

# CE 151 Advanced Networks

**Instructor: Rick Graziani**

**TA: Abdulazaz (Aziz) Albalawi**

**Reader: Barbara Moretto Dama**

<https://classes.soe.ucsc.edu/cmpe151/Spring18/>

# My Information

- Rick Graziani
- Class:
  - Tuesdays/Thursdays: 9:50 – 11:25am
- Office: Engineering 2 Room 569
- Office hours:
  - Tuesdays: 11:45am – 12:45pm
  - Thursdays: After class if needed
- Email: [rgrazian@ucsc.edu](mailto:rgrazian@ucsc.edu)
  - Begin subject with: "CE151:"

# TA Information

- Aziz Albalawi
- [aalbalaw@ucsc.edu](mailto:aalbalaw@ucsc.edu)
  - Begin subject with: "CE151:"
- Sections: Baskin Engineering 109
  - Sections:
    - 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

# Class policies

## Simple

- Safe and comfortable learning environment for everyone
- Respectful and considerate communications and behavior

# Introductions

- Introduce yourselves

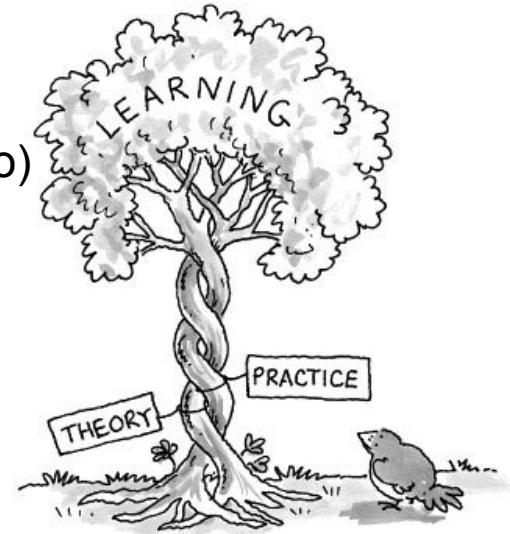
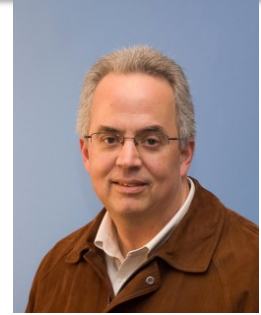


# Today

- Why take this class and my goals (and perspective)
- Class overview
- Demo of virtual lag and netref (Aziz)
- Distribute VM passwords
- Access to Cisco Networking Academy curriculum

# My background and some perspective

- Give you my perspective and my approach...
- Previous instructor: **Brad Smith**
- Co-taught Spring 2017 and collaborated over many years
  - Brad: Research oriented (developing future stuff)
  - Me: Implementation oriented (making current stuff work)
- Me:
  - Worked in IT since 1980 (Lockheed, Tandem, SCO, Cisco)
  - Cabrillo College Instructor (full time job)
  - Work for Cisco Systems Curriculum Engineering
  - Write books for Cisco Press
- More on all this later...



# My approach

- I am simple minded
- Merge between theory and real world (Brad too)
- Balance between developing new protocols and understanding the real world implications
- Understanding the theory and the protocols, but also understanding the challenges of implementing networks in the real world





# Course Information

- Lab (more later) - Aziz
  - All labs done in virtual labs
  - VM passwords passed out at end of class
  - [netref.soe.ucsc.edu](http://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
  - Worst score thrown out
- 25% project
  - Create new labs
- 25% quizzes
  - 8 quizzes
  - Worst score thrown out
- 10% class participation (Attendance)

# Why are you here?

- Why study networking?
- Why take this class?

# Why study networking

- If you are interested in studying technology, you must understand networks
- Path?
  - Developing new protocols and technologies
  - Engineering networks
- Complexity and sophistication of today's networks continue to grow.



# Why study networking?

- Bureau of Labor Statistics - <http://www.bls.gov/ooh/>
- For **Network and Computer Systems Administrators**
  - Median salary was \$78K (\$92K in California) in 2015
  - **Bachelor's degree**
  - 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.

