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Successful Integration of Practical Cisco CCNA in the Computer Networks Design Course

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***Abstract*—This paper presents a new curriculum for the Computer Networks Design course intended as advanced course for computer science students. We have developed an adaptive curriculum, which introduces two CISCO CCNA 3 (LAN Switching) and 4 (WAN Technologies) courses instead of the existing (regular) tutorials and laboratory exercises. The students can choose whether they would like to learn the course by a more practical approach using the CISCO CCNA integration, rather than by a more theoretical approach. The evaluation show much better results for the students that follow the course using the integration of the CISCO practical exercises, rather than those that follow the course regularly only by theoretical approach.**

***Index Terms*—*Curriculum*; *Education*; *Cisco*; *CCNA*; *Teaching methods*.**

I. Introduction

The network connections are the main infrastructure of current modern computing environment, such as complex data centers, grid or cloud computing. Proper planning and design of computer networks will improve the overall performance of higher services, such as web applications, web services, IPTV, VoIP, etc. It is important that the network and communication engineers can understand both the lower and upper layers in the communication stack with final goal to exploit the knowledge and skills to design and build modern networks. Therefore, the computer networks and data communication topics used in the Net-Centric Computing knowledge area, which mainly included traditional networking, web development, and network security [1] were upgraded and refactored into the new knowledge area of Networking and Communication [2].

Learning computer networks and data communication is usually more complex for the computer science students than software oriented courses are, such as programming languages and algorithms. Students usually want to use the computers for executing their applications and network devices for data transferring, without knowing how they work. Much of the time during the labs is spent on monitoring and giving answers or instructions to the students, while less time is spent on learning context [3]. However, today's elastic and scalable distributed computing environments should survive unpredictable peak demands, which requires not only to show their programming skills, but to understand how the lower protocols on network layer work.

Therefore, the Computer Networks based course curricula should be more efficient and introduce more practice [4] and hands-on, which is the preferred learning style of computer science and engineering students [5]. Cisco Systems, the leader of networking equipment vendor, introduced Cisco Networking Academy program together with learning and training materials to allow its personnel, partners and customers for better learning and training [6].

In the last five years we have successfully integrated the CISCO CCNA 1 and 2 courses with the Computer Networks (CN) course, whose goal is to introduce the students with the basic concepts of computer networking, main components of network architecture and how data is transfered across the network [7]. Computer science students have basic computer skills, which increase their achievement in the CCNA program [8]. Therefore, we used the Cisco's CCNA Exploration program, which is intended for advanced problem solving issues of computer networking (typically for degree programs in computer engineering or computer science), instead of Discovery, which is primarily intended for entry-level career-oriented IT-skills students [9]. This motivated us to continue with the integration of the other two CCNA courses (CCNA 3 and 4) in the advanced network-based course intended for computer science students, that is, the Computer Networks Design (CND) course, whose goal is teach the students to design and work with large and complex computer networks, after taking the basic CN course.

We have developed an adaptive curriculum for the CND course, which introduces two CISCO CCNA 3 (LAN Switching) and CCNA 4 (WAN Technologies) courses instead of existing (regular) tutorials and laboratory exercises. The students can choose whether they would like to learn the course with more practice or more theoretically. The evaluation of several years show much better results for the students that follow the course through CISCO practical exercises, rather than those that follow the course regularly.

The rest of the paper is organized as follows. Section II presents the related work in the computer network education with practical Cisco Networking Academy curriculum and tools. In Section III we describe the regular CND course curriculum. Section IV presents the new, more practical, curriculum by integrating Cisco CCNA 3 and 4 into the CND course. The evaluation of the successfulness of the new practical CND course is presented in Section V. Section VI discusses the benefits of the new course curriculum. Section VII concludes the work and presents the plans for enhancing the research.

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II. Related work

This section presents the related work of lab and tools used for delivery of the course, as well as the integration of the computer networking with some practical work, such as Cisco Networking Academy.

A. Educational resources for delivery of CND

The expansion of new ICT techniques and technologies alleviate both teaching and learning of computer networking. Presenting the lecture in the traditional format does not motivate enough all students to learn about computer networking [10]. Paravirtual laboratory can be used to setup virtual networking labs, which usually improves the students' performance compared with the case when the students are working directly on physical networking equipment [11].

The undergraduate network management course can be improved with Collage [12] and Gridcole [13] with a computer-supported collaborative learning [14]. Open educational resources (OER) can improve the course [15] for distance learners [16]. A web-based laboratory offers the students tools to draw, configure, test, and troubleshoot network designs [17]. VNUML-UM is a tool for virtualizing network scenarios [18].

