CE 151 – Advanced Networks

Instructors: Brad Smith & Rick Grazianni
TA: Alan Lin
Reader: TBD

https://classes.soe.ucsc.edu/cmpe151/Spring16/
My Information

- Brad Smith
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  - Include “CE151” in subject!
- Office hours: Tue 2-3pm, Wed 2-3pm
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Rick Information

- Rick Graziani
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- Office hours: TBD
- Phone: TBD
- Interested in CCNP certification?
TA Information

- Alan Lin
- alin6@ucsc.edu
  - Include “CE151” in subject!
- Sections: Baskin Engineering 109
  - Monday 11am-12:10pm, Wed 11am-12:10pm, Friday 12:30-1:40pm.
  - First 2 sections cover “how to use the virtual environment”
    - Mandatory! 10% of lab grade.
    - Can everyone make one of these?
- Office hours: TBD
Course Information

● Lab
  ● All labs done in virtual labs
    ● VM passwords passed out at end of class
  ● Physical lab available for projects
    ● Baskin Engineering 301a
    ● See me if you need access
  ● netref.soe.ucsc.edu

● Piazza used for discussion/questions/etc.

● “An Introduction to Computer Networks”
  ● by Peter L. Dordal
  ● Online only
Grading

- 40% labs
  - Submit via e-mail by midnight of due date
  - 10% of labs for VM intro section (sections for first 2 labs)
  - 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 $76K ($88K in California) in 2014
  - Bachelor’s
  - Projects 8% growth between 2012 and 2022.
  - “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 $98K ($120K 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 (Amazon, WalMart, FedEx, …)
  - Politics (recent elections…)
  - Education
  - Health
  - Military (“infostructure” 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.

*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, and lab…
  - Quiz due day before 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, 4/26*

- Project presentations last week of classes and final
  - Everyone attend
  - Early presenters will be given due consideration…
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<thead>
<tr>
<th>Week</th>
<th>Date</th>
<th>Lecture</th>
<th>Exercise</th>
<th>Quiz</th>
<th>Lab</th>
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<td>Tuesday</td>
<td>Intro (Brad)</td>
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<td>Switched &amp; Routed Pings</td>
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<td>Static Routing IPv4</td>
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<td>8? project presentations</td>
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<td>PRESENTATIONS</td>
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Spring 2016 CE151 - Advanced Networks
Topics Covered

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

- Network Layer
  - Internet Protocol (IP)
  - 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

- At least 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
In the past…

“Problems with labs…”

- Yes, we know:)!
- Too “monkey-see-monkey-do”
- How to fix this?
  - Preview and review labs in class..?
    - Try this quarter.
  - Project-oriented labs
    - “Pretend you’re an ISP… design a network for these customers.”
    - Need to be able to save configuration?
    - I believe (suspect) we need virtual lab technology

- Show me a better way in the class project!!
Now...

- We are using virtual labs… for everything(!)
- You get your own VM on an SoE server
- 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-Ctrl-D
  - Toggle through windows = Alt-Tab
  - Copy/Paste = Ctrl-Shift-C/Ctrl-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/)
Baskin 301a Network Lab

- Available for projects…
- …let me know so I can get you an access code
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 Brad, Rick and Alan… *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

Spring 2016
CE151 - Advanced Networks
CE151 Labs

- **Lab 1** – Single Segment Network: network config, IP addresses
- **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
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.
MOVING TO ENGINEERING 2 RM 506?
Projects I’m Working On

- “Connected Central Coast” fiber project
- NSF “100 Gb/s Science DMZ” project
- Research
  - Path algebras… both for single and multipath routing
  - Multipath routing
  - Boolean Constrained routing
  - Information-Centric Networks for Genomic Science
- Cisco eSupport project (part of the “NMO Lab”)
Connected Central Coast

Map showing the Unserved area, Underserved area, Proposed Route, and Existing Sunesys Route.
100 Gb/s Science DMZ

- CENIC DC and Global Internet
- Border Router
- Core Router
- 10 Gb/s Campus Distribution Backbone
- DYNES (L2)
- FDT
- Astrophysics
- Genomics
- Particle Physics

- CENIC HPR and Global Research Networks
- Science DMZ Router
- Campus High Performance Research Networks

- Science DMZ
- Existing 10 Gb/s
- SciDMZ Infra 10 Gb/s
- SciDMZ Research 10 Gb/s
- SciDMZ Infra 100 Gb/s
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.
Open Server Summit (April 13-14)
http://openserversummit.com
Free admission ($895!) with code EDULOC16

One of few excellent trade shows
  - High-speed interconnect
  - Software defined networking (SDN)
  - ...

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Introductions & Distribute VM Passwords

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