Proposal for Educational Labs in Networking Technology

University of California
Santa Cruz
Baskin School of Engineering

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Introduction
The University of California, Santa Cruz, School of Engineering is developing new educational courses to expand our core curriculum in data networking. The centerpiece of the expanded curriculum will be a state-of-the-art educational lab with technologies typically found in modern data networks. The lab will provide undergraduate students with challenging exercises in the foundations of data networks, wireless networks, and multimedia applications over data networks.

This proposal describes the School’s plans for educational labs and proposes an equipment donation that fits the School’s expected curriculum in current and approaching technologies. The expanded curriculum calls for two labs. The Introductory Lab will accommodate up to 40 student stations for large undergraduate participation. Three popular undergraduate courses will make use of the Introductory Lab. The Advanced Lab will provide an experimental environment for special undergraduate projects. The projects would include new multimedia technologies and cutting-edge networking services. It will be scheduled individually or in small groups.

Expected Course Material
Three core undergraduate courses will use the Introductory Lab. Two senior project courses will use the Advanced Lab. The core undergraduate courses are CMPE 150, Introduction to Computer Networks, CMPE 151, Network Administration, and CMPE 156, Network Programming. The advanced courses are CMPE 123A, Computer Engineering Design I, and CMPE 123B, Computer Engineering Design II. In addition, a number of graduate courses would make use of both labs.

CMPE 150: Introduction to Computer Networks
This course takes students through the fundamentals of computer networks. It introduces the concepts of data protocols, encapsulation, packetization, and addressing. The class learns about circuit, message, and packet switching, and local area networks (LANs). The treatment of medium access control includes link error correction schemes, flow control, and bridged networks. At the network layer, the course covers routing protocol concepts and IP networks. At the transport layer, the course introduces TCP and UDP, along with example applications such as HTTP and DNS.

Lab projects:
- Introduction to Cisco IOS
- Bridging, Spanning-tree
- Classful IP addressing.
- RIP protocol
- ICMP protocol (echo, echo-reply)
- RS232 asynchronous link layer
- RS422 or V.35 synchronous link layer protocols
- Ethernet (HDLC, 802.3, 802.2 link layer options)
CMPE 151: Network Administration

The Network Administration course covers hands-on topics and describes how to make networks deliver services to users. Topics include intermediate routing protocols (RIPv2, single area OSPF), DNS, DHCP, Ethernet switched networks, VLANs, caching and content routing, firewalls, VPNs, and other services.

Lab projects
- Advanced IP addressing (variable subnetting, classless addressing, supernetting).
- Ethernet switching, VLANs, trunking.
- RIPv2 and OSPF routing.
- Wide area technologies (T1 lines, frame relay).
- Web servers, HTTP, proxies, caching, and content routing.
- Access lists, stateful firewalls, NAT
- VPNs and overlay networks
- Self-configuring networks (Bootp, DHCP, TFTP)

CMPE 156: Network Programming

Students learn how to program for sockets and network services. The course focuses on the use of Berkeley sockets in student projects. Those in the networking track could program UDP or TCP applications to interact with network services.

Lab projects (network focus):
- Network configuration (TFTP, Telnet)
- Interact with network management protocols (SNMP, CDP)
- Participate in a routing protocol (RIP, RIPv2)
- Multicast services
- QoS (DiffServ, RTP)

CMPE 123A/B: Computer Engineering Design I & II

These are a sequence, the culmination of the Computer Engineering program. Students apply knowledge and skills gained in elective track to complete a major design project. They complete research, specifications, planning, and procurement for a substantial project, which includes technical discussions, design reviews, and formal presentations as well as engineering design cycles, engineering teams, and professional practices. A formal technical specification of an approved project is presented to faculty. Students fully implement and test system designed and specified in course 123A. A formal written report, oral presentation, and demonstration of successful project to a review panel of Computer Engineering faculty are required.