B. Integration with practice

Several examples exist of partial integration. Zhang et al. [19] presented how to motivate the students to learn computer networking by using Cisco Packet Tracer simulator. Janitor et al. [20] presented how students can extend the learning experience by creating their own virtual networking nodes. Petcu et al. [21] combined the Packet Tracers features with Moodle learning platform. Jasani [22] used Cisco's access point in lab exercises. However, all these examples do not follow a systematic practical approach for learning the computer networking, which is accepted by broader industry [23]. For example, Sun et al. [24] evaluated that students enjoy the use of network simulators to gain relevant experience. However, our experience in Cisco CCNA courses show that students do learn the basics of networking by using the Packet Tracer simulator, but when they start to work on a real equipment, they are faced with many other new challenges, such as working on command line interface only, cable problems, interface or port errors, physical connectivity, proper cabling and finding the appropriate cables, operating systems firewall problems, and so on.

Cisco Networking Academy is an integral part of some national academic programs [25]. Revzina [26], [27] integrated the Cisco CCNA with the four semester computer networks course. However, we believe that using only this program will profile the students as a practitioners only, and not as a scientists or engineers. Our approach is to use the Cisco Networking Academy program as a complementary part of the course, thus retaining the theoretical part. We integrated all four CCNA courses in only two courses (each delivered in one semester) and not in four.

Some curricula of Cisco Network Academy program are integrated and used in graduate courses. Ariyapperuma and Minhas [28] integrated the Cisco's Fundamentals of Network Security in the MSc Information Security. However, they were more focused on the impact of using the networking pedagogic tool on the MSc Network Management program, rather than presenting the real integration with some graduate course.

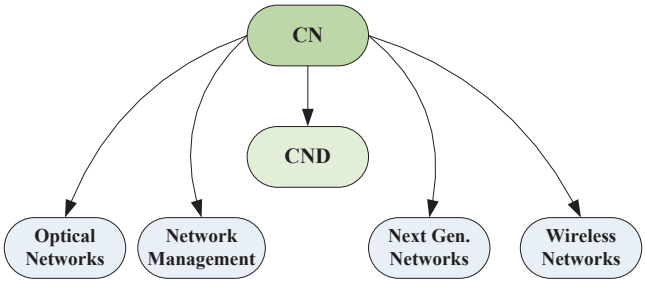


Fig. 1. Hierarchy of the computer networking courses

III. The regular CND course curriculum

This section describes the regular CND course curriculum. The details are given for the CND course format, delivery, grading scheme, course coverage and assessment of students.

A. Computer networking based courses

The computer networking based courses are organized in a three levels hierarchy, as presented in Fig. 1. The first course - CN, is mandatory for all students and it covers the computer networks basics. More details about the CN course are given in [7]. A more advanced course is the CND course. Students should have passed the CN course as a precondition to be enrolled in the CND course.

Further on, students can choose in which direction they would like to increase their computer networking knowledge. That is, several elective courses are offered, such as Optical Networks, Network Management, Next Generation Networks or Wireless Networks.

B. The CND course delivery

The CND course is an elective course that is offered in the sixth semester (third year of the study). The course is organized in three parts: theoretical lectures, exercises and lab assignments, 2+1+2 hours per week, correspondingly. The theoretical lectures and exercises are delivered in a larger group of students, while the lab assignments are delivered in a groups of maximum 20 students.

C. The course goal

The course goal is to qualify the student to work with large and complex computer networks and to interconnect collaboration of various administrative regions, after taking the basic CN course. Also, it teaches the student how to design computer networks of different types according to the customers needs.

TABLE I
STRATEGIC GRADING SCHEME

Activity	Percentage
Exams	70%
Projects	20%
Activity	10%

TABLE II
ANALYTIC REGULAR GRADING SCHEME

Activity	Points	Min. requirements
Theoretical exam	60	50%
Tutorial exam	60	50%
Laboratory Exercises	40	30%
Project	40	50%
Total	**200**	**100**

D. Course coverage

The course covers the client requirements identification, traffic analysis, logical and physical network design, network design of campus, management and security strategies, voice and wireless networks design, then testing, optimization and documentation of network design. Additionally, the students learn how to work on networks with several administrative domains. Exercises followed the lectures each week.

E. The course grading scheme and assessment

Students achieve six ECTS credits after passing the CND course. The Bologna system suggests that students should achieve credit points for each activity. Table I presents the distribution of the credit points that can be achieved for each activity.

F. Assessment

The course is delivered in several parts and Table II presents the detailed points that can be achieved for each part of the CND course, as well as the minimum percentage that must be achieved to pass the particular part. The theoretical part (theoretical and tutorial exam) carries 60% of the final grade, while the practical part carries 40% (20% for project and 20% for laboratory exercises). Theoretical and tutorial exams are performed on the e-Assessment system, while the students need to show a practical knowledge in network design for exercises parts. Starting from this year, we implemented as a pilot our e-Assessment system with interactive images [29], where the students achieve different types of questions.

IV. THE NEW PRACTICAL CND CURRICULUM

This section presents the new course curriculum with introducing more practical Cisco courses into the course. Following the good experience with practicing the CN course, we also kept the theoretical lectures points in the new curriculum. The students are offered an opportunity to choose a program (CISCO or regular) for theoretical and laboratory exercises. However, the precondition to be enrolled in the Cisco program is to have passed the previous CISCO CCNA 1 and 2 (combining with the predecessor CN course).

