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# Analysis of Students' Performances during Lab Sessions of Computer Networks Course

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**ABSTRACT**

Due to changes and developments on the information and communication technologies, computer networks gained a critical role for establishing connections to share resources in a specific domain. Sharing information is very important in the digital age for giving high-quality services to all interested people enrolled in the networks. Education of computer networks is an engineering discipline to teach network topics and subjects within the university curriculum. Network courses are offered to the students of the related departments in universities and higher education organizations. In this paper, we conducted a study for analyzing the performances of the computer engineering students at Baskent University, Ankara, Turkey on the Network Course, in both theoretical and practical means. We analyzed the weekly scores collected from the lab sessions throughout the academic semesters of 2007-2008, 2008-2009 and 2009-2010 by using One-way and Two-way Anova and Chi-Square tests. Additionally, students' opinions about the course and lab sessions were evaluated by questionnaires at the end of each semester during 3 years.

**Keywords**

Computer networks course, Engineering Education, Applets

## Introduction

Computer network is an infrastructure including computers and peripherals connected to each other for sharing resources. Due to changes and developments on the information and communication technologies, computer networks gained a critical role for establishing connections to share resources in a specific domain. Sharing information is very important in the digital age for giving high-quality services to all interested people enrolled in the networks.

Computer networking offers a basic connection constructed to provide transmission of signals over a distance for the purpose of communication. Computer networks still evolving and the study of computer networks is a necessary part of the computer engineering field. According to Surma (2003), computer network courses are in the main research fields of computer engineering field. He studied a subject based on the students activities which supports course requirements, projects and lab experiments which collaborative and discovery learning techniques were used.

For using computer network applications for educational purposes at universities, Elkateeb & Awad (1999) offered that the usage of multimedia in the educational system increases the quality and reduces the cost. For this reason they produced the Multimedia Learning Center (MLC) learning system and it was used to teach data communication and networking concepts with support of the Web. Similarly, Delialioglu & Yildirim (2007) investigated students' perceptions of the "effective dimensions of interactive learning" in a hybrid course including 25 students enrolled in "Computer Networks and Communication". Moreover, Chiu & Liu (2008) proposed a Network Tutorial System (NTS) to investigate the disadvantages of ineffective CTS (Class Tutorial System) used in Taiwanese universities/colleges and discussed the feasibility of the NTS.

Using simulations for the design and implementation of computer networks is very common due to its availability and flexibility. Bello, Mirabella & Raucea (2007) used a modular web-based test bed comprising basic components (hosts, routers, and access points) implemented on nodes equipped with operating systems and open source software for enabling students to accomplish practical applications of computer networks. Kayssı, El-Hajj, El Asır, & Sayyıd (1999) used a Web interface for computer networks course to integrate material, registration, exams and grading.

Moreover, Goyal, Lai, Jain, & Durresi (1998) produced the software package for computer networking and telecommunications. It was a simulation environment with laboratory exercises including a range of network subjects from data message flows to IP (Internet Protocol) fragmentation and reassembly. Similarly, Powell, Anderson, Spiegel, & Pope (2002) defined that Web-based teaching tools can be used to improve the quality of an undergraduate laboratory and to reduce cost with the integration of web-based teaching tools and hands-on laboratory courses. Furthermore, Aziz, El-Sayed, Esche, & Chassapıs (2009) applied Web-based educational tools to provide a detailed laboratory experience based on remote and virtual laboratory experiments for undergraduate engineering students.

Rahman, Pakštas, & Wang (2009) conducted a research on network modelling and simulation tools. TinkerNet (Winters, Ausanka-Crues, Kegel, Shimshock, Turner, & Erlinger, 2006) was developed as a low-cost platform for teaching bottom-up, hands-on networking at the undergraduate level. It enables students to build their own networking stack from Ethernet up to TCP (Transmission Control Protocol) or UDP (User Datagram Protocol). Bote-Lorenzo, Asensıo-Perez, Gomez-Sanchez, Vega-Gorgojo, & Alarıo-Hoyos (2010) presented a Distributed Network Simulation Environment (DNSE) based on grid technology used by students as an application.

Sang (2010) presented hands-on laboratory experiments for students by using low-cost Small Office / Home Office (SOHO) networking technologies. Kayssı, Sharafeddıne, & Karakı (2004) presented 10 laboratory experiments applied on UNIX workstations for simulating network software.

On the other hand, Anido, Liamas, & Fernaândez (2000) presented "learning-by doing" paradigm in the field of virtual laboratories with standalone simulators for distributed virtual environments. Wolf (2010) defined the impact of a virtual laboratory on student learning. Additionally, Jovanovıc, Popovıc, Markovıc, & Jovanovıc (2010) presented a Web-based laboratory providing basic principles of computer network. Dobrılovıc, Brtka, Berkovıc, & Odadzıc (2012) offered an approach for the evaluation of the virtual network laboratory and exercises based on the rough set theory for computer-networking course.

On the other hand, IEEE (Institute of Electrical and Electronics Engineers) Computer Society (David, 2004) defines standards for Computer Engineering curriculum including the architectures, protocols, standards and technologies of computer networks. Similarly, ACM (Association for Computing Machinery) (Barry, 2008) defines standards for Information Technology curriculum with the contents of basics of networking.

When we look at the current situation at the universities in Turkey, various applications exist for the network courses. In this part, we analyzed the network courses given in the Computer Engineering Departments of the high-ranked universities of Turkey. For example, in METU (Middle East Technical University), uses of computer networks, network hardware, network software, reference models, networks and data communication services, standardizations, OSI layers are covered (METU, 2010). Similarly, in Boğaziçi University, overview of computer networks, network hardware/software, OSI and TCP/IP reference models, standardization, OSI layers are covered (Boğaziçi University, 2010). However, in Bilkent University, introduction to computer networks and the internet, socket programming, client/server model, peer-to-peer networking, protocols, congestion control, internet routing, OSI layers, local area networks (LAN) and wireless LANs are studied (Bilkent University, 2010). But, all those universities don't conduct lab sessions for the applications of the theoretical subjects of the network course in a laboratory environment to establish interaction.

When we look at the universities in the United States of America; for example, in Columbia University, protocol layers and encapsulation, IP, connection-oriented and connectionless flows, socket programming, DNS (Domain Name System) / HTTP (Hyper Text Transfer Protocol), reliable data transfer, selective repeat / go-back-N / parity & network coding techniques, flow and congestion control, TCP, switching, routing, bit error detection / correction techniques and MAC topics are covered (Columbia University, 2010). Similarly, in Northwestern University, overview of network architectures, applications (HTTP, FTP), network programming interfaces, transport (TCP, UDP), flow control, congestion control, IP, routing, IPv6, multicast, data link protocols, error-detection/correction, multiple access, LAN, Ethernet, wireless networks, and network security are taught (Northwestern University, 2010). Moreover, in University of California San Diego, principles of computer communication networks with examples from existing architectures, protocols and standards, layering and the OSI model, switching, LAN, MAN and WAN, datagrams and virtual circuits, routing and congestion control, internetworking exists within the course (University of California, San Diego (UCSD), 2010). Furthermore, in University of Washington, basics of networking, internetworking, protocol layering, framing, error correction, packet and circuit switching, multi-access protocols (Ethernet), queuing, addressing and forwarding (IP), distance vector and link state routing, reliable transport, congestion control (TCP) and security topics are covered (University of Washington, 2010).