Lab projects (example list):
- IP Telephony, voice gateways, H.323
- Queuing and QoS.
- Differentiated Services (DiffServ), Integrated Services (IntServ).
- Advanced routing (multi-area OSPR, BGP, policy routing, content routing, route import/export).
Educational Networking Labs
School of Engineering

- Wireless networks
- Secure networks (access lists, reflexive access lists, stateful inspection, 802.1x, pap, chap, authenticated routing protocols).
- Advanced wide area technologies (channelized T1, ISDN, frame relay, frame relay QoS)
- High-speed networks (gigabit Ethernet, bandwidth-delay product issues, MPLS switching, flow switching and exporting)
- Storage area networks and iSCSI.
- Fault tolerant networks (HSRP, multipath routing, spanning-tree convergence)
- Network management (SNMP, RMON, element management, configuration and image management)

Graduate Courses
Graduate networking courses include CMPE 252A, Computer Networks, CMPE 252B, Modeling of Communication Protocols, and CMPE 257, Wireless and Mobile Networks. CMPE 252A/B provides graduate level training in the design and analysis of wireless network protocols. CMPE 257 provides graduate level training in the design and analysis of wireless protocols. Students in these courses would make use of these labs for understanding and analyzing the protocols they are studying.

Proposed Lab Equipment
The Introductory and Advanced labs have significantly different equipment requirements. This section outlines the School’s proposal for each lab. The configuration of the Introductory lab supports a general, flexible lab that supports many network topologies and technologies. The configuration of the Advanced lab follows along a suggestion from Cisco, and emphasizes flagship technology.

This section does not detail all parts for the lab. It specifies the principle Cisco parts, but we have not included all memory, power cord, power supply, or software.

Introductory Lab

<table>
<thead>
<tr>
<th>Simultaneous students</th>
<th>40</th>
</tr>
</thead>
<tbody>
<tr>
<td>Students per workstation</td>
<td>1</td>
</tr>
<tr>
<td>WAN technologies</td>
<td>Point-to-point T1, frame relay, PPP</td>
</tr>
<tr>
<td>LAN technologies</td>
<td>Ethernet, Fast Ethernet, Ethernet auto-negotiation, PPoE, Ethernet switching, VLANs, VLAN trunks, inter-VLAN routing.</td>
</tr>
<tr>
<td>Link technologies</td>
<td>Asynchronous serial, Synchronous serial, HDLC, PPP, Ethernet 802.2.</td>
</tr>
<tr>
<td>Routing</td>
<td>RIP, RIPv2, OSPF</td>
</tr>
<tr>
<td>Security Services</td>
<td>Access lists, stateful inspection, NAT, VPNs</td>
</tr>
<tr>
<td>Network Services</td>
<td>ICMP, web caching, time services</td>
</tr>
</tbody>
</table>
Core Network

Equipment
Two Cisco 3750-48 layer 3 switches.
One Cisco MGX 8230 WAN switch with 48 T1 interfaces.
One Cisco 3745 router with FastEthernet and two channelized T1 CSU/DSU interfaces.
PIX 515 (two interface)

Purpose
The core network provides two switched Ethernet ports per workstation. These may be VLAN or routed interfaces, depending on the lab. In VLAN configurations, it allows students easy access to central network services, such as an instructor web server, to validate their configurations. In routed configurations, it provides students with RIP, OSPF, or BGP connections to a peering point, such as in a corporate or ISP network.

The MGX WAN switch provides one WAN connection per student workstation. The WAN connection might be sub-rate T1 or frame relay service. In a sub-rate T1, each student receives a 64k channel, which the MGX multiplexes to a channel to the core 3745 router. The 3745 provides a IP interface (PPP or HDLC) to each student to simulate a WAN connection. In frame relay configuration, the MGX provides an over-subscribed T1 interface to each student, with end-to-end frame connectivity to the 3745 router. The two T1 interfaces on the 3640 router offer students the opportunity to see equal cost multipath between the two T1s.

The PIX 515 is not used in labs, but provides a firewall between lab work and the campus network.