# Why study networking?

- **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?

- Big changes are happening...
  - *"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?

- Networking has become a disruptive technology in:
  - Commerce (Uber, Amazon, WalMart, FedEx, ...)
  - Politics (recent elections...)
  - Education
  - Health care
  - Military (infostructure for network-centric warfare)
  - Lifestyle... cell phones, smart phones, ...
- Self-driving cars
  - Insurance
  - Car purchasing/leasing
  - After-market: Auto supply stores, car wash, car stereo, etc.
  - Drivers: Taxis, Uber, Lyft, shuttle services, delivery trucks, etc.



# Why study networking?

- Communications technology is still evolving!
  - Big Data
  - Wireless
  - IoT
  - Policy
- ...the Internet is still in its infancy.
- Huge opportunities still exist to...
- ...use the technology to do completely new things
- ...make fundamental contributions to advancing the technology

# Traditional-Based Networking

**Vendor-based** solutions with  
**closed hardware** and **closed software** (not that there is anything wrong with that – scalability, cost?)

**Separate** device configurations

Each year more devices, more complexity, more configurations



And what is on these devices?

Protocols

Protocols

Protocols

Protocols



# Carl the Network Engineer

## Programming Skills

- TCL
- EEM
- Expect Scripts



## Networking Skills

- Spanning-Tree
- Routing Protocols
- QoS
- VPN Design
- Spanning-Tree
- VOIP
- Fibre Channel
- Security Policy
- MPLS
- Spanning-Tree
- Did I mention Spanning-Tree?

**IPv6**



# Traditional-Based Networking: Configuration-Based Networking

IPv4 addressing/subnetting, VLSM, CIDR, route summarization, IPv6, EIGRP, OSPFv2, stub, totally stubby, NSSA, OSPFv3, AFs, redistribution, timers, authentication, MP-BGP, load balancing, policy-based routing, MPLS, DHCP,RA, FHRP, HSRP, VRRP, GLBP, STP, RSTP, MSTP, port security, DHCP snooping, Dynamic ARP Inspection, route maps, prefix lists, ACLs, VLANs, VTP, SLAs, Etherchannel, VPNs, NAT, VRF, QoS, VoIP, and MORE