However, at British universities in United Kingdom, for example, University of Bristol Computer Science Department offers Computer Networks course covering channels, latency, bandwidth, entropy, noice, capacity, routing, error detecting, data compression, protocols (University of Bristol, 2010). In University College London, physical and link layers, end-to-end arguments, multi-hop networks, reliable transport, congestion control, intra-domain routing: Distance vector, distance vector pathologies, link state, and inter-domain routing: BGP (Border Gateway Protocol), wireless networks are included within the scope of Communications and Networks course (University College London, 2010).

The rest of this paper is organized as follows: Main study including topics and subjects distributed to weekly schedule of the term, objectives and learning outcomes, comparison of weekly performances, questionnaire and results, discussion and conclusion.

## Material and methods

In this paper, we present the analysis of the last 3 years' lab performances of the students enrolled in the "Computer Networks" course in Computer Engineering Department, Baskent University. It is a one semester course given in both undergraduate and graduate levels. Our study focused on the undergraduate program. We analyzed the weekly scores collected from the lab sessions throughout the academic semesters of 2007-2008, 2008-2009 and 2009-2010. In every semester, around 40 final-year computer engineering students are enrolled within the course. The course lasts for 14 weeks, 5 hours (3 hours for the theoretical part and 2 hours for the lab sessions) per week. 3 quizzes, homework, a project, a midterm and a final exam are used for evaluating the students' performance. Additionally, lab sessions are conducted to teach practical applications of the course content. Labs start at the 4$^{th}$ week and conducted bi-weekly. At the end of each lab sessions, students were asked to answer the questions on paper distributed by the lab assistant. The responses of students were used for the evaluation of their performances.

### Theoretical part of the network course in Baskent University

We constructed our course outline based on the 7 layers of the OSI Model. Throughout the term, we taught each OSI layer during the successive weeks, as listed below:

- Orientation week: Introduction to network hardware and software, reference models, network standardization and OSI model.
- 1$^{st}$ part: Physical layer: Including fundamentals of data communication and transmission medium.
- 2$^{nd}$ part: Data link layer: Design issues, error detection/correction, elementary data link protocols and two sub layers; Medium Access Control (MAC) and Logical link control (LLC).
- 3$^{rd}$ part: Network layer: Routing algorithms, congestion control, quality of service, internetworking.
- 4$^{th}$ part: Transport layer: Transport service and protocols, UDP / TCP, performance issues.
- 5$^{th}$ part: Session layer: Managing sessions between end-user application processes (requests and responses), remote procure calls (RPCs), session recovery.
- 6$^{th}$ part: Presentation layer: Two sub layers: CASE (Common Application Service Element) and SASE (Specific Application Service Element), serialization, compression, encryption.
- 7$^{th}$ part: Application layer: User and system applications, network security, cryptography, Web security, Social/Ethical issues.

### Applications of the network course in Baskent University

Computer Networks course is given at the 7$^{th}$ semester. Quizzes, lab experiments, a term project, a midterm and a final are used for evaluation. 5 lab experiments were conducted with around 40 students during 2007, 2008 and 2009 fall terms.

During lab sessions, online supplementary web site of the course text book, Computer Networking: A Top-Down Approach Featuring the Internet, 3rd Edition, Kurose & Ross by Addison-Wesley. The supplementary web site (http://wps.aw.com/aw_kurose_network_3/0,9212,1406346-,00.html) (Kurose & Ross, 2010) was used for accessing Java applets to perform the lab experiments. Except for the first lab experiment taken from the Web site of EMU (Eastern Mediterranean University, 2008) Computer Engineering Department and web page of Sample Mania assignment (2008), all other lab experiments were done online by using applets on this web site. Students used these applets to experience the related subjects interactively.

Attending to the lab sessions was compulsory, so, all students attended the lab sessions during the terms. At the end of lab sessions, to evaluate the students' lab performances on the related subjects, an evaluation test including 5 questions were distributed to the students and they were asked to answer the questions by writing the solutions on the same paper. In the following section, results of the students' performances were presented with class averages of 3 terms. The students' scores were evaluated and recorded by the lab assistant each week. The lab assistant entered the scores into a spreadsheet program (Microsoft Excel) and the averages of the class were calculated and noted.

**First lab session (during the 4th and 5th week)**

Objectives: Students will learn concepts of signal spectrum and representation of a periodic signal in the form of a Fourier expansion. They will find out the concept of sampling of a signal and the effect of different sampling frequencies on the quality of the signal recovered after its sampling.

At the first week, students studied concepts of signal spectrum and representation of a periodic signal in the form of a Fourier expansion with a signal analysis program, as shown in Figure1. The concept of sampling of a signal and the effect of different sampling frequencies on the quality of the signal recovered after its sampling with SampleMania applet, as shown in Figure 2.

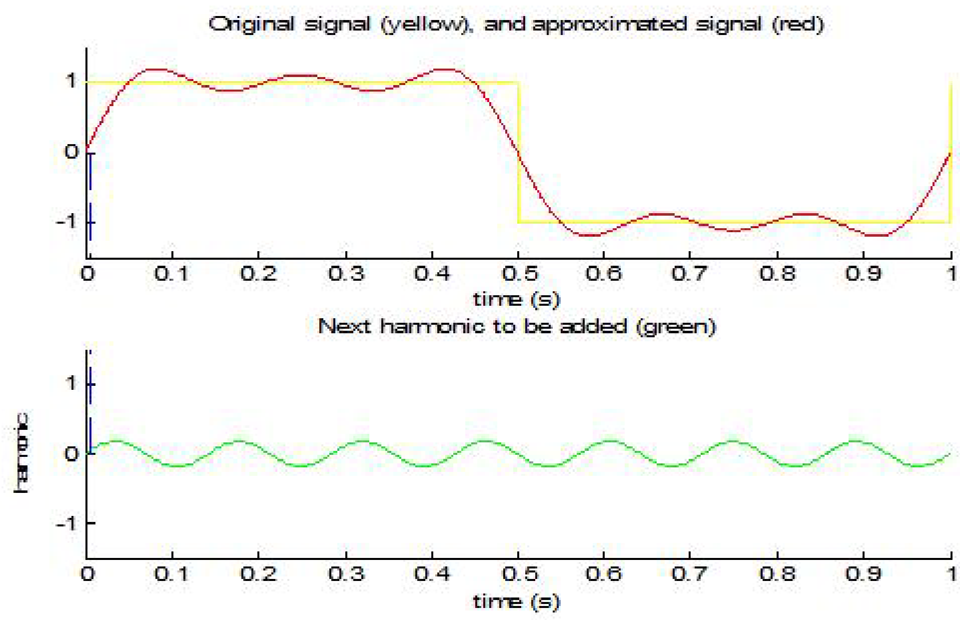


*Figure1*. The output of Signal Analysis created by Matlab program

Learning Outcomes: Students learned the concepts of signal spectrum and the representation of a periodic signal in the form of a Fourier expansion. Moreover, they were informed about sampling of a signal and the effect of different sampling frequencies on the quality of the signal recovered after its sampling.

