AC 2009-1243: DEVELOPING AN EFFECTIVE NETWORK COURSE USING THE CISCO CCNA EXPLORATION CURRICULUM

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Developing an Effective Network Course Using the Cisco CCNA Exploration Curriculum

Abstract

Undergraduate Computer Science (CS), Information Technology/Information Systems (IT/IS) curricula in many US Universities and Colleges only include one course in networking. This course, usually called Networking and Data Communications, varies in content and focus. Moreover, a number of popular textbooks lack in scope and content, and sometimes do not even address the basics of networking or how networks operate. The Cisco Networking Academy CCNA Exploration curriculum offers in-depth theory, challenging labs, and a detailed overview of protocol operations. It is designed for students who seek to develop their problem-solving and analytical skills. Degree candidates in engineering, mathematics and science, as well as working professionals who wish to advance their careers or gain certification are attracted by the depth of this curriculum. The CCNA Exploration curriculum is designed to be integrated into various technology curricula or programs offered at postsecondary institutions such as technical schools, colleges, and universities. In this paper the content of classical networking textbooks, including well established reference books[1, 2, 3], are reviewed for the purpose of developing an effective networking curriculum. Various objectives of the Cisco networking academy, which is a set of well developed courses that offer many hands on practice, were identified and integrated in the proposed networking curriculum. Furthermore, the new ACM curriculum models[4, 5, 6] in CS, IS, and IT were studied and measurable learning outcomes were identified. A critical look at the official CCNA exam, and how this exam can be integrated into a CS, IT/IS curriculum is provided. The newly proposed curriculum could be used to motivate students to attend Networking courses that use classical networking textbooks. It is anticipated that this paper may help CS and IT/IS faculty develop a better, more exciting content for their networking courses.

Introduction

An in depth examination of undergraduate curricula in Computer Science (CS) and Information Technology/Information Systems (IT/IS) in several Universities and Colleges in the US show that their curricula only include one undergraduate course in networking. In most Institutions this course is called Data Communications and Networking or Networking and Data Communications. Though the course descriptions may be similar, the content of textbooks used for this course varies substantially. For example in a well known institution this course is called Computer Networking and Communications and the recommended textbook title is "Computer Networking: A Top-Down Approach[1]". The course catalog description states "This course concentrates on typical hardware interfaces, programming methods, and communication protocols. The topics that are addressed in detail include: electrical interfaces, data transmission, protocol basics, LAN's, WAN's, bridged networks, internetworking, and application support". However this textbook does not address all of these topics. The textbook consists of nine chapters and each chapter is approximately ninety five pages. The titles of these chapters are: Computer Networks and the Internet, Application Layer, Transport Layer, The Network Layer, The Link Layer and Local area Networks, Wireless and Mobile Networks, Multimedia Networking, Security in Computer Networks, and Network Management. It is very hard for the student to comprehend the basics of networking without understanding IP address, subnetting,

and routing protocols. Another example from another well known academic institution shows a course catalogue title: "Computer Network and Communications". The course description states: "Network architecture and the OSI model, physical protocols for data transmission and error detection/correction, data link concepts, LAN protocols, internetworking, end-to-end service and security consideration". The recommended textbook title is "Data and Computer Communications[2]". The textbook consists of 24 chapters mainly in data communications but there is no place where the student can learn about IP addressing and subnetting. Another popular textbook in Networks is called "Computer Networks and Internets[3]", but this textbook is too brief and does not cover any networking subject in depth. There are numerous textbooks that address the CCNA curriculum such as "CCNA Guide to Cisco Networking[4]", these textbooks are however too brief and they are written as a guide to taking the Cisco CCNA exam. Other similar well known networking textbooks are listed in three references[8, 9, 10]. Cisco Press has a textbook for each of the courses offered by the Cisco Networking Academy[11, 12]. Moreover, the Cisco Networking Academy offers all their courses using a web-based curriculum so students have a choice of either buying the textbook or taking the course using the Internet. The rest of this paper introduces the CCNA Exploration curriculum, and the new ACM model curriculum. Next the paper shows how to develop a strong curriculum based on the CCNA exploration and the ACM model curriculum objectives. Finally, the Cisco CCNA certification exam is introduced and critiqued to allow students to make an informed decision as to whether to take the exam to acquire the Cisco CCNA certification.

