ELECTRONICS AND ELECTRICAL ENGINEERING
ISSN 1392 – 1215 *2010. No. 6(102)*
ELEKTRONIKA IR ELEKTROTECHNIKA

TELECOMMUNICATIONS SCIENCE

TELEKOMUNIKACIJŲ MOKSLAI

Experiences of Teaching Complicated Undergraduate Course for Large Number of Students in the Tallinn University of Technology

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Introduction

The discipline of modern telecommunication systems and methods for undergraduate students in Tallinn University of Technology (TUT) curriculum is taught during the second year of study. Course assumes developing of knowledge of basic communication systems concepts: frequency, amplitude, bandwidth, modulation, switching; network architecture etc. Deeper understanding of basic communication systems and methods is very important for all students in electrical and computer engineering fields. In this paper we present our experiences and observations on teaching of "Telecommunication" (in Estonian "Side"), gained during last 5 years; course number at TUT is IRT3930. Course homepage (in Estonian) is available at http://www.lr.ttu.ee/side. Course itself has been in TUT curricula from 1991.

Learning outcomes of the course are to describe main parameters of communications systems and data streams; find signal parameters in a communications system; apply link budget estimation for analysis of communications system components; to use general parameters of multimedia services for quality estimations; to estimate coverage area of mobile communications systems; estimate level of QoS of communications system; to validate the results obtained as solutions to practical exercises.

Course capacity is 5 ECTS credits and teaching methods includes weekly lectures (2 academic hours per week) and laboratory exercises (1 academic hour per week), total 16 weeks/semester. Course is employing e-learning environment and the lectures are recorded and broadcasted using multiple streaming video technologies. Laboratory exercises are conducted in small groups: maximum 12 students in a group. The course employs multiple laboratory exercise instructors. Most exam questions are different for every student. Each year between 350-450 students complete the course. Not all the students come from within the University: some students (about 10 to 15) are from the Estonian Aviation Academy.

Telecommunication course is multilingual - Estonian and Russian are both used in the lectures and laboratory exercises guidance.

As the goals of engineering education are multifaceted, and include the development of skills in such areas as communication and teamwork, writing and presentation, argumentation and discussion, development of these skills was integrated in the teaching methods and format of the course. This course also aims at introducing the students to a sufficient knowledge base to be able to adapt themselves to the constant technological changes taking place in this field.

Laboratory exercises

The purpose of the laboratory exercise is that students can try in near real-world environment different basic telecommunication applications. All the devices and software used are in everyday use by IT companies and management.

At the moment student have to pass five laboratory exercises during the course. Laboratory exercises with their descriptions are listed below.

1. **Analog interface and telephone terminal to fixed-line** – students measure different parameters of fixed line analog telephone terminal and interface. They calculate and estimate interface and signal parameters in the system using basic knowledge of electrical engineering. The students also introduce themselves to signal representation both in time and frequency domain.
2. **Access to packet switched network and network interconnection** – students get acquainted with packet networks and they do some practical hands-on experiments on packet network parameter tuning and solving troubleshooting cases.
3. **Wireless LANs (IEEE 802.11)** – students will learn the different wireless standards in use today and the features that each standard offers. In the lab environment they set up small secure wireless network. Students analyze radio spectrum usage in a radio

channel from WLAN base-station to client terminal using spectrum analyzer. Results of spectrum estimation are compared to theoretical calculations based on Shannon–Hartley theorem, including channel capacity estimation.

4. **RS-232 interface and low speed modem** – students are introduced to the principles of serial interface and analog modems. Future development of this lab will be based on USB 2.0 and HDMI interface. Details of this development constituted a main task of the Master thesis [1].
5. **Telephone services and IP telephone network** – students use different telephone services and evaluate call quality in different network conditions. They calculate network channel capacity and connection establishment blocking probability using Erlang formula.

These laboratory exercises will cover, in our opinion, most of the course topics. Set of exercises are developed so that they will cover most important technology limitations and resource allocation methods in modern communication infrastructure and service development.