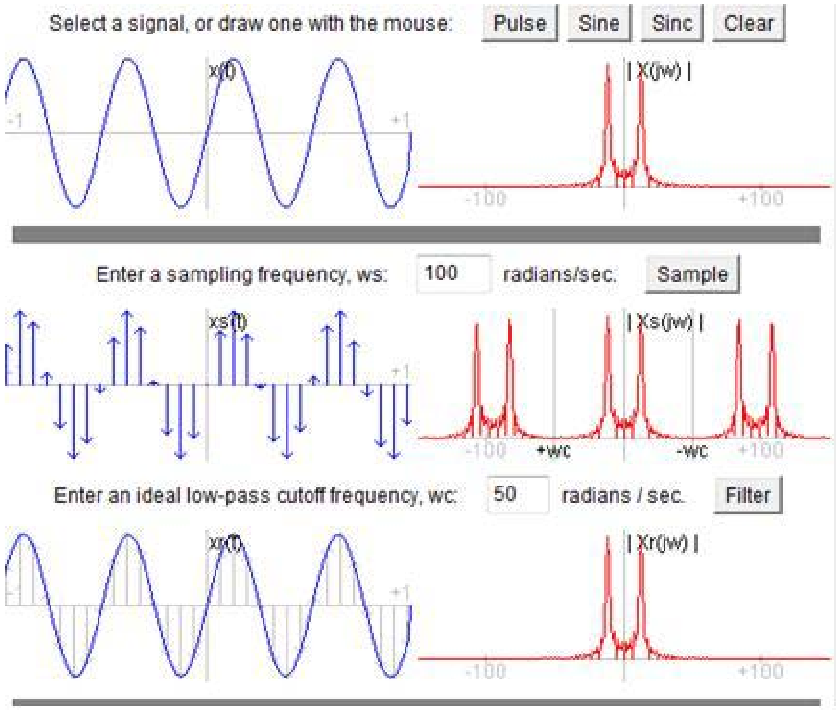


*Figure 2*. Output of sampling created by SampleMania applet

For measuring the learning outcomes, following questions were asked to the students:

- What is the purpose of this lab work? (20p)
- Draw the data communications model and show the signal transmission over this model and what are definitions of a signal and the signal types? (20p)
- What is the meaning of the Fourier expansion of a periodic signal and what is the meaning of Fourier coefficients in the Fourier expansion of a periodic signal? (20p)
- What is the meaning of the sampling theorem? (20p)
- What is the meaning of the channel capacity? Explain the data rate, bandwidth, noise and error rate concepts and define the maximum channel capacity using the Nyquist and Shannon formulations. (20p)

According to the responses of students, following class averages appeared:
2007-2008 Fall: Class average of 42 students was 69.52
2008-2009 Fall: Class average of 45 students was 71.49
2009-2010 Fall: Class average of 40 students was 73.13

**Second lab session (during the $6^{th}$ and $7^{th}$ week)**

Objectives: Students will focus on data communication concepts with the use of simple applets. They will study performance issues including transmission and propagation delays, queuing and loss of data packets and transmission media.

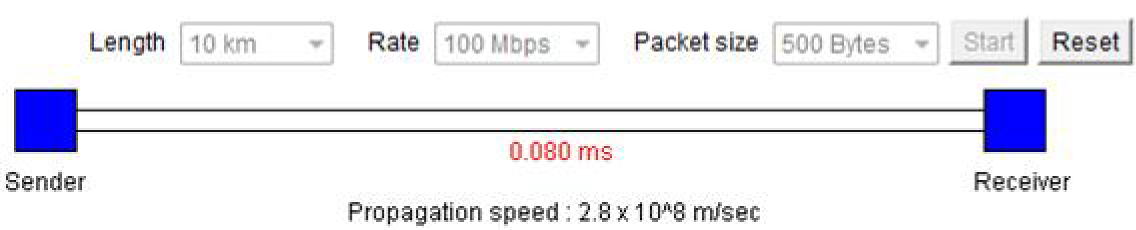


*Figure 3*. Output of transmission versus propagation applet

In Figure 3, the applet represents the relationship between transmission and propagation time with transmission link length, data rate, and packet size. Students changed values of these terms and created their graphs and discussed these results. For example, in this applet, transmission distance was 10 km, data rate was 100 Mbps and packet size was 500 bytes. However, different variables could give different transmission time results.

After performing the experiments, students reached the following results:

- If transmission link length is decreased, then the transmission time will decrease.
- If data rate is increased, packet transmission time will decrease.
- If packet size is increased, the packet transmission time will increase.
- Propagation delay depends on the transmission distance, so If the distance is increased, the propagation delay will increase and Propagation Time = Transmission distance/ Propagation speed.

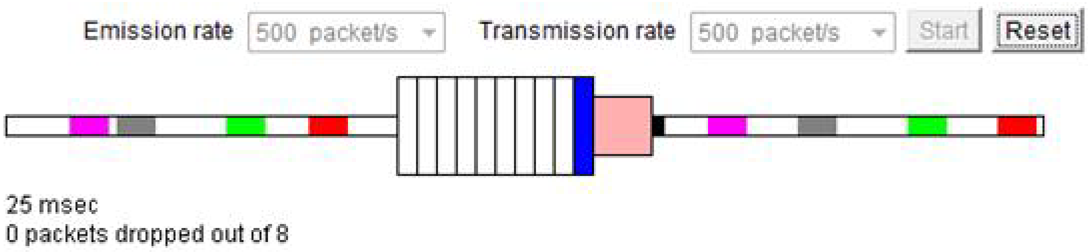


*Figure 4.* Output of queuing and loss applet

In Figure 4, the applet demonstrates the buffer mechanism for calculating the rate of queuing and loss of data packets. Students tried 3 possible conditions and following results were gathered:

- If emission rate is greater than the transmission rate, then the time duration for packet transmission is not enough, so, buffer may have overflow problem and many packets may get lost.
- If emission rate is equal to the transmission rate, then sending and receiving transmission time rate is adequate for packets, so, no packets get lost.
- If emission rate is smaller than the transmission rate, then we have enough time for sending all of the packets. As a result, the buffer cannot overflow and no packets get lost.