Cisco Networking Academy & Networking Curriculum

Cisco Networking Academy offers four courses in basic Networking called CCNA exploration. The CCNA exploration curriculum provides a comprehensive overview of networking. It is based on a top-down approach to networking that is popular in many colleges and universities. The four courses emphasize theoretical concepts and practical application, while providing opportunities for students to gain the skills and hands-on experience needed to design, install, operate, and maintain networks. The curriculum offers in-depth theory, challenging labs, and a detailed overview of protocol operations. It is designed for students with advanced problem-solving and analytical skills, such as degree candidates in engineering, or science, or for working professionals who would like to advance their careers or gain certification. The CCNA exploration is designed to prepare students for a successful IT career in small-to-medium businesses, as well as enterprise and service provider environments. The curriculum can be easily integrated into Technology curricula or continuing education programs at postsecondary institutions such as technical schools, colleges, and universities. The CCNA exploration courses include embedded e-doing, which enables students to complete interactive activities that stimulate learning and improve knowledge retention experience. Furthermore, the courses include challenging hands-on labs to help students develop critical thinking, problem solving, as well as practical knowledge.

The CCNA exploration curriculum is composed of four courses:
• Network Fundamentals
• Routing Protocols and Concepts
• LAN Switching and Wireless
• Accessing the WAN

Network Fundamentals is the first course and has no prerequisites. It is however a prerequisite for the other three courses. Routing Protocols and Concepts is the preferred second course in the sequence followed by LAN Switching and Wireless and Accessing the WAN. The curriculum encourages students to explore networking concepts with tools such as Packet Tracer, a powerful network simulation program, developed by Cisco that allows students to experiment with network behavior. The CCNA exploration curriculum prepares students for the Cisco CCNA network associate certification exam.

There are many institutions in the US and worldwide which have access to the Cisco Networking Academy that offer the CCNA Networking courses, among twenty six other Cisco Networking Academy courses. These institutions include community colleges, technical colleges and universities that offer engineering technology programs. Usually, students usually take all four courses in order to prepare themselves for the CCNA certification exam. However, sometimes students elect to take only the first two courses to prepare for the Cisco CCENT certification exam. Most institutions in the US offer only one course in Networking in their undergraduate programs in CS or IT/IS unless these institutions offer a major or a minor in networking[13]. In this particular case student cannot benefit from the Cisco Networking Academy program. Faculty members in many IT/IS Colleges are not very familiar with the Cisco Network Academy curriculum and continue to use classical networking textbooks, even though these textbooks fail to address critical concepts such as IP addressing and subnetting. One of the objectives of this paper is to propose a curriculum based on the Cisco Networking Academy curriculum which can be used in one networking course in institutions which do not have access to the Cisco Networking Academy program.

CCNA Exploration Curriculum Details

The CCNA exploration curriculum is composed of four courses:

- Network Fundamentals
- Routing Protocols and Concepts
- LAN Switching and Wireless
- Accessing the WAN

Each course requires approximately 75 hours of instruction including a lab component. Credits given to the four courses vary among institutions from as low as 12 semester credit hours up to a maximum of 20 credit hours. An ideal course for the undergraduate program in Computer Science or Information Technology/Information Systems should cover some components from the first three CCNA exploration courses. Some of these components are included in one particular textbook by Beasley[14] designed for two semesters rather than just one semester. To use this textbook[14] effectively, the instructor must be familiar with Cisco Internetwork Operating System (IOS) and must have access to Cisco routers and switches. Moreover, the instructor should preferably be familiar with the Cisco Packet Tracer simulation software. If the instructor does not have access to Cisco routers and switches, Packet Tracer can be used as a tool to simulate Cisco routers and switches.