Student Workstation

Each student workstation consists of an 8 rack-unit (8u) open frame cube. This allows students easy access to both front and rear equipment sides. Most equipment will be pre-wired to pass-through patch panels to minimize equipment connector wear. The patch panel also has cross-connects to the core network Ethernet and T1 circuits.

Equipment
Three Cisco 2621 modular routers
WICS: 2x WIC-1DSU-T2-V2, 1x VWIC-2MFT-T1, 2x WIC-2A/S
NM: 1x NM-4E, 1x NM-CE-BP-20G-K9
CABLES: 1x CAB-SS-449MT, 1x CAB-SS-449FC, 1x CAB-SS-232MT, 1x CAB-SS-232FC

One Cisco 3550-24-EMI
Purpose
The three 2621 routers provide the core layer 3 environment. Three routers allow students to experiment with multi-hop environments in their own workspace. The combination of WICs and NMIs allow students to connect to the core network with T1 and Ethernet technologies and to create workspace serial environments.

The two switches allow students to experiment with VLANs and spanning-tree. We expect full spanning-tree labs will have two students co-operate to see four-switch spanning tree configurations. The layer 3 Cisco 3550 switch exposes students to layer 3 switching and provides a fourth hop for layer 3 labs, when combined with the three 2621 routers.

The PIX 506E gives students the opportunity to experiment with VPNs, NAT, and tunneling.

Advanced Lab

<table>
<thead>
<tr>
<th>Simultaneous students</th>
<th>1 – 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Students per workstation</td>
<td>Small group</td>
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<tr>
<td>WAN technologies</td>
<td>None</td>
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<tr>
<td>LAN technologies</td>
<td>Ethernet, Fast Ethernet, Ethernet auto-negotiation, PPoE, Ethernet switching, VLANs, VLAN trunks, inter-VLAN routing, Wireless LANs</td>
</tr>
<tr>
<td>Link technologies</td>
<td>FastEthernet, Gigabit Ethernet, GigaChannel, 802.11a/b/g,</td>
</tr>
<tr>
<td>Routing</td>
<td>OSPF, BGP, MPLS</td>
</tr>
<tr>
<td>Security Services</td>
<td>Access lists, stateful inspection, NAT, VPNs</td>
</tr>
<tr>
<td>Network Services</td>
<td>IP telephony, Voice gateways, Wireless authentication (802.1x), network analysis, storage networking</td>
</tr>
</tbody>
</table>

Equipment
One 6509 switch with: SUP720 MSFC/PFC, 48-port PoE, 24-port GigE, firewall blade, IDS blade, NAM blade.
Three 3750-48 PoE SMI switches
One 1760-V voice gateway with: 4-channel PVDM, 1x VIC-2FXO, 1x VIC-2FXS
Two CP-7970G color IP phones
Eight CP-7960G 4-line IP phones
Two CP-7920 wireless (802.11b) IP phones
Ten Software IP phones (SW-IPCOMM)
Cisco Call Manager and Unit Messaging software
Cisco Wireless LAN solution (CWWLSE-1130-19-K9)
Twenty 802.11 b/g access points
Ten 802.11a access points
CiscoWorks and CiscoSecure software (CSA-STARTER-K9, CSA-SRVR-K9)
One MDS 9216 storage switch with IP storage switching module

Purpose
As depicted on page 8, the Advanced Lab centers on a Cisco 6500 switch. The School recently purchased three 6500 switches for the new Engineering building and School network. The lab 6500 enables staff to prototype configuration changes and experiment with new technologies before release to the campus production network. The switch also gives advanced students an opportunity to see state-of-the-art technologies, such as integrated firewalls, MPLS, IPv6, and network analysis.

The 6500 switch integrates Voice over IP (VoIP) technology. The lab will contain several flavors of IP telephones, including color picture, multi-line IP, and wireless IP phones. A voice gateway enables integration with the campus phone system and analog handsets.