Learning Outcomes: Students learned data communication concepts with the use of applets. They understood performance issues including transmission and propagation delays, queuing and loss of data packets and transmission media.

For measuring the learning outcomes, following questions were asked to the students:

- Explain the purpose of this lab work (20p)
- What are the design factors relating to the transmission medium and the signal which determine the data rate and distance? (20p)
- What is a transmission delay and does the transmission delay depend on the distance between a sender and a receiver? (20p)
- What is a propagation delay and does the propagation delay depend on the used transmission media? (20p)
- What is the purpose of a queue when packets (messages) are being received and why can packets be lost? (20p)

According to the responses of students, following class averages appeared:

2007-2008 Fall: Class average of 42 students was 68.50
2008-2009 Fall: Class average of 45 students was 74.16
2009-2010 Fall: Class average of 40 students was 75.35

**Third lab session (during the 8$^{th}$ and 9$^{th}$ week)**

Objectives: Students will learn the segmentation of messages and multiplexing of communication channels.

At the third week, segmentation of messages and multiplexing of communication channels were studied, as shown in Figure 5 below:

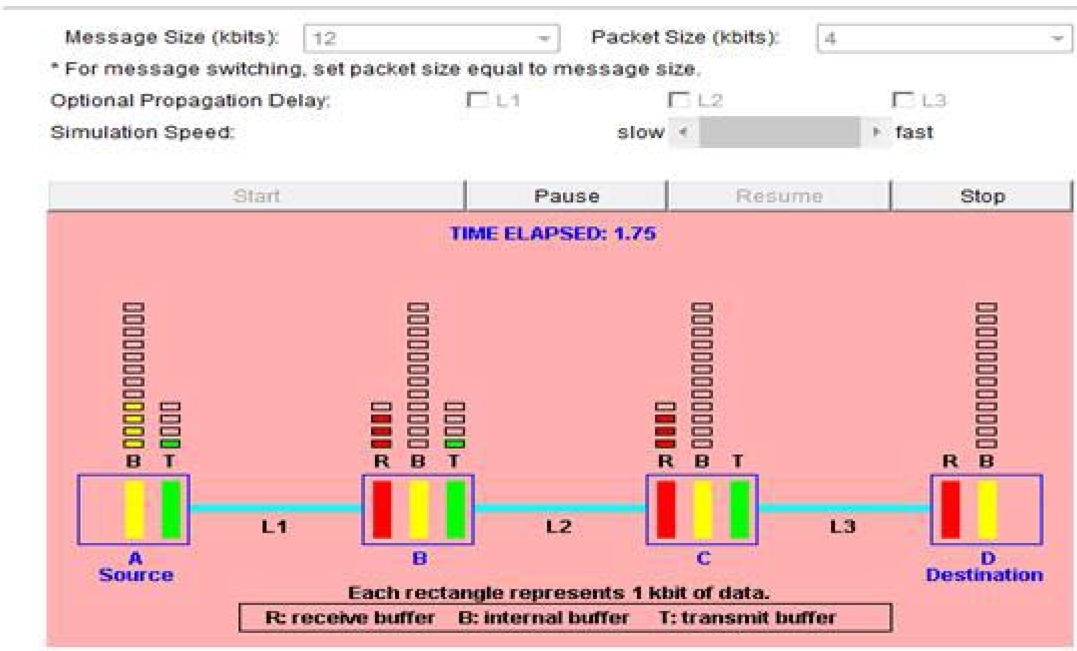


*Figure 5*. Output of message segmentation applet

This applet represents message segmentation/switching and packet switching concepts. For message switching, message and packet size had equal values; for packet switching, message size were greater than the packet size. The applet includes four nodes: Source (node A), destination (node B), and two intermediate store-and-forward switches. Each packet sent from node is transmitted over three links before it reaches the destination. Each of these links has a transmission rate of 4 kbps with an optional propagation delay of 1 second and each small rectangle demonstrates 1 Kbit of data. Simulation starts with the grouping of rectangles into 1 packet in the source buffer and the packet is transmitted to the destination. This applet is also a representation for multiplexing concepts.

When students run the simulation, they saw packet switching had smaller end-to-end delay than message switching. Students calculated end-to-end delay and compared their results with those gathered from the applet. They used optional propagation delay in their calculations. Moreover, students learned multiplexing concepts.

Learning Outcome: Students learned segmentation of messages in a network and multiplexing of communication channels. Moreover, students tested end-to-end delay times for message and packet switching separately.

For measuring the learning outcomes, following questions were asked to the students:

- What is the segmentation of a message and why message segmentation is used in a network system? (20p)
- Why do we need some type of switching or multiplexing in communication channels and what are the most often used types of channel multiplexing? (20p)
- What can happen if transmitting and receiving ends of a TDM channel are not synchronized? (20p)
- Three packet-switching networks each contain n nodes. The first network is a ring has a star topology with central switch, the second has a star topology with central switch and the third is fully interconnected with a wire from every node to every other node. What are the best and worst case transmission paths in hops? (20p)
- Compare the delay in sending an m-bit message over a r-hop path in a circuit-switched network and in a packet-switched network. The circuit set up time is s sec, the propagation delay is d sec per hop, the packet size is p bits and the data rate is b bps. What is the main condition that the packet network has a lower delay? (20p)

According to the responses of students, following class averages appeared:

2007-2008: Class average of 42 students was 70.33
2008-2009: Class average of 45 students was 69.84
2009-2010: Class average of 40 students was 71.55

**Fourth lab session (during the 10th and 11th week)**

Objective: Students will learn Go-Back-N and stop-and-wait flow control operation.