Due to limited availability of laboratory room and equipment students can do one laboratory exercise at a time. Usually this allocation period is 3 weeks, except for laboratory exercise 1 which is set up for 4 weeks. After the allocated time for a given laboratory exercise is over, the current setup is dismantled and a new laboratory exercise set is set up. We usually leave a set of laboratory exercise up for students who for some reason couldn't do that exercise in time. But they have to arrange the time for the exercise with laboratory exercise teacher. The reason for lab 1 to take longer time is that it is the first lab in the sequence and for some students it may require more than one laboratory hour to make measurements. Also at the beginning of the semester students have two week timeframe where they can decide if they want to take the course or not. So in the beginning of the semester we don't know the exact number of course participants.

Laboratory exercises are conducted in small groups: maximum 12 students in a group. Our experience over many years has shown that this is nearly optimal number of students. With this number of students we can assure necessary level of tutoring and active dialog between students and instructor during the laboratory exercise.

To avoid overcrowding on the first week of the lab period we have set up an on-line laboratory exercise workplace reservation system where students can reserve for themselves a lab time on one of the weeks. This system has also helped students to organize their lab teams and manage their time better due to the fact that some students cannot come to the laboratory at their assigned time.

Measurements in laboratory exercises are done as teamwork. Team size is dependent from laboratory exercise complexity and availability of lab equipment (i.e. how much equipment we can provide for parallel measurement) and is in range from 2 to 4 students. To ensure that every student would participate in work some labs (for example lab 1, 2 and 3) have individual measurements. For example in the lab 1 to calculate current in the telephone line a different resistance is assigned to each student to make the measurements.

All laboratory experiments and measurements are conducted in the real life environment i.e. for example in the WLAN network setup (lab 3) university WLAN networks are accessing the same frequency bands and will interfere with networks set up by students.

Department IP network infrastructure is used simultaneously for IP telephony lab (lab 5) and also for daily traffic, which sometimes generates very high level network load. That will affect call quality. Also traffic on the IP backbone network and load on the servers can be considerable and will affect measuring results. This above-mentioned everyday communications activity and interferences will teach students to take into consideration surrounding environment and to understand that applications aren't standalone, but a part of surroundings. Students themselves have to set up measuring devices during the exercise, for example select correct input range for voltage or correct frequency range on spectrum analyzer.

There are individual assignments associated with every exercise, and solutions to these must be presented in the exercise reports. These assignments are similar to the exam assignments. This, together with changes in the environment and individual measurement will assure that each exercise report, presented by a student is partially unique.

We are testing a solution where students do all the measurements individually and then enter results into the interactive lab manual. At the end of the laboratory exercise a HTML page will be generated from the filled manual with the exercise results. Generated HTML page is also saved into database with student ID. Each student will have his/hers own "thin client" terminal to enter the results. This, together with previously described randomization of measuring process will make harder for dishonest students to use someone else lab report. At the moment we can't make any conclusions on the effectiveness of this method, but we have deployed interactive lab manuals for a couple of exercises (labs 1 and 3), so that the measurement results are automatically saved in HTML file format.

Students must present their lab reports as W3C standards compliant HTML page. Choice of a standard is left for student, but compliance with the selected standard is mandatory. This will force students to write standard compliant web pages. Link to report web page is presented through e-learning environment (at the moment Blackboard Learning System). This will ensure that the student, presenting the report, is authenticated and lab teacher can easily send questions/comments to the student. If the report is done as a team work with individual parts then we will assume that student knows what the report includes and has approved it.

We employ second-year Master students at our Department or recently graduated Masters who work in telecommunication field as laboratory exercise instructors. These people tend to communicate well with students as they have recently passed most of the laboratory exercises themselves and they know what may be the complicated and hard to understand parts in the exercise. Side benefit of

employing them is that they will help us to modify and develop exercises as they have lab experience both as a student and as an instructor. We even have at the moment one Master thesis written on the subject [1]. Bi-directional collaboration between university and graduated Masters employers allows practical knowledge transfer and of course simplifies head hunting procedures for employers.

Usually the instructors supervise exercises several consecutive years. New instructors can work under guidance of the more experienced instructors to follow up all laboratory guidance knowledge and to learn exercise caveats and tricks.

We have a couple of times tried to introduce requirement that students have to read lab manual and understand background information before the exercise. We haven't found satisfying way to verify that students are really doing pre-exercise assignments. Verification must be done automatically and it should be fast to not to waste instructor's time. Studies on time usage by students indicate that students do not spend as much time studying as expected. Total amount of time spent for studies is, in many cases, as low as a mere 50% of that which is allocated in the curriculum [2].

