CE 151 – Advanced Networks

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https://classes.soe.ucsc.edu/cmpe151/Spring17/
Prof Garcia-Luna Information

- Prof JJ Garcia-Luna
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- Office hours: TBD
- Phone: TBD
My Information

- Brad Smith
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  - Include “CE151” in subject!
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- Office phone: 459.2370
TA Information

- Aziz Albalawi
- aalbalaw@ucsc.edu
  - Include “CE151” in subject!

- Sections: Baskin Engineering 109
  - Monday 1-2:10pm, Wed 1-2:10pm, Thursday 1-2:10pm.
  - First week sections cover “how to use the virtual environment”
    - Mandatory! 50% of lab grade.
    - Can everyone make one of these?

- Office hours: By Appointment
Course Information

- Lab
  - All labs done in virtual labs
    - VM passwords passed out at end of class
  - netref.soe.ucsc.edu

- Piazza used for discussion/questions/etc.

- “An Introduction to Computer Networks”
  - by Peter L. Dordal
  - Online only (link @ class web site)
Grading

- 40% labs
  - Submit via e-mail by midnight of due date
  - VM intro section is 50% of score for first lab
  - Worst score thrown out

- 25% project
  - Create new labs

- 25% quizzes
  - 8 quizzes
  - Worst score thrown out

- 10% class participation
Today…

- Why take the class and my goals…
- Class overview
- Demo of virtual lab and netref
- Introductions & distribute VM passwords
Why are you here?

- Why study networking?
- Why take this class?
Why study networking?

- For Network and Computer Systems Administrators
  - Median salary was $78K ($92K in California) in 2015
  - Bachelor’s
  - Projects 8% growth between 2014 and 2024.
  - “Employment of network and computer systems administrators is projected to grow 8 percent from 2014 to 2024, about as fast as the average for all occupations. Demand for information technology workers is high and should continue to grow as firms invest in newer, faster technology and mobile networks.”
- Computer and Network Architects
  - Median salary was $100K ($127K in California) in 2014
  - Bachelor’s + 5 years experience
  - Projects 9% growth between 2014 and 2024.
  - “Employment of computer network architects is projected to grow 9 percent from 2014 to 2024, faster than the average for all occupations. Demand for computer network architects will increase as firms continue to expand their information technology (IT) networks.”
- *It’s a good career path*…
Why study networking?

- Interesting, and important... but implies something bigger
  - “Revenues from POTS are plummeting as customers cut their landlines in favor of the convenience and advanced features of wireless and VoIP services. At the same time, due to the high fixed costs of providing POTS, every customer who abandons this service raises the average cost-per-line to serve the remaining customers. *With an outdated product, falling revenues, and rising costs, the POTS business is unsustainable for the long run.*”

- Who do you think wrote this?

- *There is a fundamental shift in communications taking place!*
Why study networking?

- Also interesting, and important… but implies something even bigger
  - Analyzes Democracy in terms of Economic “rationality”.
  - Cost of information is the ultimate driver of the system!

- Differential access to information creates advantage
  - Commerce (Uber, Amazon, WalMart, FedEx, …)
  - Politics (recent elections…)
  - Education
  - Health
  - Military (“infrastructure” for “network-centric warfare”)
  - Lifestyle… cell phones, smart phones, …

- Any information, any time, anywhere...
  - Information is the currency of the 21st century...
  - Much information is free or cheap...
  - ...the network is the competitive advantage.
Why study networking?

- Communications technology is still evolving!
  - Big Data
  - Wireless
  - QoS
  - Policy
  - …the Internet is still in its infancy.

- With the Internet you can deploy your own global information, broadcasting, conferencing, gaming… information centric service(s).

- Huge opportunities still exist to…
  - …use the technology to do completely new things
  - …make fundamental contributions to advancing the technology
Why take this class?

- What is “advanced networking?”
  - USE focus… understand how to use networks.
  - DEPTH focus… deeper pass at topics.
  - New TOPICS… study lower layers of the network stack.
  - THEORY focus… how to design network protocols.
USE focus…

- UCSC is a “research university”

- Purpose
  - Research, teaching, public service.
  - Creation, dissemination, application of new knowledge.