At the 4th week, students studied Go-Back-N and stop-and-wait flow control operation, as shown in Figure 6 and Figure 7 below:

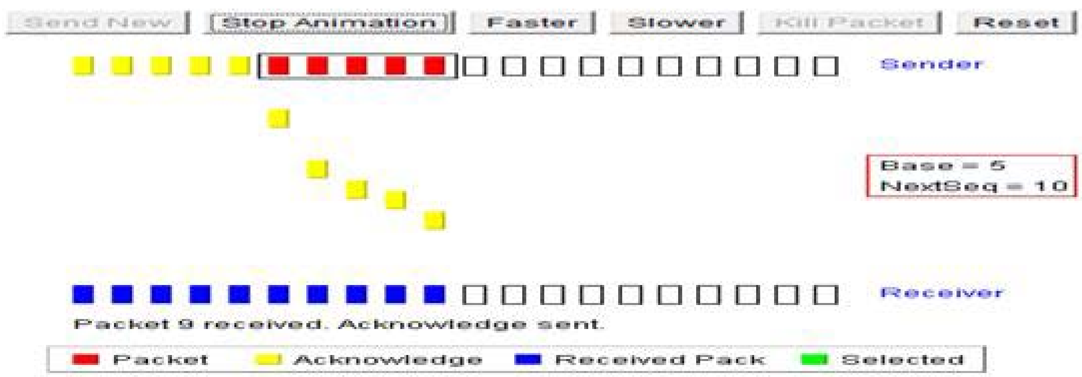


*Figure 6*. Output of Go-Back-N Protocol Applet

In Figure 6, the applet represents how data link layer protocols and go-back-n sliding window data link layer protocol operate. For testing these, following items accomplished:

- Because the limit of sliding window was 5 here, a maximum of 5 unacknowledged packets could be send to the sender.
- Students sent the packets with the length of sliding window and stopped the simulation before first 5 packets reach the receiver and clicked on the first packet to kill. Then students observed no acknowledgement received from the sender. 5 packets must be sent again and this repetitive transmission of packets was the basic idea for go-back-n protocol.
- Students sent the packets with length of sliding window and stopped the simulation after the first packets reach the receiver and then killed its acknowledgement. Students observed 4 acknowledgements and 1 acknowledgement get lost, which could not cause any problem.
- Students sent more packets comparing to the length of sliding window. Students observed no change occurred and the system permitted to send packets only with the size of the sliding window.


*Figure 7*. Output of flow control applet

In Figure 7, the applet simulates sending and receiving processes for TCP send/receive buffer. Students tested different combinations of file size and buffer size to learn buffer management for TCP system. They performed necessary computations and interpreted information flow with buffers. In the applet, TCP receive buffer reads with 2Kbyte chunks at random times. If receive buffer becomes full, TCP receiver advertises a receive window of 0 and sender then continues to send segments with 1 byte of data.

Learning Outcomes: Students learned Go-Back-N and stop-and-wait flow control operations. They found out fundamentals of buffer management, sending and receiving processes for TCP send/receive buffers.

For measuring the learning outcomes, following questions were asked to the students:

- Explain the purpose of this lab work. (20p)
- What are the three important mechanisms which are item of data link control?
- What are the differences between stop and wait flow control and the error free sliding window flow control? (Write 3 of them). (20p)
- What is ARQ, piggybacking and pipelining? (20p)
- Sender node (S) and Destination node(D) use a Go-Back-N sliding window Protocol with a window size of 4 and a 3-bit sequence number. If S is a transmitter and D is receiver, show the window positions for the following choices: (20p)
  1. After S sends frames 0, 1, 2 and D acknowledges 0, 1 and the ACKs are received by S.
  2. After S sends frames 3, 4 and 5 and D acknowledges 4 and the ACK is received by S.

According to the responses of students, following class averages appeared:
2007-2008 Fall: Class average of 42 students was 63.74
2008-2009 Fall: Class average of 45 students was 64.18
2009-2010 Fall: Class average of 40 students was 67.78

**Fifth lab session (during the 12th and 13th week)**

Objective: Students will learn CDMA/CD, 802.11 CSMA/CA without hidden terminals and 802.11 CSMA/CA with hidden terminals.

At the 5th week, students studied CDMA/CD, 802.11 CSMA/CA without hidden terminals and 802.11 CSMA/CA with hidden terminals, as shown in the applets below:

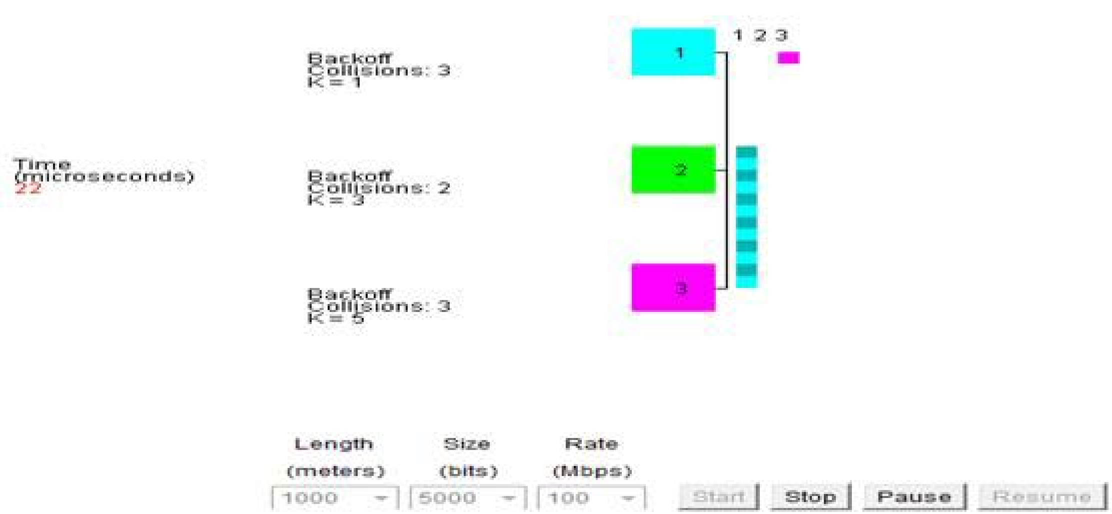


*Figure 8*. Output of CDMA/CD Applet

In Figure 8, the applet represents relationship between transmission and propagation time with bus length, frame size, and transmission rate for CDMA/CD systems. To do so, students changed the values of these items, created their graphs and discussed the results. Moreover, they analyzed the back off algorithm which is the basic algorithm for both wired and wireless type of CDMA/CD systems.


*Figure 9*. Output of 802.11 CSMA / CA without hidden terminals applet

In Figure 9, the applet demonstrates a wireless type of CDMA/CD systems called as 802.11 CSMA/CA without Hidden Terminals. There is 1 access point and 3 mobile stations. The mobile stations can listen each other's transmissions. Students analyzed the access point which listens all mobile stations. Each mobile station can listen other mobile stations.

In Figure 10, the applet demonstrates another wireless type of CDMA/CD systems called as 802.11 CSMA/CA systems with hidden terminals. There is 1 access point and 3 mobile stations. The mobile stations can not listen each other's transmissions. Students analyzed the access point which listens none of the mobile stations. No mobile station can listen other mobile stations.

Learning Outcomes: Students learned Carrier Sense on Multi-Access Networks (CSMA) (CSMA/CD and CSMA/CA). They tested relationships between transmission and propagation time with bus length, frame size, and transmission rate for CDMA/CD systems. Moreover, they found out concepts of CDMA/CD, 802.11 CSMA/CA without hidden terminals and 802.11 CSMA/CA with hidden terminals.