Although some academies deliver the CCNA courses using blended distance learning [30], we use only partial blended learning, and we are more focused to traditional learning in the laboratory with equipment, where each group of students will work on its own equipment. The traditional physical approach also offers broader experimental setup rather than remote laboratories or simulation [15].

A. Cisco Courses

The students are offered to attend the CCNA 3 (Lan switching) and 4 (Wan Networking) courses instead of regular theoretical and laboratory exercises. The teachers are CISCO instructors.

Students learn the topics of LAN switching and wireless networking in the Cisco CCNA 3 Exploration course. The CCNA 3 course covers:

- LAN Design - Network Hierarchical Design Layers;
- Basic Switch Concepts and Configuration;
- Virtual LANS (VLANs);
- Virtual Trunking Protocol (VTP);
- Spanning Tree Protocol (STP);
- Inter VLAN Routing; and
- Basic Wireless Concepts and Configuration.

The CCNA 4 course delivers knowledge about the WAN protocols:

- Wan protocols - Cisco HDLC (High-Level Data Link Control) protocol, Point to point (PPP), Frame Relay;
- Network security;
- Filtering the network traffic with access lists;
- Teleworker services;
- IP Addressing Services DHCP (Dynamic Host Configuration Protocol) / NAT (Network Address Translation) / PAT (Port Address Translation) / IPv6; and
- Network Troubleshooting.

Both CCNA 3 and 4 courses have two exams: practical in the CISCO Packet Tracer simulator, and one theoretical on the CISCO's online web learning environment. The courses extend the student knowledge about designing LAN and WAN networks extending the theoretical part. Another very important benefit for the students is the possibility of obtaining the CCNA certificate, which will provide them with the opportunity to find a better job after graduation.

B. The new grading scheme

The main idea of the course changes was to increase the practical part of the course instead of theoretical.

Table III presents the details of the new grading scheme, together with the minimum percentage that must be achieved to pass the particular part and its subparts. The new grading scheme consists of three parts, theory 30% and CCNA 3 and CCNA 4 by 35%.

The assessments of the students in both CCNA 3 and 4 courses consist of five parts:

- *Laboratory exercises*, which corresponds to the regular lab exercises, but the students work on real Cisco equipment;

TABLE III
ANALYTIC CISCO GRADING SCHEME

Activity	Points	Min. requirements
Theoretical exam	60	50%
CCNA 3	70	by 70% of Skills and Final Exam
CCNA 4	70	by 70% of Skills and Final Exam
Total	**200**	**100**

- *Homework assignments*, where the students are given challenge exercises of a given subject, defined by Cisco, and some by the instructors to extend the knowledge even more;
- *Chapter assessments*, which are optional and the students are allowed to make them at home with accessing the learning materials.
- *Practical skills exam* is taken in front of the instructor. It is a self-graded assessment task in the Cisco's Packet Tracer simulator.
- *Final exam* is conducted on Cisco Networking Academy web site in front of the instructor.

At the end of each course, 70 points of Table III are distributed as:

- 40% - Final exam;
- 40% - Skills exam; and
- 20% - Chapter assessments.

Laboratory exercises and homework assignments are not graded, but they are mandatory as a student can go on practical skills and final exams. The idea is for the students to gain both the necessary experience for working on real equipment and simulator.

C. Optional challenge problem

Sometimes, a challenge problem is given to the students by the instructors that are adapted to the students' knowledge. The first student that will solve the challenge does not need to take the practical exam of CCNA4. An example of such challenge is presented in Fig. 2. This is a nonstandard problem to allow ping between the PC with each server, where the servers can communicate outside of the local network without being configured with Default Gateway. The students can configure only the intermediary devices (the router and the switch), without changing the configuration of end devices (neither PC nor servers) and without changing the network topology. Advanced knowledge of CCNA 3 (VLANs and Intra Routing on a stick) and CCNA 4 (ACLs and NAT/PAT) is required by the students.

D. Regular vs Cisco grading scheme

Fig. 3 presents the comparison of regular and Cisco grading schemes. We observe that the tutorial exercises are moved to the practical part of the course. That is, the tutorial exercises, project and lab exercises from the regular curriculum are equalized with CCNA 3 and CCNA 4.

30% of the theoretical part are moved to the practical part, thus moving it from 40 to 70% of the course.