The textbook by Beasley[14] covers the following chapters: Introduction to Computer Networks, Physical Layer Cabling: Twisted Pair, Computer Fundamentals, Interconnecting LANs, TCP/IP,

Introduction to Router Configuration, Routing Protocols, Wide Area Networking, Configuring and Managing the Campus Network, Network Security, Wireless Networking, Optical Networking, Voice over IP, The Network Server, Linux Networking, and Industrial Networks. This textbook is an excellent resource for engineering technology programs as well as Computer Science and Information Technology/Information Systems programs which focus on applied rather than theoretical knowledge. Moreover, the textbook covers chapters on Voice over IP, Wireless Networking, and Network Security. These chapters are covered in details in separate courses offered by the Cisco Networking Academy.

The new ACM model curriculum in Computer Science[4] includes 27 hours in network communication (core) and 6 hours in network security (core). The proposed curriculum for a network course should take the learning objectives of these thirty three hours into consideration. However, the IT 2008 curriculum[6] includes 22 hours in networking (core) and all the topics are covered in the CCNA curriculum. In general small institutions in the US which offer majors in CS, IS, and IT do not have a separate course in Networking for each major. Instead, one Networking course is offered for the three majors. Table 1 give some details about the networking component of the core curriculum in the ACM model curriculum CS 2008, IT 2008, and IS 2002[5].

Table 1. Networking components of the ACM model curriculum

CS 2008 (33 hours in core)	IT 2008 (22 hours in core)	IS 2002 (IS 2002.6 3credits)
• Introduction to Networking (2h) • Networking Security (6 h) • Network Communication (7 h) • Net-centric Computing (18 h)	• Foundations of Networking (3h) • Routing and Switching (8h) • Physical Layer (6h) • Security (2h) • Network Management (2h) • Application Areas (1h)	Telecommunication configurations; network and Web applications; distributed systems; wired and wireless architectures, topologies, and protocols; installation, configuration, and operation of bridges, routers, switches, and gateways; network performance tuning; privacy, security, firewalls, reliability; installation and configuration of networks; monitoring and management of networks; and communications standards.

The CCNA exploration curriculum covers the following skills and competencies.

Network Fundamentals:

- Use network protocol models to explain the layers of communications in data networks
- Design, calculate, and apply subnet masks and addresses
- Build a simple Ethernet network using routers and switches
- Employ basic cabling and network designs to connect devices
- Use Cisco CLI commands to perform basic router and switch configuration and verification
- Analyze the operations and feature of the transport and network layer protocols and services

Routing Protocols and Concepts:

- Configure and verify router interfaces
- Demonstrate comprehensive RIPv1 configuration skills
- Design and implement classless IP addressing scheme for a network
- Use advanced configuration commands with routers implementing EIGRP
- Apply the basic RIPv2 configuration commands and evaluate RIPv2 classless routing updates
- Identify the characteristics of distance vector routing protocols

LAN Switching and Wireless:

- Troubleshoot common network problems at Layers 1, 2, 3 and 7 using layered model approach
- Interpret network diagrams
- Perform and verify initial switch configuration tasks including remote access management
- Configure, verify, and troubleshoot VLANs, interVLAN routing, VTP, trunking on Cisco switches, and RSTP operation
- Manage IOS configuration files
- Identify the basic parameters to configure a wireless network and common implementation issues

Accessing the WAN:

- Describe the impact of applications (Voice Over IP and Video Over IP) on a network
- Configure, verify, and troubleshoot DHCP and DNS operation on a router
- Verify, monitor, and troubleshoot ACLs in a network environment
- Configure and verify basic WAN serial connection, a PPP connection between Cisco routers, and Frame Relay
- Configure and verify a PPP connection between Cisco routers, and Frame Relay on Cisco routers
- Troubleshoot WAN implementation issue

The Proposed Network Course Objectives & Measurable Learning Outcomes

Based on the Cisco CCNA exploration curriculum, the following course objectives are the most important objectives which could be effectively integrated into a network course[7]. Although the use of Packet Tracer is not listed as an objective, its use could facilitate student understanding of Cisco routers and switches configuration. Furthermore, the use of Packet Tracer is included in the new CCNA certification exam. Though the list of the course objectives is long, careful planning is required to include all these objectives into a single Networking course. These objectives are distributed into nine modules or chapters, which are listed in details below.