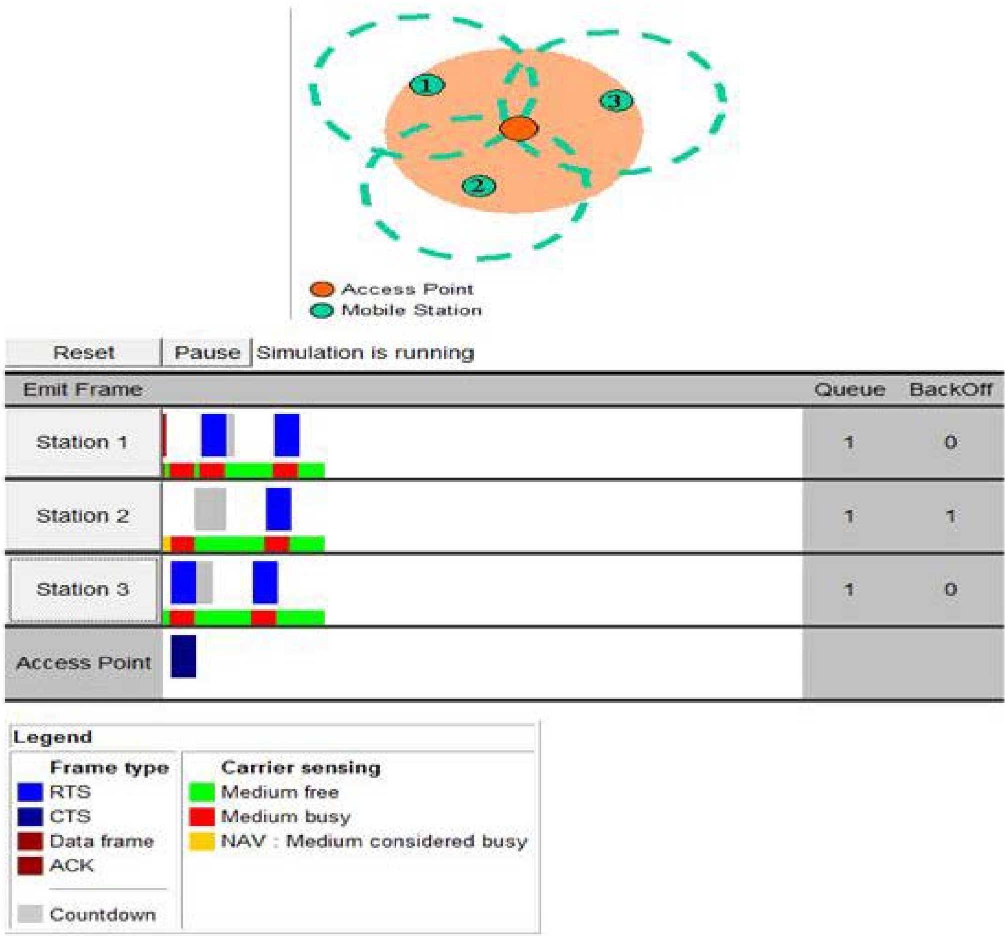


*Figure 10*. Output of 802.11 CSMA / CA with hidden terminals applet

For measuring the learning outcomes, following questions were asked to the students:

- Explain the purpose of this lab work. (20p)
- What are the LAN technologies and the related MAC techniques which are used by them? (20p)
- If two or more computers happen to choose nearly the same amount of delay after a collision for an Ethernet System, they will both begin to transmit at nearly the same time and producing a second collision. What is the solution to avoid a sequence of collisions? (20p)
- What is the minimum frame size if a CSMA/CD network running at 5 Gbps over a 1-km cable with no repeaters in a building and the signal speed in the cable is 500000 km/sec? (20p)
- What is the most important advantage of CSMA/CD systems over network? (20p)

According to the responses of students, following class averages appeared:
2007-2008 Fall: Class average of 42 students was 71.36
2008-2009 Fall: Class average of 45 students was 72.89
2009-2010 Fall: Class average of 40 students was 76.45

## Results

### Comparison of weekly performances based on 3 groups

As shown in Table 1, when we check the averages of 3 academic semesters, students showed the best lab performance (average is 73.57 over 100) on the $5^{th}$ Lab Session. According to the results, it can be stated that students of 2009-2010 academic semester are the best performing (76.45 over 100 on Lab 5) amongst others.

*Table 1*. Weekly performance of students based on 3 different academic years

| Years | Lab 1 | SD | Lab 2 | SD | Lab 3 | SD | Lab 4 | SD | Lab 5 | SD |
|---|---|---|---|---|---|---|---|---|---|---|
| 2009-2010 | 73.13 | 23.32 | 75.35 | 19.30 | 71.55 | 21.46 | 67.78 | 21.52 | 76.45 | 18.21 |
| 2008-2009 | 71.49 | 23.95 | 74.16 | 18.94 | 69.84 | 15.20 | 64.18 | 13.50 | 72.89 | 24.22 |
| 2007-2008 | 69.52 | 14.47 | 68.50 | 19.74 | 70.33 | 18.21 | 63.74 | 26.05 | 71.36 | 24.74 |
| Averages | 71.38 | | 72.67 | | 70.57 | | 65.23 | | 73.57 | |

For the analysis of results gained from the weekly performances of students, One-Way Anova, Two-Way Anova and Chi-Square Tests were applied consequently in Minitab statistical software package.

**Testing for normality**

Firstly, normality was tested to determine the normal distribution for our data set and to control suitability of it for other tests. Anderson-Darling test was used for testing normality of lab performances and represented in Figure 11. Since p_value (0.738) is greater than significance level value of p = 0.05, our data set was normally distributed.

**Testing for homogeneity**

Secondly, homogeneity of variances was tested before Anova tests. Two different tests were applied, and as shown in Figure 12, both of them have greater p_values, proving that variances of our data set were roughly same.