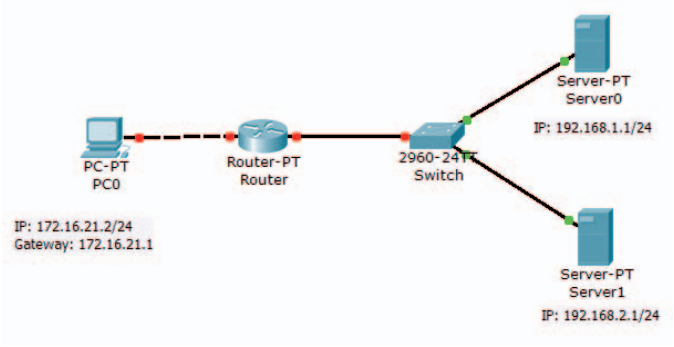


Fig. 2. A challenge problem for additional student motivation

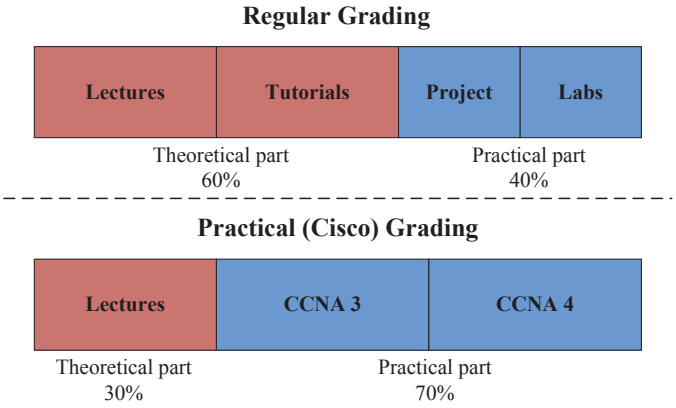


Fig. 3. Moving the points from theoretical to practical part

E. New course practical approach for theoretical exercises (CISCO program)

The CND course has one lesson of theoretical exercises weekly and this section elaborates the proposed curriculum changes.

Table IV presents the summary of the material covered with the theoretical exercises, week by week during the semester. Since the CND course has only one lesson per week for theoretical exercises, usually one CISCO CCNA Chapter is lectured each week. However, an exception is made with the introduction chapters of both CCNA 3 and CCNA 4, which are lectured together with other chapter in a week since that material is introductory, because they are covered in theoretical lectures. We shuffled the chapters of the CCNA 4 course in order to equalize the material and to fit it into the one lesson slot. Another reason is that chapter 4, 6 and 8 do not have much laboratory exercises, while chapters 5 and 7 are more difficult to learn and we give the students more time for practical learning. The next Section IV-F discusses these changes in more detail.

TABLE IV
THEORETICAL EXERCISES BY WEEKS WITH CISCO PROGRAM

Week	CISCO CCNA Module
1	CCNA 3 - Chapters 1 and 2: LAN Design and Switch configuration
2	CCNA 3 - Chapter 3: VLANs
3	CCNA 3 - Chapter 4: VTP
4	CCNA 3 - Chapter 5: STP
5	CCNA 3 - Chapter 6: Inter-VLAN routing
6	CCNA 3 - Chapter 7: Wireless
7	**Midterm 1: CCNA 3 - Practical (Skills) and Final Exam**
8	CCNA 4 - Chapters 1 and 3: Wan services and Frame Relay
9	CCNA 4 - Chapter 2 : HDLC and PPP
10	CCNA 4 - Chapter 5 : ACL
11	CCNA 4 - Part of Chapter 7 : DHCP / NAT / PAT
12	CCNA 4 - Chapter 4 : Enterprise Network Security
13	CCNA 4 - Chapter 6, part of 7 and 8 : Teleworker services, IPv6, RIPng and Network Troubleshooting
14	**Midterm 2: CCNA4 - Practical (Skills)**
15	**Final Exam: CCNA 4 - Final Exam**

F. New course laboratory exercises (CISCO CCNA 3 and 4 program)

There are 12 CISCO laboratory exercises that cover the practical part of CCNA 3 and CCNA 4 courses, i.e., by six laboratory exercises for each course. Each laboratory exercise is explained in detail below.

Lab 1 - Switch configuration - This laboratory exercise covers the basic switch configuration. Students learn the differences and similarities between router and switch configuration. Since the students have exam session between CCNA 2 and CCNA 3, it is good for students to refresh the knowledge about routing (both static and dynamic EIGRP), especially because they need to learn in the further modules inter-VLAN routing. Thus, students should solve redistributing static route by the routing protocols RIP and OSPF for homework.

Lab 2 - Configuring VLAN and Trunking - Students continue with configuring switch ports as access and trunk. They learn the intra-VLAN routing. A homework is assigned to the students to troubleshoot several common switched network configurations (both hardware and software) with VLANs.

Lab 3 - VTP - After learning the basics of switching, it is time to learn how to efficiently configure a network with many switches? Students learn the VTP protocol in order to design synchronized VLANs across the network. For homework, students achieve challenged tasks where they need to solve multiple domains and improving the network performance with VTP pruning.

Lab 4 - STP - Now it is time to implement redundancy in the hierarchical network design, what can easily generate loops and network congestion. Students are learning how to configure and administer the STP protocol in order to prevent loops. For homework, students should configure the variants of STP, that is, Per-VLAN spanning tree protocol (PVST), PVST+, rapid PVST+, Rapid spanning tree protocol (RSTP) or Multiple STP.

