overall structure called the Internet
  - With a capital I
  - Defined as the network of networks
Internet structure: network of networks

- roughly hierarchical
- at center: “tier-1” ISPs (e.g., MCI, Sprint, AT&T, Cable and Wireless), national/international coverage
  - treat each other as equals
Tier-1 ISP: e.g., Sprint

Sprint US backbone network

POP: point-of-presence

to/from backbone

peering

to/from customers

DS3 (45 Mbps)
OC3 (155 Mbps)
OC12 (622 Mbps)
OC48 (2.4 Gbps)
Cables Laid Out in the Oceans

Optical Fiber cross-section
Cable Connections carry 95% traffic (rest?)
Internet structure: network of networks

- “Tier-2” ISPs: smaller (often regional) ISPs
  - Connect to one or more tier-1 ISPs, possibly other tier-2 ISPs

- France telecom, Tiscali, etc. buys from Sprint

Tier-2 ISP pays tier-1 ISP for connectivity to rest of Internet

Tier-2 ISPs also peer privately with each other, interconnect at NAP
Internet structure: network of networks

- “Tier-3” ISPs and local ISPs (Time Warner, Earthlink, etc.)
  - last hop (“access”) network (closest to end systems)

Local and tier-3 ISPs are customers of higher tier ISPs connecting them to rest of Internet
Internet structure: network of networks

- a packet passes through many networks!
  - Local ISP (uber) → T3 (bus to ORD) → T2 (flight to NYC) → T1 (flight to Tokyo)
Organizing the giant structure

Networks are complex!

- 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?
Turn to analogies in air travel

- ticket (purchase)
- baggage (check)
- gates (load)
- runway takeoff
- airplane routing

- ticket (complain)
- baggage (claim)
- gates (unload)
- runway landing
- airplane routing

**a series of steps**
Layering of airline functionality

<table>
<thead>
<tr>
<th>Your laptop</th>
<th>CNN server</th>
</tr>
</thead>
<tbody>
<tr>
<td>ticket (purchase)</td>
<td>ticket (complain)</td>
</tr>
<tr>
<td>baggage (check)</td>
<td>baggage (claim)</td>
</tr>
<tr>
<td>gates (load)</td>
<td>gates (unload)</td>
</tr>
<tr>
<td>runway (takeoff)</td>
<td>runway (land)</td>
</tr>
<tr>
<td>airplane routing</td>
<td>airplane routing</td>
</tr>
<tr>
<td>departure airport</td>
<td>intermediate air-traffic control centers</td>
</tr>
</tbody>
</table>

### Layers:
- Each layer implements a service
- Layers communicate with peer layers
- Rely on services provided by layer below
Why layering?

- Explicit structure allows identification, relationship of complex system’s pieces

- Modularization eases maintenance, updating of system
  - change of implementation of layer’s service transparent to rest of system
  - e.g., runway delay (wheels up time) depends on clearance of destination runway ... doesn’t change the baggage tagging systems ... or flight to gate assignment
Protocol “Layers”

- Service of each layer encapsulated

- Universally agreed services called PROTOCOLS

A large part of this course will focus on understanding protocols for networking systems
Internet protocol stack

- **application**: supporting network applications
  - FTP, SMTP, HTTP, DNS ...

- **transport**: host-host data transfer
  - TCP, UDP ...

- **network**: routing of datagrams from source to destination
  - IP, BGP, routing protocols ...

- **link**: data transfer between neighboring network elements
  - PPP, Ethernet, WiFi, Bluetooth ...

- **physical**: bits “on the wire”
  - OFDM, DSSS, CDMA, Coding ...
Encapsulation

Message → Segment → Datagram → Frame

If Source == laptop
Then forward to next route

Dest: Atlanta
Next Hop = Chicago

Index.html

Give me cnn.com

index.html

Coiffeurs

Et
Encapsulation

message
segment
datagram
frame

source
application
transport
network
link
physical

destination
application
transport
network
link
physical

router

switch

CNN server

Atlanta, D.C.

Chicago

Atlanta

D.C.

Encapsulation = switch - Router
Success of Layering

- Protocol stack successful in Internet

- Internet uses wired physical layer links
  - Very reliable
  - Bit Error Rate (BER) = $10^{-8}$

- What about wireless networks
  - Very unreliable due to channel fluctuations
  - Due to co-channel interference
  - Due to external noise

- Does horizontal layering still hold?
Questions ?
Bandwidth of comm.

**Data Rate** = bits/s

- **WiFi** - 20 MHz
- **GPS** - 2 MHz
- **5G** - 500 MHz

\[
\text{Speed} = \frac{B \text{ Hz}}{\text{Data Rate} \ (\text{bits/s})} \log \left(1 + \frac{\text{Preceived}}{\text{Noise}}\right)
\]
The diagram illustrates the relationship between signal voltage and frequency. The term 'fmax' is used to represent the maximum frequency a system can handle, also known as bandwidth. The waveform shows a comparison between two signals, one marked as '1' and another as '0', indicating binary or digital signals.

The text 'fmax < fmax' suggests a condition where the maximum frequency 'fmax' is less than a reference 'fmax'. The phrase 'Larger B/W' likely refers to a wider bandwidth.

The diagram includes a waveform with binary codes '1100101110101110' and '011011011100', which could be used to represent different digital patterns or codes.
Assignment # 1

Watch “City in the Sky” documentary on Netflix

You will appreciate both airline systems and The Internet much more than you do now ...