- 4388 colleges and universities in the US… how many research universities?
  - 96 (2.2%) total, 63 (1.4%) public

- The taxpayers fund UC to discover “new knowledge”…
- …how to design new protocols vs use existing.
USE focus…

- Focus is less on using the existing Internet…
- …and more on designing the next one!
- But we want to give you as broad a range of skills as possible
- …and you need to know how to fly a plane to design a better one 😊.
- **Focus on USE at a very fundamental level…**
DEPTH focus…

- CE150 covered a lot of material!

- By necessity it had to go relatively shallow.

- *We dive a bit deeper… understand details of how things work.*
  - Related to “USE” focus…
New TOPICS…

- There are important topics you haven’t seen
  - Network layer
    - Routing
  - Link layer

- The glue that holds the Internet together.
THEORY focus…

- Given UC’s mission, theory is clearly important!
- Network communication is an extremely challenging distributed computation.
- The Internet pushed this to whole new levels

Network resources
- Data rates spanning 8 orders of magnitude (Kbps to 100Gbps)
- Latency spanning 5 orders of magnitude (10µsecs to seconds)
- Queuing delays from 0 to seconds
- Packet loss from 0 to 90%
THEORY focus…

- Diversity of applications… data transfer requirements
  - Sensitivity to latency (or not)
  - Tolerant of jitter (or not)
  - Tolerant of loss (or not)
  - …

- Throw it all together… and it should just work!

- The days of trial-and-error protocol design are largely gone…
- …a more analytical, theory-based approach is required.

- \textit{Begin to introduce the challenges of protocol design in CE151.}
- …CE 252
“Why are networking courses so boring?”

- Posed by Scott Shenker in UCB EE 122 intro lecture…
  - his answers
    - Research community has failed to provide a general framework for understanding protocols
    - We therefore just teach a big bag of protocols - and let you try to make sense of it yourself

- My explanation… similar to aeronautics (I imagine 😊)
  - Lots of abstractions…
  - Hard to relate to anything of practical value…
  - …until you get in the plane!
Solution – hands-on

- We investigate each technology down to how to use it…
- In-class exercises
- Network labs
Review

- Why study networking?
  - Because it is changing the world and is a rewarding career (academic or industrial)

- Why take this class?
  - Teach you how to USE networks.
  - Go into more DEPTH on topics
  - Try to cover more TOPICS
  - Introduce you to the THEORY behind networks
  - Use hands-on experience to motivate the material

- The labs have improved a lot…
  - But if you think you have a better idea, use it in your project!
Class goals…

● Understand lower layers of the protocol stack
  ● Layer 3 – the network layer
  ● Layer 2 – the link layer

● Know how to use them…
  ● Solve problems with (virtually) real systems
  ● In your own “dedicated” (virtual) lab environment
My Goal

- In the end you will have the background to be either
  - An engineer with a fundamental view of the technology, or
  - An academic with a good sense of how things really work

- Whichever you choose…
Class Schedule

- Ordered as lecture, exercise, quiz, then lab…
  - Quiz due Thursday before Sunday lab… lab seems to help with quiz
- Guest lecturers as we can fit them in
  - EIGRP
  - Cable-Plant & physical layer
  - …tbd
- Project proposals due *Tuesday, 5/2*
- Project presentations last week of classes and final
  - Everyone attend
  - Early presenters will be given due consideration…
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<th>Date</th>
<th>Lecture</th>
<th>Exercise</th>
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Spring 2017
CE151 - Advanced Networks

FINAL: Thursday 6/15 8-11am
PRESENTATIONS
Topics Covered

- Link Layer
  -Repeaters, Hubs, Bridges, and Switches
  -Spanning Tree Protocol (STP)
  -Address Resolution Protocol (ARP)

- Network Layer
  -Internet Protocol (IPv4 and IPv6)
  -Internet Control Message Protocol (ICMP)
  -Routing and forwarding

- Routing
  -Distance vector and RIP
  -Link state and OSPF
  -Path vector and BGP
  -Advanced topics