The wireless environment consists primarily of 802.11a access points. These will be distributed about the new engineering building for real-life experiments in wireless. The School chose 802.11a technology because the existing and future production wireless network will be 802.11b/g. Using 54 GHz A technology ensures that the experimental network will not interfere with the production environment. The lab includes twenty 802.11b access points because the 7920 wireless IP phones only support 802.11b.

The MDS 9216 storage switch would be used for instruction and research by faculty and graduate students in the Storage Systems Research Center (http://src.cse.ucsc.edu/)

Summary
The School of Engineering at U.C. Santa Cruz proposes establishing two labs for undergraduate education. The Introductory lab provides a teaching environment for up to 40 students in basic to intermediate networking technologies. The Advanced lab is for senior projects and small group projects with cutting-edge networking technologies and services. The Advanced lab also allows University and School staff to prototype new technologies before deploying to the production University network.

The table on page 7 summarizes the high-level equipment needs of the two labs. The introductory lab accommodates up to 40 students working at individual stations. It makes use of low- to mid-end equipment to study link-layer and basic routing technologies. The advanced lab has high-end flagship equipment, which allows students and staff to configure and experiment with state-of-the-art networking services. The advanced lab supports networking services such as voice over IP, wireless voice over IP, advanced routing technologies, and storage networking.
# Lab Equipment Summary

<table>
<thead>
<tr>
<th>Lab</th>
<th>Workstations</th>
<th>Quantity per station</th>
<th>Description</th>
<th>Total Items</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intro</td>
<td>40</td>
<td>3</td>
<td>2621XM routers</td>
<td>120</td>
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<td>3550-24-EMI switch</td>
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<tr>
<td>Intro</td>
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<td>1</td>
<td>2950-24-SMI switch</td>
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<td>1</td>
<td>PIX 506E</td>
<td>40</td>
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<td>WIC-1DSU-T2-V2</td>
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<td>Intro</td>
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<td>VWIC-2MFT-T1</td>
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<td>Intro</td>
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<td>2</td>
<td>WIC-2A/S</td>
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<tr>
<td>Intro</td>
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<td>NM-4E</td>
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<td>Intro</td>
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<td>NM-CE-BP-20G-K9</td>
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<td>CAB-SS-449MT</td>
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<td>Intro</td>
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<td>1</td>
<td>CAB-SS-449FC</td>
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<td>3750-48 switch</td>
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<td>Intro</td>
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<td>1</td>
<td>MGX 8230 w/ 48 T1</td>
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<tr>
<td>Intro</td>
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<td>3745 router w/ 2 T1</td>
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<tr>
<td>Intro</td>
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<td>PIX 515E</td>
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<td>Adv</td>
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<td>6509 switch</td>
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<td>Sup 720 MSFC/PFC</td>
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<td>6500 fastethernet 48-port PoE</td>
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<td>1760 4-channel PVDM</td>
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<tr>
<td>Adv</td>
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<td>VIC-2FXO</td>
<td>1</td>
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<td>VIC-2FXS</td>
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<td>2</td>
<td>CP-7970G color IP phones</td>
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<td>Adv</td>
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<td>CP-7960G IP-phones (4 line)</td>
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<td>Software IP phones</td>
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<td>Adv</td>
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<td>Call Manager &amp; Unit messaging</td>
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<td>Adv</td>
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<td>CiscoSecure starter pack</td>
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<tr>
<td>Adv</td>
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<td>MDS 9216 storage switch</td>
<td>1</td>
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</tbody>
</table>
Cisco Proposal for Advanced Lab

UCSC
Lab Logical Topology

PSTN

Voice Gateway
2 FXO – 2 FXS
FW Service Module w/ 25
Virtual FW
Intrusion Detection Module
Network Analysis Module
Catalyst 6500
Call Manager Server
Unity Server
L2

Multilayer Intelligent
Storage Networking

SAN

Cisco IP Storage
Switching Module

Fiber Channel

MDS 12/10
Storage Switch

Servers in SAN

iSCSI

Access Layer

Core/Distribution Layer