Lab 5 - Inter-VLAN routing - This is maybe the most important exercise. Student learn both types of inter-VLAN routing: traditional and router-on-a-stick. A challenge exercise is given to the students to troubleshoot the common inter-VLAN connectivity issues. Some routing protocol, as well as redistributing the default route is given in the homework, as the students prepare better for the practical exam.

Lab 6 - Wireless - The last exercise of the CCNA 3 course consists of configuring the wireless router in order to design wireless LAN (WLAN).

Lab 7 - Frame Relay - Although Frame Relay is the third chapter in CCNA 4, we moved it as the first laboratory exercise because of balancing the lecture size (Chapter 1 and 3 are lectured in the first week). Students learn to design and configure frame relay using WAN emulation cloud. For homework, students have a task to configure a point to multi-point.

Lab 8 - HDLC and PPP - This laboratory exercise teaches the students how to use PPP, instead of the default HDLC protocol that is used on Cisco equipment. They configure the PPP to use PAP (Password authentication protocol) or CHAP (Challenge-Handshake Authentication Protocol) authentication. For homework, the students should debug and troubleshoot a PPP serial connection.

Lab 9 - ACL - The computer networks should be designed to be secured by using standard and extended ACLs. The students achieve a challenged homework in which they should configure several dependent ACLs. That is, allowing some traffic on one router, will deny some other traffic that is not allowed on the same interface. They should also reduce the ACLs by summing ACLs where possible.

Lab 10 - DHCP - We divided Chapter 7 to two and a half lab exercises (DHCP, NAT/PAT and IPv6), because it is too practical and should be given more attention by the students. In a huge network, the administrator should spend a lot of time in configuring IP addresses. Thus, it is time to learn how to configure automatic obtaining IP addresses and other similar parameters. Students should configure the router as a DHCP relay server for homework.

Lab 11 - NAT / PAT - This is the second exercise of the Chapter 7. Students learn to configure private to public IP address translation. If the inter-VLAN routing was the most

important lab exercise for CCNA 3, this is the most practical exercise from CCNA 4. For homework, the students should solve a more challenged problem. That is, they need to hack (avoid) an ACL by using NAT/PAT.

Lab 12 - Port Forwarding - This is the last exercise of our practical approach, which is not defined as an exact exercise by Cisco. That is, we enhance their knowledge by teaching them port forwarding on a real example. For homework, the students are given an example of the practical project skills exam as they can prepare better.

G. The Cisco students' assessments

This section presents what and how the Cisco's students are taking the assessments in the CND course.

1) Midterm 1 (CCNA 3): The exercise part of midterm 1 consists of two parts: the theoretical and practical. The former is in fact the final exam of CCNA 3, conducted on CISCO Networking Academy's web site. The latter consists of task that usually covers chapters 1 to 6 (without wireless). Each student solves the same network topology with a certain IP address range and the number of hosts per subnet in the CISCO Packet Tracer simulator. An example of the practical exam of CCNA3 is presented in Fig. 4. The skills exam is given to the students as a self assessment Packet Tracer task where the students can see the percentage of their successfulness.

The learning objectives are:

- Design the networks with hierarchical model of network;
- Basic switch and security configuration of both Access and Distribution layer switches;
- Propagating VLANs by using VTP;
- Ensure the redundancy by using STP;
- Using router-on-a-stick routing for PC part (left part of Fig. 4);
- Using traditional routing for server part of the network (right part of Fig. 4); and
- Routing the traffic between PC and server part (between the routers).

This skills exam is much harder than those proposed by Cisco.

A student must achieve a minimum of 70% of the CCNA 3 skills exam in CISCO Packet Tracer simulator to pass this part of the midterm 1 and to get a chance to take the midterm 2.

2) Midterm 2 (CCNA 4): The exercise part of midterm 4 also consists of the same theoretical (final CCNA 4 exam) and practical portions. The practical portion of midterm 2 consists of the topic that are covered in lab exercises, i.e. routing, ACLs, PPP with PAP or / and CHAP, NAT/PAT, and DHCP. Students will pass if they solve 70% of the task, i.e. three of four topics. This practical exam is also conducted in the CISCO Packet Tracer simulator. The similar network configuration as the one for CCNA 3 is used as a framework for the skills exam for CCNA 4.

3) Final exam (CCNA 3 and 4): The students that have passed both midterms are released from having to attend the final exam. Those students that will fail at least one of the midterms must take the final exam.

