Computer Network Architecture

ECE 156 Fall 2007

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Course Logistics
Welcome to ECE 156

- **Timings:** Tu/Thu 1:15pm to 2:30pm
- **Location:** 212 Engineering
- **Course TA:** TBA

- **Instructor:** Romit Roy Choudhury
  New faculty in ECE & CS.
  Ph.D from UIUC in Summer, 2006
  Research in Networking and Distributed Sys.

- **Office hours:** Tu/Th 2:30–3:30 or appointment
  Email me at romit@ee.duke.edu
  and visit me at 203 Hudson Hall
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Prerequisite: ECE 52
Else, come and talk to me

Further courses:
- ECE 256 (previously 299.02):
  Wireless Networking and Mobile Computing
  • Spring 2008
Welcome to ECE 156

- Class broadcast email:  
  ece_156_01@ee.duke.edu

- Course Website:
  http://www.ee.duke.edu/~romit/courses/f07/ece156-f07-networking.html
  - Most course related information will be posted on the website

- Please check the course website frequently
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Make up classes

- Will be occasionally necessary due to travel
- Would like to schedule on a case by case basis
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Grading:

- Participation/Presentation: 10%
- Homework: 20%
- Programming Assignments: 20%
- 1 mid-term exam: 20%
- Final exam: 30%

- Programming project may be in groups of 2
- One of the exams is likely to be open book
Finally

- Academic honesty
  - Please please please ...
  - A few points is not worth a tarnished career
  - In the long run, GPA does not matter as much as you think it does

- More importantly
  - Let’s not make the CNN headlines for the wrong reasons anymore
Course Summary
(Very Briefly)
Course information

- **Course materials:**
  - **Text:**
  - **Class notes**
  - **Some supplementary reading material**
What is this course about?

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

- learn **principles** of computer networking
- learn **practice** of computer networking
- Internet architecture/protocols as case study
- Real wireless networks as case studies
- Intro to next generation networking
Course information

- By the time you are finished ...
  - You understand variety of concepts (not just factoids)
  - Internet, HTTP, DNS, P2P, ...
  - Sockets, Ports, ...
  - Congestion Control, Flow Control, TCP, ...
  - Routing, Basic Graphs, Djikstra’s Algorithm, IP, ...
  - DSL Vs Cable, Aloha, CSMA, TDMA, Token, 802.11, ...
  - Security, RSA, ...
  - Cellular Networks, Mobile Networks, Satellite Networks, ...
  - Wireless Multihop Networks (ad hoc, mesh, WLANs)
  - Sensor Networks

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

- Not a “communications” course
- Does not cover
  - Modulation schemes
  - Transmitter/Receiver design
  - Signal processing and antenna design
  - Etc.

This is course on
- Understanding, analysing, and (perhaps) designing of protocols and algorithms in wired/wireless networking systems
What’s the difference between

Communications
And
Networking Systems
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 156
Acknowledgments:

Many slides borrowed from Jim Kurose (UMass)
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

IP picture frame
http://www.ceiva.com/

Web-enabled toaster + weather forecaster

World’s smallest web server
http://www-ccs.cs.umass.edu/~shri/iPic.html

Internet phones
And Of Course YOU and ME ...
InterNetwork

- Millions of end points (you, me, and toasters) are connected over an 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 providers interconnect (peer) privately
Tier-1 ISP: e.g., Sprint

Sprint US backbone network

- Seattle
- Atlanta
- Chicago
- Roachdale
- Stockton
- San Jose
- Anaheim
- Fort Worth
- Orlando
- Kansas City
- Cheyenne
- New York
- Pennsauken
- Relay
- Wash. DC
- Tacoma

- DS3 (45 Mbps)
- OC3 (155 Mbps)
- OC12 (622 Mbps)
- OC48 (2.4 Gbps)

POP: point-of-presence

to/from backbone

peering

to/from customers
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 telecome, Tiscali, etc. buys from Sprint
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 (taxi) → T1 (bus) → T2 (domestic) → T3 (international)
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) → ticket (complain)
- baggage (check) → baggage (claim)
- gates (load) → gates (unload)
- runway takeoff → runway landing
- airplane routing → airplane routing

- a series of steps
Layering of airline functionality

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., change in gate procedure doesn’t affect rest of system
Protocol “Layers”

- Service of each layer encapsulated
- Universally agreed services called PROTOCOLS

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

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

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

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

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

- **physical**: bits “on the wire”
Success of Layering

- Protocol stack successful in Internet

- Internet uses wired physical layer links
  - Very reliable
  - 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 ?