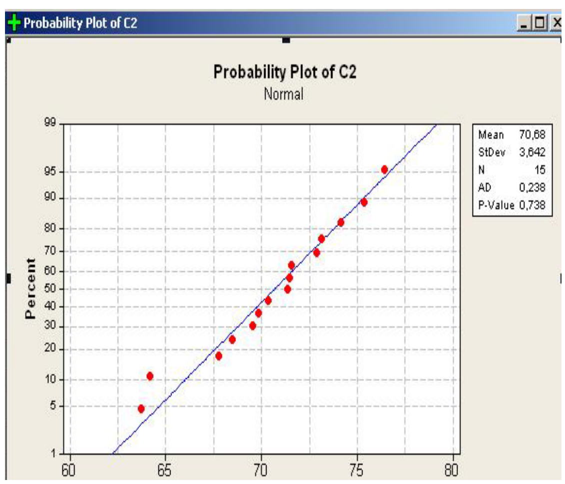


*Figure 11.* Normality of Lab Performances

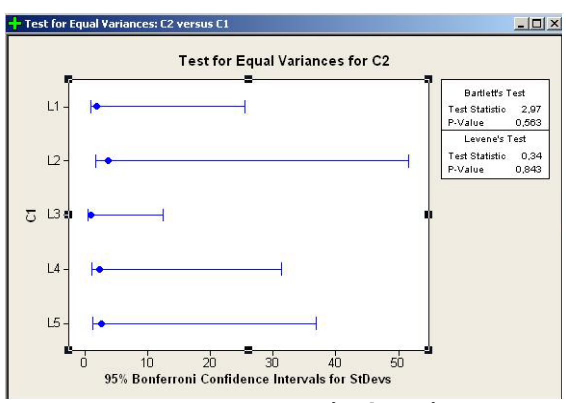


*Figure 12.* Homogeneity of Lab Performances

**Results for one-way Anova**

In One-Way Anova test, obtained p-value (0.014) of the lab sessions is less than the significance level value of p = 0.05. It shows that at least one score has significant difference. With respect to One-way Anova results of three years' scores, there is at least one significant difference amongst lab sessions, as shown in Figure 13.

```
One Way ANOVA

Source  DF      SS     MS     F      P
C1       4  127,38  31,85  5,46  0,014
Error   10   58,34   5,83
Total   14  185,72

S = 2,415   R-Sq = 68,59%   R-Sq(adj) = 56,02%

                                Individual 95% CIs For Mean Based on
                                Pooled StDev
Level  N    Mean  StDev  -----+---------+---------+---------+----
L1     3  71,380  1,808                 (-------*-------)
L2     3  72,670  3,660                    (-------*-------)
L3     3  70,573  0,881               (-------*-------)
L4     3  65,233  2,216  (-------*-------)
L5     3  73,567  2,612                       (-------*-------)
                         -----+---------+---------+---------+----
                            64,0      68,0      72,0      76,0

Pooled StDev = 2,415
```

*Figure 13.* One-Way Anova test

```
Tukey's Test

Source  DF      SS     MS     F      P
C1       4  127,38  31,85  5,46  0,014
Error   10   58,34   5,83
Total   14  185,72

S = 2,415   R-Sq = 68,59%   R-Sq(adj) = 56,02%

                                Individual 95% CIs For Mean Based on
                                Pooled StDev
Level  N    Mean  StDev  -----+---------+---------+---------+----
L1     3  71,380  1,808                 (-------*-------)
L2     3  72,670  3,660                    (-------*-------)
L3     3  70,573  0,881               (-------*-------)
L4     3  65,233  2,216  (-------*-------)
L5     3  73,567  2,612                       (-------*-------)
                         -----+---------+---------+---------+----
                            64,0      68,0      72,0      76,0

Pooled StDev = 2,415

Tukey 95% Simultaneous Confidence Intervals
All Pairwise Comparisons among Levels of C1

Individual confidence level = 99,18%

C1 = L1 subtracted from:

C1    Lower  Center  Upper  ---------+---------+---------+---------+
L2   -5,195   1,290  7,775              (-------*-------)
L3   -7,291  -0,807  5,678           (-------*-------)
L4  -12,631  -6,147  0,338     (-------*-------)
L5   -4,298   2,187  8,671               (-------*-------)
                            ---------+---------+---------+---------+
                                  -8,0       0,0       8,0      16,0

C1 = L2 subtracted from:

C1    Lower  Center   Upper  ---------+---------+---------+---------+
L3   -8,581  -2,097   4,388          (-------*-------)
L4  -13,921  -7,437  -0,952    (-------*-------)
L5   -5,588   0,897   7,381             (-------*-------)
                             ---------+---------+---------+---------+
                                   -8,0       0,0       8,0      16,0

C1 = L3 subtracted from:

C1    Lower  Center  Upper  ---------+---------+---------+---------+
L4  -11,825  -5,340  1,145     (-------*-------)
L5   -3,491   2,993  9,478               (-------*-------)
                            ---------+---------+---------+---------+
                                  -8,0       0,0       8,0      16,0

C1 = L4 subtracted from:

C1  Lower  Center   Upper  ---------+---------+---------+---------+
L5  1,849   8,333  14,818                     (-------*-------)
                           ---------+---------+---------+---------+
                                 -8,0       0,0       8,0      16,0
```

*Figure 14*. Tukey's test

**Results for two-way Anova**

In Two-way Anova test, analysis of variance was performed with two factors, including Lab performances and years. In this test, obtained p-values (0.001 and 0.004 respectively) are less than the significance level value of p = 0.05. Also, it shows that at least one score is significantly different than others, as shown in Figure 15.

```
Two-way ANOVA

Source  DF       SS       MS      F      P
C1       4  127,145  31,7863  17,15  0,001
C2       2   43,446  21,7230  11,72  0,004
Error    8   14,825   1,8532
Total   14  185,416

S = 1,361   R-Sq = 92,00%   R-Sq(adj) = 86,01%
```

*Figure 15*. Two-Way Anova test

## Results for chi-square

Chi-square test was applied to compare the intervals for lab scores of students with respect to each academic year and to perform contingency test for our data. As shown in Figure 16, obtained p-value = 0.000 is less than the significance level value of p = 0.05. This result shows that there is a dependency between the intervals for lab scores of students and academic years.

```
Chi-Square Test

Expected counts are printed below observed counts
Chi-Square contributions are printed below expected counts

           C1      C2     C3      C4      C5  Total
    1       6      16     42      67      69    200
         8,19    5,67  47,24   91,65   47,24
        0,585  18,825  0,582   6,631  10,019

    2       9       2     55     110      49    225
         9,21    6,38  53,15  103,11   53,15
        0,005   3,005  0,064   0,460   0,324

    3      11       0     53     114      32    210
         8,60    5,95  49,61   96,24   49,61
        0,671   5,953  0,232   3,279   6,249

Total      26      18    150     291     150    635

Chi-Sq = 56,884; DF = 8; P-Value = 0,000
```

*Figure 16*. Chi-square test

According to these results, it can be stated that students of 2009-2010 academic semester are the best performing amongst others. This result can be explained with the scores students got in the university entrance exam. In Turkey, a centralized exam is used for entering the university. Every year, students were selected for the undergraduate programs of the universities by this centrally administered exam. The organization responsible for the administration of this exam is The Student Selection and Placement Center, affiliated to The Higher Education Council (2011).

*Table 2*. Upper and Lower Bound Scores of Baskent University Computer Engineering Department for the University Entrance Exam

| Exam Year | Lower Bound | Upper Bound |
|---|---|---|
| 2003 June | 321 | 361 |
| 2004 June | 328 | 360 |
| 2005 June | 329 | 362 |

As seen in Table 2, the students who entered the university in year 2005 has taken Computer Networks course on their final year during 2009-2010 academic semester.