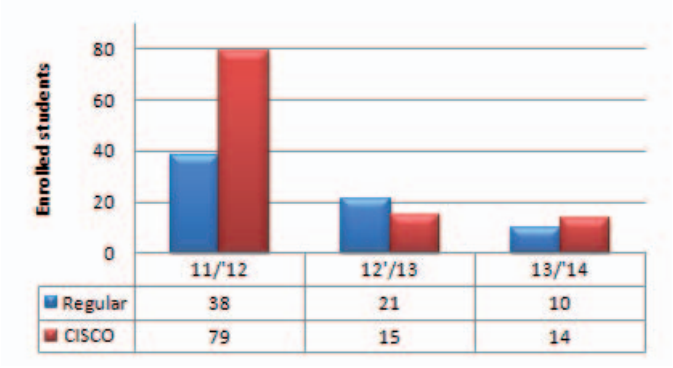


Fig. 5. The number of CISCO and regular students by years

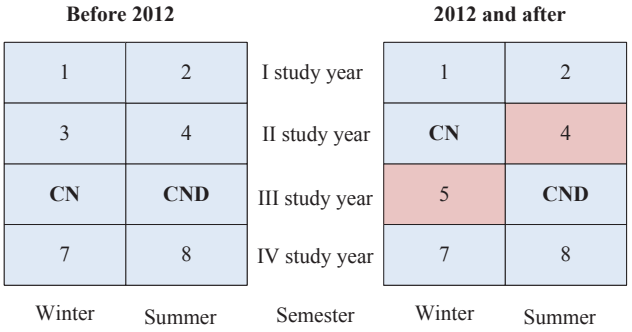


Fig. 6. Moving the CN course from the fifth to the third semester

Three additional attempts for CCNA 3 and CCNA 4 are allowed to take the final exams during the semester, that is, the exam sessions are exactly the same as the regular students. Instead of the CCNA 3 and CCNA 4 practical midterm exams, the final practical exam covers the whole material of both CISCO CCNA 3 and 4 courses with the similar framework network.

V. The Evaluation of the New Curriculum

This section presents the evaluation of introducing CISCO in the CND course's curriculum in the past study years.

A. The number of enrolled students

Fig. 5 depicts the number of the CISCO and regular students. There are two reasons why the number of student reduced significantly in 2012. The basic CN course was moved from the third (the fifth semester) to the second study year (the third semester). This violated the continuum of computer networking area from two iterative courses and raised a gap of two semesters between the courses.

Fig. 6 presents the difference in the overall curriculum change for the cases prior and after 2012. The course continuum has been broken and the number of students that elected the course has reduced immediately, especially for computer science students.

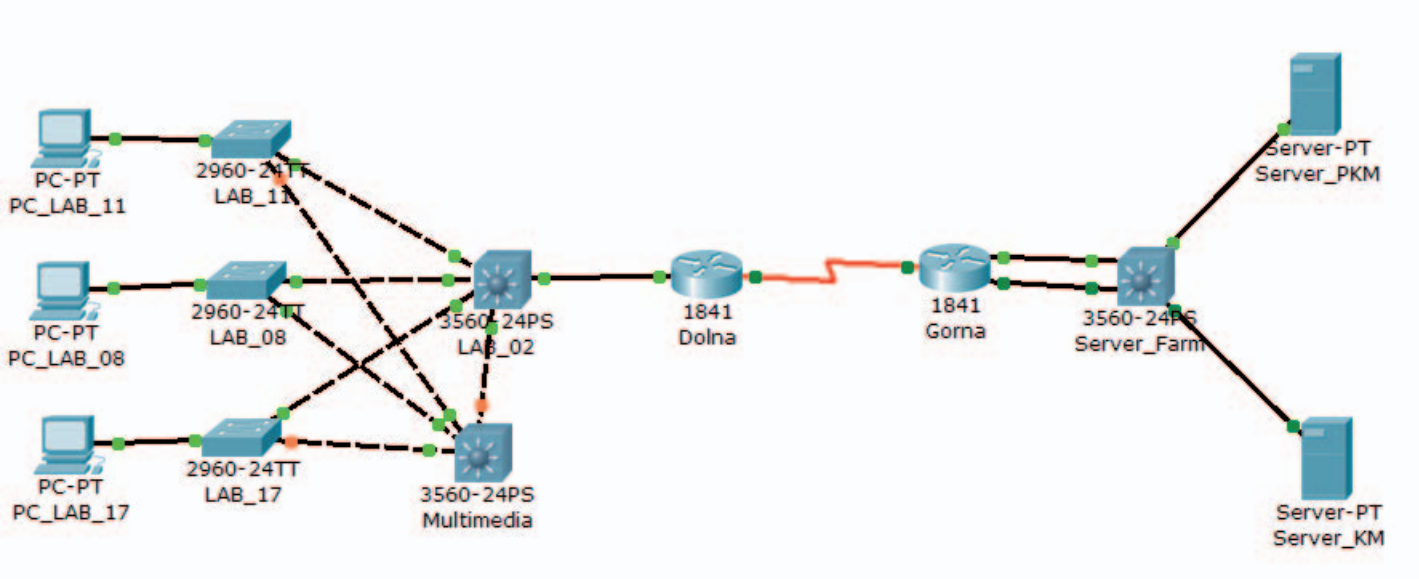
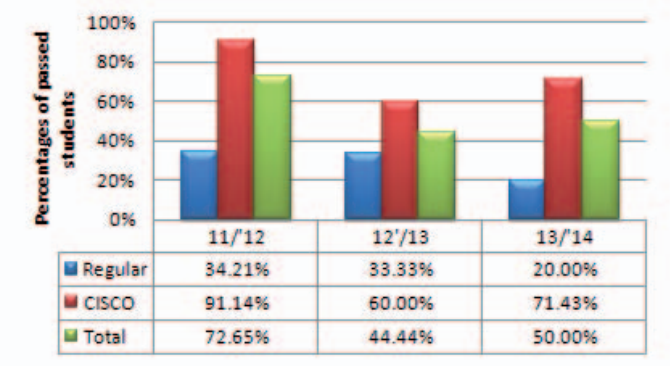
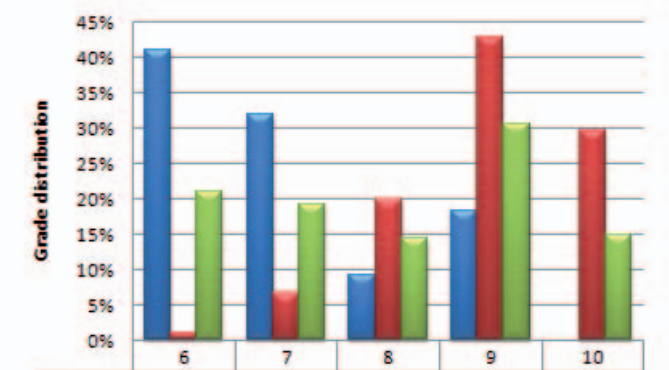