Exam prerequisite is that a student must pass all laboratory exercises. He/she has to defend the exercise reports to the exercise instructor. Instructor can require a student to solve problems similar to those to be solved during exam to assure that student has understood the exercise.

Exam setup

A two-hour final written examination will be held during the final examination period. This exam will be closed-book, but we allow student to bring one sheet of A4 size paper to the exam. On one side of the paper student can write any information he/she seems appropriate and necessary for this exam, other side of the paper must be blank. They may also use a non-programmable calculator.

Written exam is developed on expectancy that practical knowledge acquired from laboratory exercises has important part in exam as subjects covered in laboratory are in more general terms covered during the lectures. The strict exam prerequisite that all laboratory exercises must be defended to and approved by laboratory teacher comes from this expectancy.

During the exam students have to analyze and solve telecommunication problems. Problem definitions are set up so that students have to add some missing data themselves i.e. problem description doesn't have all the data to successfully find the solution to the problem. They should have acquired knowledge about this missing data from lectures and laboratory exercises. Students also have to demonstrate that they can understand precisely and correctly the engineering language used to describe problem. They have to use precise and correct engineering language.

Exam is a combination of theoretical and numerical exercises and consists of three parts. First part is analysis of communication system solution (communication system and service it provides) in a form of short essay. The problem is defined so that it has to be presented as a whole picture. Parts of this picture are disserted in different lectures but at none of the lectures has the problem been decomposed entirely, i.e. student can't provide correct answer in this part, relying only on one lecture.

In part two students have to solve five numerical exercises. These exercises utilize basic equations discussed in the lectures and laboratory exercises. Sample exercises used here are discussed and solved in the lectures.

Part three has two multiple choice questions. These questions have some numerical problem and some possible answers for this problem. Each question has 5 choices and there can be any number of correct choices, i.e. even all choices can be correct. Student has to demonstrate that he/she can find all wrong answers or recognize (without a doubt) all the right ones. Short calculation to give good reasons for the choices is mandatory.

Generally calculations in part two and three aren't difficult and require only some skills in mental calculation, (although we observe that skill is in decline amongst students) so that students do not need calculators. There is strict requirement that students have to provide details of the arguments they used to solve the exercises. Providing only correct answer is not sufficient.

Exam grading scale is following. Part 1 gives 30 %, part 2 gives 50% and part 3 gives 20 % of grade.

Each student has its own computer-generated examination paper which contains earlier mentioned parts. The exam questions on the paper are taken from large pool of questions. This guarantees that every student examination paper is personalized and the sets of questions are unique, i.e. a student does not have the same questions that his/hers neighbor has. We have observed that this together with rigid time limit hampers dishonest student's chances for plagiarism. We have also observed that this arrangement stops spreading wrong answers.

Form tool is used to generate examination paper databases and it facilitates to make a query according to the date of examination. When students have answered questions and solved assignments, examinator assigns points for every question and assignment and it is possible to enter those points into database to get feedback statistics about which questions and assignments were easy and which ones were difficult.

During exam registration student can choose in which language (Estonian or Russian) he/she wants exam questions.

Exam results analysis

In this chapter we present the analysis of exam questions answers what we have collected over 5 years. Each year approximately 350-450 students take the exam and complete the course.

As mentioned in previous chapter exam consists from 3 parts.

Essay type answer has very good correlation with exercise solving part i.e. students with good answers in exercise solving part have also written good essay. Grade scale is from 0 to 3.0, with step 0.5.

Typically well answered question is a question which has close ties with laboratory exercises. Positive example of this type of question is "Describe building of

IEEE 802.11 network, its communication channel parameters and general limitations on connecting terminals". Answers average grade 2.5. We have to point out, that essay type of question gets lower grades if students have to describe networks with 3 access points. Questions with higher generalization and with students lacking hands-on experience on subject get lower grades. Negative example of this type of question is "Most widely used UMTS radio channels and terminal handover control" Answers average grade 1.6.

We have to note that the essay-type examination is one of the most practical on showing students general understanding of the course, as it shows students ability to view problems within broader contexts.

For exams second and third part also the highest success rate is for questions what have close ties with laboratory exercises or bear resemblance to assignments given at laboratory exercise defense or during academic discussions with laboratory instructor. Questions what doesn't have close ties with laboratory exercise or which are discussed only in lecture get lower grades. For each assignment grade scale is from 0 to 1.0, with step 0.5.