# So what does a Network Engineer do...



**Network device  
configuration,**

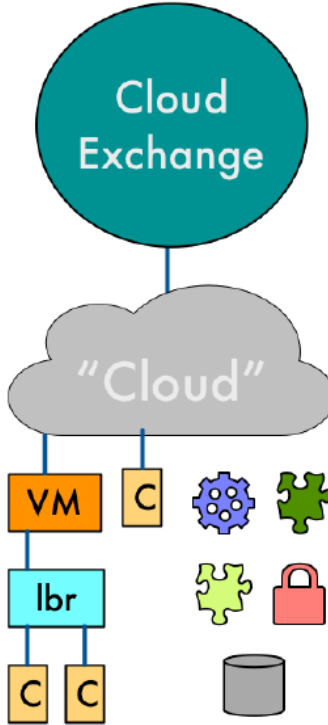
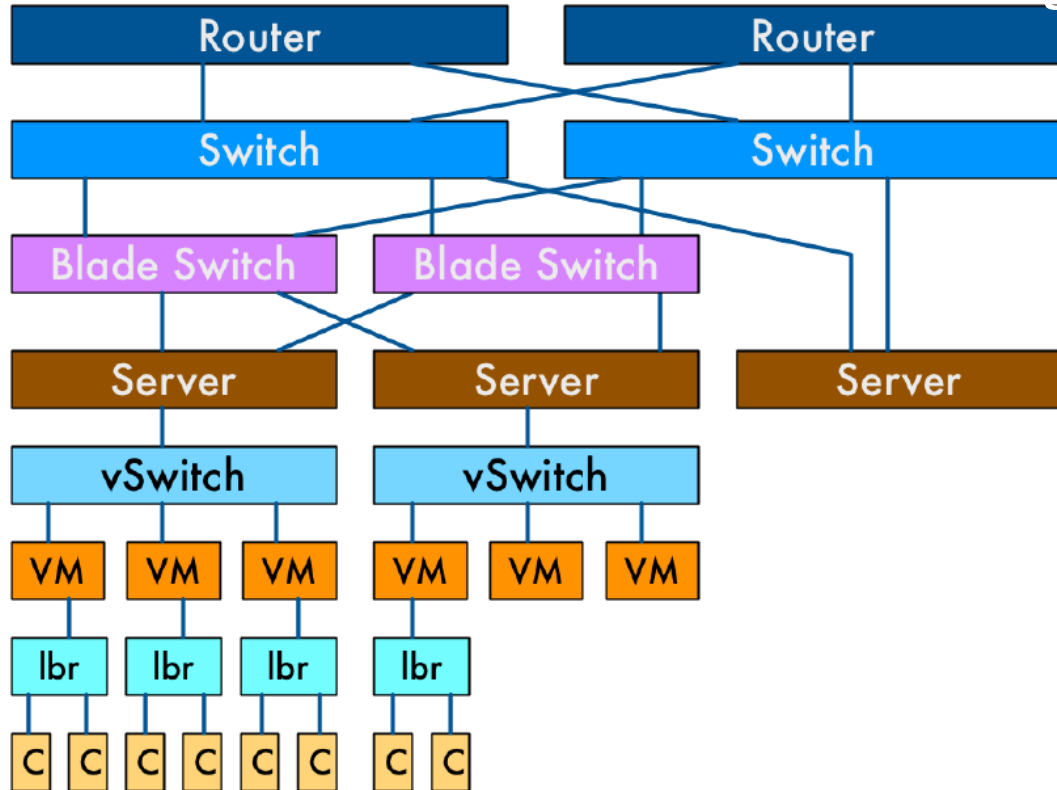


**Followed by...  
troubleshooting  
misconfigurations**



# The Network has changed

- Load Balancer
- Firewall
- IPS
- DNS
- Gateways
- Others...

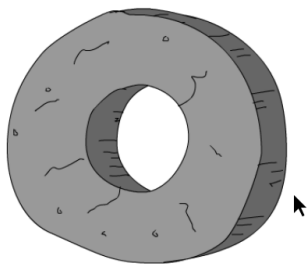


# Traditional-Based Networking

- **High operating expenditures** including increasingly complex configurations
- Repetitive **command-line-interface** driven management
- **Changes difficult** to implement - requiring **long lead times**, change windows, change meetings, rollback options
- **Troubleshooting** – ping, traceroute, show - CCIE
- **Network management** and **network analytics** require **complex tools** and lesser desirable **protocols** and **results**
- **And what ever happened to our design?**
- Is our **design** "still" based on **business intent** or what we had to do to **make it work?**
- Has the **network** become the **"source of truth"?**

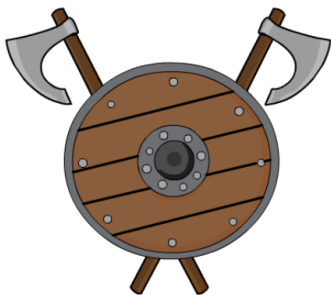






## STONE AGE

Spanning Tree  
VLANs



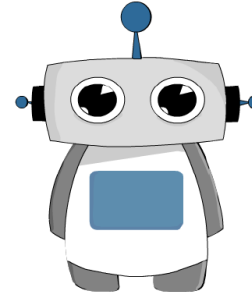
## BRONZE AGE

Routing Protocols  
WAN Design  
IP-magedon



## THE RENAISSANCE

**SDN**  
OpenFlow  
Controllers  
Overlays  
MP-BGP  
VXLAN  
Micro-Segmentation  
White Box ?



## PROGRAMMABLE AGE

Cloud  
Python  
REST / APIs  
NETCONF / YANG  
“Fabrics”  
Network Function  
Virtualization (NFV)  
Containers  
**DevOps**  
**NetDevOps!**

**Intent-Based Networking**

# The Four Ages of Networking.....

# Network Engineers and Protocol Developers

- We need network engineers, network architects, protocol developers, etc., that understand the technology and the challenges, and have a vision of the future.