Fig. 4. The framework for skills exam for CCNA 3



	11/'12	12'/13	13/'14
Regular	34.21%	33.33%	20.00%
CISCO	91.14%	60.00%	71.43%
Total	72.65%	44.44%	50.00%

Fig. 7. The percentages of passed CISCO and regular students by years



	6	7	8	9	10
Regular	40.91%	31.82%	9.09%	18.18%	0.00%
CISCO	1.10%	6.59%	19.78%	42.86%	29.67%
Total	21.01%	19.21%	14.44%	30.52%	14.84%

Fig. 8. The grade distribution of CISCO and regular students

The second reason was reduced number of students that followed the basic CN course through practical Cisco CCNA (1 and 2) program. That is, students can not follow the advanced CND course through practical Cisco CCNA (3 and 4) program if they have not complete the first two CCNA courses (CCNA 1 and 2).

B. The course throughput distribution

The percentage of the passed students that have enrolled the course by practical Cisco program is significantly greater than regular ones. Fig. 7 depicts the results of the evaluation during the last three years. From 60% in the 2012/2013 study year up to impressive 91% of the students in 2011/2012 have passed the complete course. Even more, comparing the students of both programs, the pass rate is two to three times greater for the CISCO students.

C. The grade distribution

We use a grading scale where the students that score $\geq 50\%$ pass the exam. The smallest grade is 6 equivalent to E, moving up to $> 90\%$ score for the best grade 10 equivalent to A.

The conducted evaluation of how the CND course's changes impact the grade distribution is presented in Fig. 8. We observe that the course changes are welcomed and the grade distribution has been significantly improved. That is, almost 73% of the regular students' grades are minimal (6 or 7), while almost the same percentage of the Cisco students have maximal grades (9 or 10). Another important improvement is found in the fact that no regular students did pass the course with a maximum grade 10, while 30% of the Cisco students achieved a maximum grade 10.

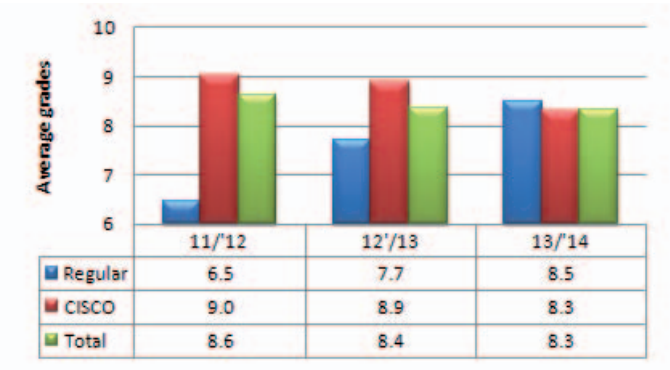


Fig. 9. The average grade distribution through years

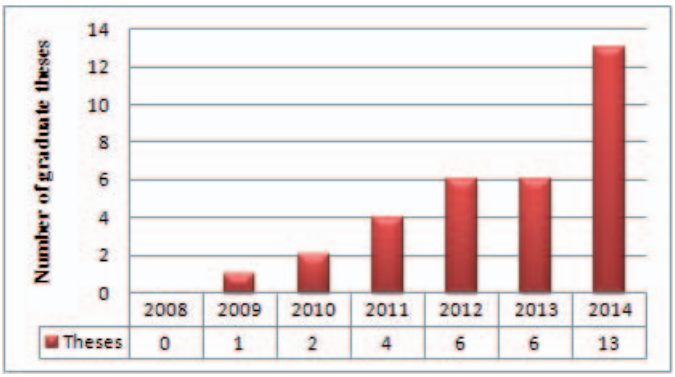


Fig. 10. Diploma theses of computer networking through years

The average grade of Cisco's students is very high (9.03), compared to the regular students' 6.46. For comparison, the average grade for all students is 8.64, which is close to the average grade of the Cisco students.