Typical well answered question for part 2 is "Distance between endpoints of communication channel is 1500 kilometers. Calculate total data transmission time when amount of data is 5000 bytes, packet length is 500 bytes and data transmission speed is 100 kbit/s". For part 3 (multiple choice question) well answered question is "Frequency band used in analog line modems is: 300-3400 Hz; 300-3000 Hz; 20-20000 Hz; 6000-30000 Hz or 30-16500 Hz", as this question is discussed in laboratory exercise 3.

Students who did well in the laboratory exercises usually answer correct to the question "What is signal-to-noise ratio in GSM/EDGE radio channel (speed 600 b/s)", as they comprehend that this question requires knowledge of Shannon–Hartley theorem.

Negative example question for part 2 is related to multimedia flow generation and synchronizations of different multimedia sources. For part 3 negative example of question has choices which are correct if communication system consists of different blocks and matched connections. For correct answers student needs to understand building blocks amplification/attenuation and blocks matching rules. Sample question "Which are correct answers: 40 mW + 0 dBm = 41 mW; 40 dB + 10 dB = 50 dB; 40 mW + 3 dBm = 43 mW; 40 dBm + 10 dB = 50 dB or 20 mW + 3 dBm = 60 mW".

Conclusions

Technology driven telecommunication course is important basis for modern IT curricula.

If laboratory instructors have everyday engineering practice then it is introduced during laboratory supervising. These people are well trained in everyday company's life, have experience and transfer their knowledge during laboratory supervising and laboratory report approval.

Written examination results confirm that broad understanding on topic during laboratory work is excellent basis for high graded examination.

We believe that laboratory exercises should be conducted in small groups: maximum 12 students in a group. To this we employ for the course a number of laboratory exercise instructors.

Computer generated and database managed written examination development allows for efficient examination control and reliable grading. Sets of exam questions are different for every student.

References

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Received 2010 05 03

I. Rokk, M. Kulmar, A. Ots, E. Lossmann. Experiences of Teaching Complicated Undergraduate Course for Large Number of Students in the Tallinn University of Technology // Electronics and Electrical Engineering. – Kaunas: Technologija, 2010. – No. 6(102). – P. 119–122.

Common knowledge of basic communication systems and methods is very important for all students in electrical and computer engineering fields. The modern telecommunication systems and methods for undergraduate students in Tallinn University of Technology are taught during the second year of study in the course "Telecommunication" (in Estonian "Side"). Course is 5 EAC credit value course. Laboratory exercises are conducted in small groups: maximum 12 students in a group. The course employs multiple laboratory exercise teachers. Most exam questions are different for every student. Each year between 350-450 students complete the course. In this paper we present our experience and analysis of the study result accumulated over the course of many years. Bibl. 2 (in English; abstracts in English, Russian and Lithuanian).

И. Рокк, М. Кулмар, А. Отс, Е. Лоссманн. Особенности преподавания модулей при больших патоках студентов в Таллинском технологическом университете // Электроника и электротехника. – Каунас: Технология, 2010. – № 6(102). – С. 119–122.

Описываются опыт и анализ результатов при обучении больших потоков студентов по изучению моделей информатики и телекомуникационных систем. Такие модели изучают ежегодно 350–400 студентов, а лабораторные занятия проводятся в группах до 12 студентов. Библ. 2 (на английском языке; рефераты на английском, русском и литовском яз.).

I. Rokk, M. Kulmar, A. Ots, E. Lossmann. Modulių dėstymo problemos Talino technologijos universitete esant dideliems studentų srautams // Elektronika ir elektrotechnika. – Kaunas: Technologija, 2010. – Nr. 6(102). – P. 119–122.

Visiems elektros ir informacinių technologijų inžinerijos srities studentams labai svarbu turėti bendrų žinių apie ryšio sistemas ir metodus. Studentams pateikiama informacija apie modernias telekomunikacines sistemas ir metodus. Studentai išklauso modulį antraisiais studijų metais. Laboratoriniai darbai atliekami mažomis grupėmis – ne daugiau kaip 12 studentų vienoje grupėje. Kiekvienais metais maždaug 350–450 studentų baigia šį kursą. Pristatoma per daugelį kurso dėstymo metų sukaupta patirtis ir studijų rezultatų analizė. Bibl. 2 (anglų kalba; santraukos anglų, rusų ir lietuvių k.).