- Multicast
Topics NOT Covered

● Assume covered in CE150
  ● Transport Layer
    ● User Datagram Protocol (UDP)
    ● Transmission Control Protocol (TCP)
  ● Network Address Translation (NAT)
  ● Dynamic Host Configuration Protocol (DHCP)
  ● Domain Name System (DNS)

● There are many other topics we’d like to cover…
  candidates for projects!
Quizzes

- 7 quizzes
  - Network layer
  - Link layer
  - IPv6
  - Intra-domain routing (architecture, link-state, distance-vector)
  - STP
  - BGP
  - Multicast

- Cover material highlighted on Review slides
The Labs
Virtual Labs!

- *We are using virtual labs... for everything(!)*

- You get your own VM on an SoE server
  - Use account “student” on your VM (not your CruzID!)

- GNS3 software used to simulate networks
  - Dynamips runs IOS for 3640 routers
  - VirtualBox runs same Linux as in Baskin 301a
  - You each get your own lab environment!
  - Using Cisco 3640 routers...
    - ...with network switch module (NM-16ESW)
    - Allows us to do link layer (L2) labs in virtual environment!

- *Work in progress.*
Virtual Labs

- Access them from anywhere… all you need is an Internet connection😊

- Access them whenever you want😊

- Goal is to structure lab as solving a problem.
Virtual Lab and Netref Demo

- Remote Desktop
- GNS3 with router and Virtual Box VM
- Netref
Virtual Machines

- Don’t leave simulation running in VM!

- Ubuntu keyboard shortcuts
  - Ctrl-D = Shift-Ctl-D
  - Toggle through windows = Alt-Tab
  - Copy/Paste = Ctl-Shift-C/Ctl-Shift-V

- RDP
  - Can’t copy/paste into/out-of VM
  - Need to save all data to Ubuntu disk and scp to your laptop
  - Microsoft client comes with Windows and available for Mac OS
  - Open source Linux clients available (see “Lab Resources” link on class page https://classes.soe.ucsc.edu/cmpe151/Spring16/)
Virtual Machines (cont.)

- Always shutdown VB VMs before closing GNS3!
  - Either window disappears…
  - Or shows "sd 0:0:0:0: [sda] Stopping disk” message (next two slides)
  - Can’t use “cruznet” wireless network… must use “eduroam”

- Don’t let a halted VB VM “capture” your mouse/keyboard!

- In event of problem with your VM… you can reboot it!
  - Open terminal window or login using ssh (putty on Windows)
  - Run “sudo reboot”… It will ask you for your “student” account password
  - Wait for a bit (try pinging your VM)... and then log back in
Lab mechanics

- **At your pace…**
  - No scheduled lab sections… do them on your schedule, at your pace.
  - You can do them early, and should do them as early as possible

- Pair labs (like “pair programming”…)
  - Two people can work together on the lab
  - Must submit own report (same data, separate reports)… *include partners name!*

- All labs linked to from web site

- Submit by e-mail to Brad and Aziz… *no late labs!*
  - Lowest score will be dropped in final grading
  - Incomplete is better than nothing
  - Due by midnight of due date…
  - Will grade updates turned in after due date… but won’t count towards grade

- **NO GOOGLE DOCS!! Because you can change…**
CE151 Labs

- **Lab 1** – Single Segment Network: network config, IP addresses *(SUNDAY!)*
- **Lab 2** – IPv4 static routing (netstat, Linux and Cisco routers, ICMP, ARP)
- **Lab 3** – LAN Switching: Linux as a switch, Cisco VLANs, monitoring ports
  - *Extra Credit Lab 3e* - VLANs
- **Lab 4** – IPv6 static routing
- **Lab 5** – OSPF - basic config; hierarchical routing.
- **Lab 6** – RIP - basic config; experiment with counting-to-infinity problem.
- **Lab 7** – Spanning Tree Protocol: how it works
- **Lab 8** – BGP – basic configuration, and basic policies.
  - *Extra Credit Lab 6e* – BGP convergence problems
- **Lab 9** – Multicast - IGMP; multicast forwarding; PIM-SM and PIM-DM.
The Project
The Project