D. The average grade

Not only that the integration of the CISCO CCNA 3 and 4 with the CND course improved the course quantity (pass rate), but it also improved the quality of the course (grade distribution of passed students). Fig. 9 shows the average grades for each year. The results of the evaluation show that CISCO students achieved significantly better grades than regular students, especially in the prior years when the number of enrolled students in the course was greater.

VI. Discussion

This section discusses the benefits of the changing the CND course's curriculum and allowing the students to learn the course in a more practical way.

We observed an emerging group of students that followed and passed the CN course in 2012 in their third semester in the regular curriculum, and then enrolled in CCNA 1 and 2 in their fifth semester, as they can be able to follow the CND course in the sixth semester through Cisco practical curriculum. Unfortunately, this number of students is much smaller than the trend of reducing the total number of students that follow the CN and CND courses through Cisco program. We believe that this trend is not only because the gap between both courses, but the poor financial condition of the students, as well, since the students should pay additional amount of money for each CCNA course.

The improved CN and CND courses increased the popularity of computer networking among students, as well as their motivation to learn computer networking courses, which resulted in defining and successfully finishing diploma theses. Fig. 10 presents the number of the diploma theses through years, starting from 2008 up to now. The rising trend is obvious, especially in the last 2014 year.

Note that, as teachers of the computer networking courses, we have offered various projects as diploma theses from computer networking area, but none of the students have accepted them prior to 2009. Instead of computer networking, the computer science students mostly prefer diploma theses with web oriented programming, mainly motivated by the job offers.

The latest diploma theses are not only based to the Cisco learning material, but they can be classified as more general area of computer networking. For example, real time communication, low level load balancer on network layer, energy efficient data center, programming many network protocols. Also, there are several theses about cloud networking (Software Defined Networks - SDN, OpenFlow, open source private cloud networking, etc). Another very important result is publishing scientific and application papers based on students diploma theses [31], [32], [33].

Our dilemma at the beginning was if we should promote a certain company for a certain course, and if yes, which one? For example, since there is a Microsoft Academy at our Faculty, the computer science students are offered these courses. However, the interest for these courses is much lower than the Cisco's. The reason lies in the current market share. Locking in with Microsoft platforms tightens the developer's freedom, since there are many other systems and platforms for programming, rather than Windows-based. However, the networking area is not similar to the software's. If mostly of the Microsoft's courses are directly connected with Windows-based operating systems and applications, the Cisco's CCNA courses are more focused on the broad vendors, rather than to be focused on one vendor only and its own proprietary equipment. Even more, the faculty has collaboration agreements with more than 100 ICT companies and most of them (even software development companies) require employees with already finished Cisco courses, as a kind of advantage over the others. Our students achieve diplomas after finishing each CCNA course, and they can take the final CCNA VUE certificate to be more competitive on the market.

Another dilemma was to select program topics for CN and CND courses. Our choice on Cisco CCNA Exploration was based on several reasons. First, usually the CCNP course series is usually used in a graduate program. Second, using other more advanced topics, such as SDN or OpenFlow in the third

semester is not appropriate, since the students are tabula rasa for system software and databases.

VII. Conclusion and future work

Most of the applications and services in today's broadband world are distributed and acquire the services by the lower network protocols. This requires from the students (future engineers) to understand more deeply how data flows through the network and network hierarchy in order to design scalable networks.

This paper proposes a new curriculum for the CND course by allowing the students to choose either to follow the course according to more practical exercises and tutorials, or to follow the regular exercises, which are more theoretical and scientific.

Our faculty participates in the CISCO CCNA academy program for the last ten years, and educated more than 100 students for the CND course by integrating the CCNA3 and 4 programs. We have compared the results of these students with those following the course by a classical approach. The presented conclusions show that the changes in the curriculum improved the student's pass rate and the quality of the grades.

Several lessons are learned of integrating Cisco CCNA Exploration in both CN and CND courses. Although computer science prefer to learn much more the software-based courses, they will learn the hardware-based, as well, with a proper approach of the instructors. Apart of the increased knowledge, the additional actuator is the obtaining the diplomas and final certificate as a wild card for finding the better job on the market.

We have also concluded that there has to be a continuum from the CN to the CND courses, and the delivery of both of these courses better fits in the third study year, instead of the second.

Recently, Cisco introduced the new 5.0 version of CCNA, called CCNA Routing & Switching. Our future work will be towards adapting and integrating this new curricula into both CN and CND courses.

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