# 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...

- 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
- 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
    - IPv6
  - Link layer
    - STP
- 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 (10 $\mu$ secs to seconds)
  - Queuing delays from 0 to seconds
  - Packet loss from 0 to 90%
- Begin to introduce the challenges of protocol design in CE151 (**USE**).
  - ...CE 252
  - Brad Smith, JJ Luna-Garcia, and others



# 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
- Labs are great (thanks Brad and others)...
- 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 (Brad's 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
- Project proposals due Tuesday, May 1
- Project presentations last week of classes and final
  - Everyone attend
  - Early presenters will be given due consideration...



Week	Date	Lecture	Exercise	Quiz	Lab	Projects
1	Tuesday	4/3	Introduction			
	Thursday	4/5	IPv4	Address Prefixes		
2	Sunday	4/8			Single Segment Network	
	Tuesday	4/10	Link Layer			
	Thursday	4/12		Switched & Routed Pings	IPv4	
	Sunday	4/15			Static Routing IPv4	
3	Tuesday	4/17	IPv6			
	Thursday	4/19		IPv6	Link Layer	
	Sunday	4/22			LAN Switching VLAN Extra Credit	
4	Tuesday	4/24	Link-State Routing			
	Thursday	4/26		Link-State Routing	IPv6	
	Sunday	4/29			Static Routing IPv6	
5	Tuesday	5/1	Distance-Vector			Proposals Due
	Thursday	5/3	Guest?	Distance Vector		
	Sunday	5/6			OSPF	
6	Tuesday	5/8	STP			
	Thursday	5/10		STP	Intra-Domain Routing	
	Sunday	5/13			RIP	
7	Tuesday	5/15	IDR and BGP			
	Thursday	5/17		IDR	STP	
	Sunday	5/20			STP	
8	Tuesday	5/22	Multicast			Status Reports Due
	Thursday	5/24	Guest?		Inter-Domain Routing	
	Sunday	5/27			BGP	
9	Tuesday	5/29	Guest?		BGP Extra Credit	
	Thursday	5/31			Multicast	
	Sunday	6/3			Multicast	
10	Tuesday	6/5		Project Presentations		Project Presentations
	Thursday	6/7		Project Presentations		Project Presentations
	Final	Thursday	6/14		Project Presentations	Project 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 (Thanks Brad!)

- 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 (More thanks to Brad)

- 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
  - Ctl-D = Shift-Ctl-D
  - Toggle through windows = Alt-Tab
  - Copy/Past = 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

# 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 Rick and Aziz...
- 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

# Baskin 301a Network Lab

- Available for projects...
- ...let me know so I can get you an access code

# 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



# The Project

- Create a new lab or *other project*
- Proposal
  - Due Tuesday, May 1st (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...



# The Project

- Deliverables
  - Presentation... 10 mins w/ some time for questions
  - Turn in... by the day of our final slot (Thursday, June 14th)
    - Slides from presentation
    - Paper describing
    - Technology covered in the lab (or other project)
    - Lessons learned
  - Lab, answer key, netref content

# Project Ideas (new projects)

- Firewall
- IPSec
- TLS/HTTPS
- EIGRP
- Named EIGRP (Address Families)
- OSPFv3 with Address Families
- IS-IS
- Server load balancing
- Software Defined Networking
- Block chain
- TRILL
- L2 security features
- MPLS (vs. VLANs)
- Rapid Spanning Tree Protocol
- BGP with iBGP
- IPv6 security

## Project reports

- UCSC ITS IPv6 wireless project

# 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!
  - Do your own lab
  - Write your own lab report
  - Use your own data
  - Give attribution for any quotes, pictures, etc.

# Introductions & Distribute VM Passwords

- Use the Linux command “*passwd*” to change your password.

# Access

- My web site
- Routing and Switching (CCNA, CCNP) and IPv6
  - PowerPoints
  - Labs
- Cisco Network Academy: CCNA and CCNP curriculum (and other)

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