- Create a new lab

- Proposal
  - Due Tuesday, 5/2 (5th week of class)… e-mail (same as lab reports)
  - A document (pdf) including
    - Describe topic you will develop a lab for
    - Draft outline of what you plan to include in the lab
    - What you need to investigate
  - Remember… links to command references are on web site…

- Deliverables
  - Presentation… 10 mins w/ some time for questions
  - Turn in… by the day of our final slot (Thursday, June 15th)
    - Slides from presentation
    - Paper describing
      - Technology covered in the lab
      - Lessons learned
    - Lab, answer key, netref content
Project Ideas (new projects)

- Firewall
- IPSec
- TLS/HTTPS
- EIGRP
- Server load balancing(?)
- Software Defined Networking
- QoS
- L2 security features
- MPLS (vs. VLANs)
- Rapid Spanning Tree Protocol
- “Buffer bloat”(?)
- BGP with iBGP
Academic integrity

- UCSC’s academic integrity policies strictly enforced.
- See the course web site for details

Bottom line
- Don’t present someone else’s work as your own
- Including cut and paste from web sites!
- Write your own lab report (possibly sharing data)
- Give attribution for any quotes, pictures, etc.
Projects I’m Working On

- “Connected Central Coast” fiber project
- NSF “100 Gb/s Science DMZ” project
- Research
  - Path algebras… understand how metrics impact routing
  - Multipath routing
    - Performance constraints
    - Traffic constraints
  - Information-Centric Networks for Genomic Science
- Cisco eSupport project (part of the “NMO Lab”)
Connected Central Coast
100 Gb/s Science DMZ

- CENIC DC and Global Internet
- CENIC HPR and Global Research Networks
- Border Router
- Border Router
- Core Router
- Core Router
- Science DMZ Router
- DYNES (L2)
- Campus High Performance Research Networks
- FDT
- perfSONAR
- Science DMZ
- 10 Gb/s Campus Distribution Backbone
- Existing 10 Gb/s
- SciDMZ Infra 10 Gb/s
- SciDMZ Research 10 Gb/s
- SciDMZ Infra 100 Gb/s

Astrophysics
Genomics
Particle Physics
Case Study: Cisco NMO Lab

Network Management & Operations (NMO) Lab
- Collaboration between Cisco Technical Support & Customer Advocacy and SoE
  - Facilitate collaborations between SoE and Cisco
  - Real world problems for students and researchers
  - Pre-professional experience for students
  - Cisco access to expertise and new perspectives
  - Formally started August 2008

Leadership
- Cisco: Joe Pinto, Senior VP TS&CA
- UCSC: Profs. Patrick Mantey and Brad Smith

Logistics
- Network “teaching hospital”
- Assume no IP will result from NMO lab work
- Project proposals from either Cisco or UCSC; project team of students, researchers, managers
- Work performed in space provided by CITRIS in E2
- Biannual NMO Lab retreats (Winter and Summer); includes managers, faculty, and students, students present status update of their work
- Cisco provides funding and equipment

NMO Lab experience
- Problems have ranged from QA and release testing to large research projects.
- A number of significant contributions
- To date 32 students, ~6 faculty

UCSC benefits
- Researchers access to new, real world problems
- Students have a “life changing experience”

Cisco benefits
- Improved recruiting pipeline
  - Accelerated hiring and on-boarding
  - Better sense of student’s capabilities
- More efficient and effective project staffing
- Faster project spin-up
- Disruptive influence...
  - “Think outside the box”
  - Less bound to corporate culture
  - More risk tolerant
- Less expensive and more effective alternative to professional consultants
- Increases the “agility” of an organization’s workforce.
Logistics

- Sign up for Piazza (piazza.com)

- Thursday
  - IPv4 lecture
  - IP addresses exercise

- Sunday
  - First lab due!
  - First lab section is half of the lab grade!
    - 85 points for the lab
    - 85 points for attending first lab section
MOVING TO ENGINEERING 2 RM 506.
Introductions & Distribute VM Passwords

- Use the Linux command "passwd" to change your password.