**Questionnaire for students' opinions about the lab sessions**

At the end of each term, paper-based questionnaire were distributed to the students to gather their views and opinions about the online simulations and lab sessions. We used a five-level Likert scale, including the items listed as follows:

- Strongly disagree
- Disagree
- Neither agree nor disagree
- Agree
- Strongly agree

Within the questionnaire, 10 statements were asked to the students as shown in Table 3. Mean scores and standard deviations (SD) were obtained by the students' responses of the related term. Means and SDs were calculated with different number of students of each term (2007-2008 Fall, 2008-2009 Fall and 2009-2010 Fall).

*Table 3.* Students' Responses for the Usefulness of the Online Simulations in the Lab Sessions

| **Statements** | 2007-2008 | | 2008-2009 | | 2009-2010 | |
|---|---|---|---|---|---|---|
| | Mean | SD | Mean | SD | Mean | SD |
| 1. I like to use online simulations on the Web during the Lab sessions | 3.48 | 0.50 | 3.71 | 0.46 | 4.60 | 0.49 |
| 2. I like to receive information e-mails from the Instructor and Assistant of the course prior to the lecture. | 3.62 | 0.62 | 4.33 | 0.88 | 4.78 | 0.42 |
| 3. Interacting with the simulations during the Lab sessions help me to learn. | 3.52 | 0.55 | 3.51 | 0.50 | 4.88 | 0.35 |
| 4. I also use online simulations after lab sessions at home. | 2.65 | 0.49 | 3.67 | 0.47 | 3.78 | 0.97 |
| 5. I compare my performance with other students during the lab sessions. | 3.12 | 0.70 | 4.47 | 0.62 | 4.15 | 0.70 |
| 6. Simulations are useful for me to apply theoretical knowledge on practical applications. | 3.50 | 0.80 | 4.16 | 0.52 | 4.43 | 0.50 |
| 7. I also want to design and develop simulations. | 2.93 | 0.26 | 4.31 | 0.93 | 4.33 | 0.47 |
| 8. I wish there will be more simulations about topics of the course content. | 3.27 | 0.67 | 4.52 | 0.63 | 4.95 | 0.22 |
| 9. I wish there will be more lab sessions during the term. | 4.40 | 0.73 | 4.74 | 0.58 | 4.93 | 0.27 |
| 10. Lab sessions were not boring for me, I enjoyed them all. | 4.02 | 0.84 | 4.87 | 0.34 | 4.98 | 0.16 |

Mean scores of the students' responses were compared by using statistical software, MiniTab. According to the responses in Table 3, the lowest scores (2.65, 3.67 and 3.68 over 5.00) belong to the item "I also use online simulations after lab sessions at home". It shows that most of the students don't prefer to study at home. To solve this problem, some of the lab exercises can be assigned to the students as homework to increase the students' motivation for studying at home. On the other hand, the highest scores (4.02, 4.87 and 4.98 over 5.00) belong to the items "Lab sessions were not boring for me, I enjoyed them all." It shows that students were happy to be involved in practical applications during lab sessions.

In Table 3, mean scores of the students' responses are increasing from 2007-2008 to 2009-2010, except for the 5th item: "I compare my performance with other students during the lab sessions." The scores of this item decreased from 4.47 to 4.15 from 2008-2009 to 2009-2010 years. According to the questionnaire, it can be stated that students of 2009-2010 academic semester has the best mean scores about online simulations and lab sessions except on the subject about the comparison of student performances with others.

## Discussion

This study covers network applications in educational environment to analyze how real-life situations about computer networks can be simulated for teaching in engineering courses. There is no internationally accepted standard for the curriculum of computer networks course in the undergraduate level of university education. Various universities design their own curriculum with the help of existing instructors, instructional materials, available computer labs and infrastructure. As a result, every faculty/department conducts network courses differently, leading to irregularity and chaos in this domain.

Moreover, there is no internationally accepted tool/platform for simulating network applications in the lab sessions of the computer networks courses. There are many tools on the Web for demonstrating network conditions to the students in different ways. Students use those tools according to their preferences and just follow the directions given to them by the instructor. As a result, interaction is limited and insufficient for reflecting the creativity of those students.

In our study, we tried to examine the effects of existing tools (applets, animations and simulations) on teaching of computer networks in computer engineering curricula. Analysis of weekly lab performance scores showed us that students learn better with involving in practical applications of computer networks. Applets used for simulating the concepts and subjects during lab sessions. But, the number of applets available is limited to specific topics and not covering all. Students agreed that simulations are useful for them to apply theoretical knowledge on practical applications and they asked for more lab sessions with more simulations provided.

Students enjoy the lab sessions as they involve actively in the learning process but they don't prefer to use and study applets at home after lab sessions. Additionally, some students don't like to compare their performance with others during the lab sessions. Maybe group work can be encouraged to increase the motivation of students for sharing their knowledge and abilities with others. Moreover, a group project can be assigned to the student to encourage them for studying both in lab and at home.

At this point, it can be stated that theoretical parts conducted in classrooms can be combined with the lab sessions by lecturing in the computer labs. If possible, labs specially designed and equipped for applications of computer networks can be used. To do so, constructive methodology can be preferred to enable students benefit from learning by doing paradigm. According to the scores of the lab performances and questionnaire results, it is clear that students learn concepts of computer networks much better by actively using the related applets.

## Conclusions

The main problem for the conduction of computer networks courses is that most of the existing computer labs at the universities are not sufficient for teaching concepts and subjects of the course effectively. As a solution, animations and applets are used during lab sessions for simulating the concepts of computer networks. This study aimed to show the effects of applets on the learning activities of the computer engineering students. We mentioned about the routine operational procedure for Computer Networks course in Baskent University including details of theoretical information given in lectures and practical applications conducted in lab sessions.

Students' performances for weekly lab sessions were analyzed and scores of 2007 - 2008, 2008 - 2009 and 2009-2010 were compared to see the similarities and differences. According to results, students of 2009-2010 year were better than others. This result was explained with the scores students got in the university entrance exam for that year. Additionally, a questionnaire was applied at the end of every year for evaluating the students' satisfaction about animations and applets used for lab sessions. Questionnaire results showed that students were happy to be involved in practical applications of computer networks subjects during lab sessions. However, additional practice needed to encourage students for studying at their own time and place, after the lab sessions.

Results of this study showed that blending practical applications with theoretical parts of any subject domain during the process of higher education of engineering may help for increasing the quality level of the graduates. For training prospective engineers and scientists of computer science in a better way, universities should invest more in hardware and software of computer labs to simulate real cases in a more economical way.

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