1.1 Identify and describe the functions of each of the seven layers of the OSI reference model
1.2 Identify the reasons why the networking industry uses a layered model
1.3 Define and explain the conversion steps of data encapsulation
1.4 Define and describe the function of a MAC address
1.5 Describe connection-oriented network service and connectionless network service
1.6 Explain the uses, of repeaters, hubs, wireless access points, bridges, switches, and routers
1.7 Define the standards associated with wireless media

1.8 Explain basic wireless connection parameters, security, and troubleshooting
1.9 Explain network segmentation using bridges, switches, routers, brouters, and gateways
1.10 Explain Ethernet operations, define Fast Ethernet and Gigabit Ethernet
2.1 Discuss the origins of TCP/IP, identify and discuss the different layer functions of TCP/IP
2.2 Describe the functions performed by protocols ICMP, UDP, TCP, ARP, and RARP
2.3 Use Ping and Trace and describe their functions, explain how packets are transmitted
3.1 Explain the different classes of IP addresses configure IP addresses, subdivide an IP network
3.2 Discuss advanced routing concepts such as CIDR, summarization, and VLSM
3.3 Convert between decimal, binary, and hexadecimal numbering systems
3.4 Explain the differences between IPv4 and IPv6
4.1 Describe the benefits of network segmentation with routers
4.2 Understand the elements of the Cisco router user interface
4.3 Describe the various router configuration modes, describe the various router passwords
4.4 Understand the enhanced editing features of the Cisco IOS
4.5 Compare router components to typical PC components
4.6 Describe the steps involved in starting a router, describe and use the Cisco Discovery Protocol
4.7 Configure IP on the Cisco router, troubleshoot router connectivity problems
5.1 Differentiate between nonroutable, routed, and routing protocols
5.2 Define IGP, EIGP, distance-vector routing protocols, and link-state routing protocols
5.3 Explain the concepts of count-to-infinity, split horizon, split horizon with poison reverse
5.4 Describe classful and classless routing protocols, describe and configure RIPv2, EIGRP, and OSPF
6.1 Understand the purpose and operation of NAT, static NAT, dynamic NAT, and PAT
6.2 Understand and configure DHCP, DNS, and Cisco's Security Device Manager (SDM)
7.1 Describe the usage and rules of access lists, establish standard IP access lists
7.2 Produce extended IP access lists, apply access lists to interfaces, monitor and verify access lists
7.3 Create named access lists, use Security Device Manager to create IP access lists
7.4 Use Security Device Manager to create a router firewall
8.1 Explain the technology and media access control method for Ethernet networks
8.2 Explain network segmentation and basic traffic management concepts
8.3 Explain basic switching concepts and the operation of Cisco switches
9.1 Perform and verify switch configuration tasks, implement basic switch security
9.2 Distinguish between the different types of network security threats
9.3 Explain how to mitigate network security threats, implement SSH on Cisco routers and switches
9.4 Configure VPNs with the Cisco Security Device Manager

Proposed Network Course Content

The detailed course objectives listed in the previous section can be integrated into the following nine chapters or modules. Moreover, the ACM model curriculum objectives in network security should be integrated into chapter 9.

1. Introducing Networks and Network Devices
2. TCP/IP
3. IP addressing and subnetting
4. Introduction to Router and Router Configuration
5. Routing Protocols and Router Configuration
6. Network Services (NAT, PAT, DNS, DHCP, and Cisco SDM)
7. Access List
8. Basic Switching and Switch Configuration
9. Network Security

Although each objective is assigned to a specific chapter, an objective could be met in more than one chapter. The proposed course objectives cover approximately 75% of the CCNA exploration objectives. In order to cover all the CCNA exploration objectives in one course, the number of semester credits hours need to be increased to six semester credit hours. The CCNA objectives that are not covered in this course are included in accessing the WAN module and LAN switching and Wireless module.

The Lab Component

The Cisco Networking Academy includes a lab component with each module of the CCNA Exploration curriculum. Typically, it requires two hours per week for each module in a typical sixteen week semester. Cisco Networking Academy provides students with lab projects either in downloadable PDF files or if they wish, student can purchase the lab textbook[15] from Cisco Press. The proposed course curriculum also includes a lab component which is vital for understanding key concepts in each chapter. Ideally the lab should include Cisco routers and switches to provide hand-on learning experiences, but Packet Tracer can be used to facilitate the required learning if the instructor of the course is familiar with routers and switches configurations. The lab projects can be mapped into the course learning outcomes and they can be developed based on Cisco Networking Academy lab curriculum[15]. The CCNA exam includes three lab questions and students need to use a simulator to answer them. These questions normally focus on subnetting, (NAT) Network Address Translations, and Basic Router/Switch configuration and troubleshooting. It is expected that in the near future CCNA exams will use Packet Tracer for their lab simulation questions.

The CCNA Certification Examination: A Critical Review

Even though there are many references which address the CCNA exam[7], it is almost impossible to integrate the CCNA objectives into a one semester course[16]. The proposed networking course

curriculum prepares the student for most of the CCNA objectives. After completing all the courses, the student can proceed to prepare for the certification exam[17]. The actual and proper curriculum which should be used to prepare students for the CCNA exam is the Cisco Networking Academy course sequence. The Cisco CCNA curriculum is excellent when its content is compared to the content of a number of classical textbooks in Networking & Data Communications[1, 2, 3, 8, 9, 10]. However, the CCNA exam format and the time allocated for the exam need to be discussed.

The current version of the exam consists of 52 problems including three simulation problems and the passing score is 85%. The time for the exam is 90 minutes and it is a critical factor to consider for successfully completing the exam. The exam questions are easy, but the time constraint and the exam format make it very hard to achieve the passing score of 85%. There are three simulation problems and the order of these problems is not know. Some problems require one minute to solve while others require ten minutes to solve. Moreover, the grade distribution for all the questions/problems (easy and difficult) is unknown. It is not possible to go back and change any solved question and it is necessary to answer each question before proceeding to the next. The other problem is the fact that there are many Web based companies which sell sample questions for the CCNA exam. To counteract that problem, Cisco introduced new security measures to a number of testing centers in China, Hong Kong, and India but many students still rely on "buying" these questions to increase their chances to pass the exam. For example, there is a website that posted 10 sample questions and all the ten posted questions appeared in the CCNA exam. Another example is the case of a student who managed to get a 100% in the CCNA exam. Interestingly, the student admitted that all the questions were part of a sample test which was purchased from the Internet. Unfortunately, for ordinary students who decide to study the CCNA curriculum and get certified, passing the CCNA exam can be quite challenging.

There are many institutions that teach the CCNA curriculum without requiring their student to take the CCNA exam. However, there are exceptions to that rule. As an example one institution requires passing the CCNA certificate as a prerequisite for several IT courses. Taking the CCNA certification exam should be integrated into the Cisco Networking Academy Curriculum when certification is critical for the students. Currently the Cisco Networking Academy does not require their students to take the CCNA exam. However, in order to acquire the title of CCAI (Cisco Certified Academy Instructor) the instructor has to pass the CCNA certification exam.

Conclusions

In this paper, popular textbooks which are often used in the first Networking course in Computer Science, Information Technology, and Information Systems undergraduate programs were examined. Findings reveal that the contents of these textbooks vary substantially even though these textbooks are used for courses having similar descriptions. Furthermore, these textbooks do not address IP addressing and subnetting in enough details to enable students to understand the basics of networking. The Cisco Networking Academy exploration curriculum was carefully examined. The curriculum considers IP addressing and subnetting as two critical topics in the CCNA certification exam. A number of reference books typically used as a guide for the CCNA exam were also studied. Sybex publishes reference books for many IT certification exams. These reference books can be used to prepare for the certification exam but they are not designed and

written the same way as textbooks making them less desirable as textbooks. Based on studying the CCNA exploration curriculum and after taking the ACM model curriculum recommendations into consideration, a number of Networking course objectives are proposed. These course objectives can be integrated into nine chapters of a Network course and the contents of these nine chapters can be mapped directly into the Cisco CCNA exploration curriculum. Moreover, these detailed course objectives can help instructors focus their course content and design specific learning experiences to facilitate student learning. Finally for students interested in pursuing the certification track, the CCNA certification exam is discussed and a critical review of the exam's format and structure are discussed. It is anticipated that such an approach will reduce students' fear of CS and IT/IS courses and hopefully renew their interest in the computing field.

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