Teaching Communication Software Platforms

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ABSTRACT: *The mobile communication course is organized with the laboratory exercises which are evaluated in this work. We have used the new ways of teaching telecommunication software related platforms. We have gained considerable experiences in organizing the mobile communication system and assisting students in learning the wireless communication systems. GSM base station system is implemented with Universal Software Radio Peripheral (USRP) hardware and OpenBTS software. Students' experience with the new laboratory exercise was assessed using a system of questions.*

1. Introduction

Software-defined radio is a system with characteristics that can be changed by software, that is, without the need to change system hardware components. In SDR the components that have typically been implemented in hardware in traditional radio

systems are implemented in software, which allows for easy reconfigurabillity. Apart from being innovative wireless technology emerging in commercial market, SDR platforms offer great opportunities in enhancing practical teaching in the field of wireless and mobile communications [1]. The costs of SDR systems are minimal compared to conventional radio and network equipment and therefore enable academic institutions to deliver relevant, real world, practical exercises. The other important impact on the telecommunication engineering education of the current industry trends in SDR development and applications is that these changes inspire integrated SDR curriculum design [2]. The main advantages of SDR technology is flexibility in creating different communication technologies with little hardware components and usage of free, open source, publicly available software, which together makes this a very cost effective solution for various communications system implementation. This allows more rapid communications system development and testing. Some of the examples of the implemented communications systems are: FM radio transmission and reception, digital video signal transmission, radio frequency identification, cognitive radio systems.

One of the very popular hardware platforms used for research and teaching in academia is universal software radio peripheral (USRP) [3,4]. This platform is commonly combined with LabView [4], or GNU radio software [5] to create software defined radio. Block diagram of the SDR platform is shown in Figure 1. Radio Frequency (RF) front end is used for signal transmission and reception. Intermediate frequency part of the USPR is used for analog to digital and digital to analog conversion (ADC/DAC) and signal processing by the Field Programmable Gate Array (FPGA) that can include filtering, modulation and demodulation as well as digital up conversion (DUC) or digital down conversion (DDC). The last block is used for baseband signal processing in software run at personal computer.
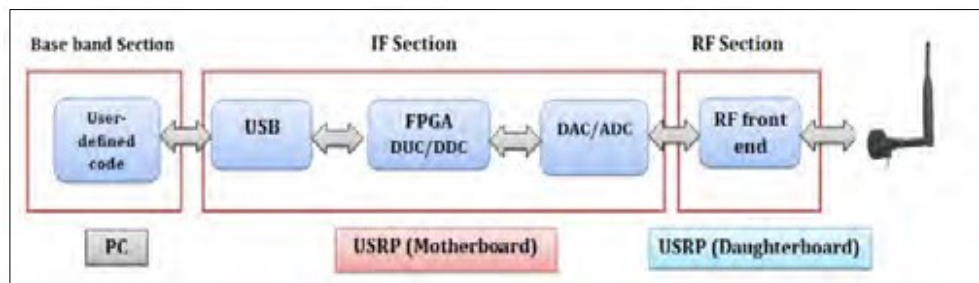

Figure 1. Block diagram of the SDR platform

In our laboratory exercise the software run on PC is OpenBTS application [6], open source software for GSM base transceiver station (BTS) implementation. Open BTS together with USRP implements GSM access point which allows GSM compatible phones to communicate. Open BTS is the first free open source implementation of the standardized GSM protocol stack. This application implements air interface of the GSM standard (Um interface) and mobile stations (MS) see identical interface as in the case of conventional GSM systems. The rest of the network differs from the conventional GSM in that, that it uses Internet Telephony protocols [7]. The Session Initiation Protocol (SIP) and Real-time Transport Protocol (RTP) are the two protocols that OpenBTS uses to convert GSM traffic into voice over Internet Protocol (VoIP) traffic [7]. Open source software Asterisk Private Branch Exchange (PBX) [8] is used to connect calls. OpenBTS GSM system components are shown in Figure 2 [7].
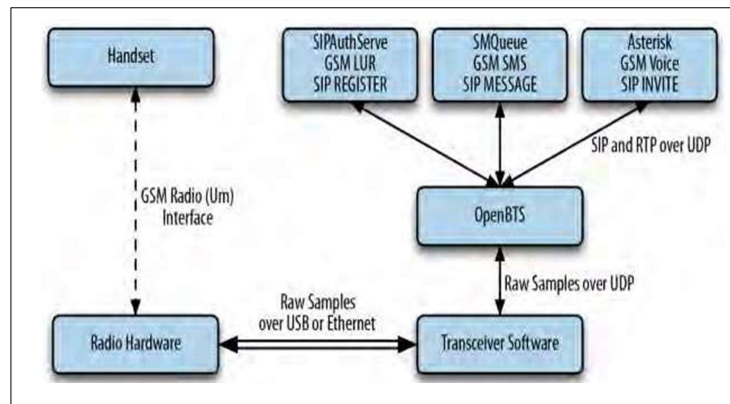

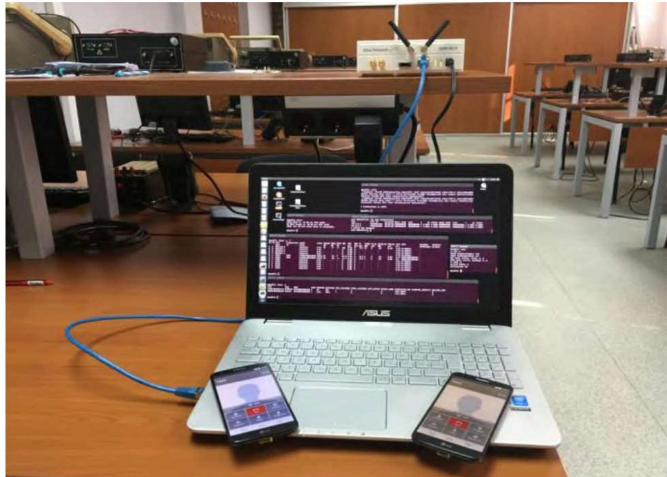Figure 2. OpenBTS GSM system components

Figure 3. Laboratory set up picture

GSM system architecture and Um interface are studied in detail theoretically in lectures. What was lacking was a practical experience with the GSM Um interface parameters that would help students to faster adopt knowledge in the field. The implemented excersise is based on reference [7].

Hardware that we used consists of USRP N210 with SBX daughterboard, GSM quad band antenna, PC and mobile phone. The installed software is Ubuntu 14.04LTS, OpenBTS 5.0, ASTERISK 11.7.0.4. The laboratory set up is shown in Figure 3.

2. Overview of Laboratory Exercise

Laboratory exercise is divided in four sections: GSM configuration, identification of GSM users, testing GSM services, and measuring signal quality.

2.1. GSM Configuration
Within GSM Configuration part of the laboratory exercise students gain experience with GSM system parameters, revise knowledge of frequency bands, downlink and uplink frequency separation, received signal strength indicator (RSSI) and examine relationship between noise levels and signal strength in respect to changes in transmit output power and receive and transmit antenna orientation.

Students set frequency band of GSM to 900MHz and select uplink/downlink channel pair by setting ARFCN (Absolute Radio Frequency Channel Number) to 124. This channel is not used by mobile operators in Serbia. The other parameters are set to default values.

Figure 4. Configuration parameters

Apart from examining the frequency settings, students get acquainted with the other characteristics of mobile communication systems by inspection of other parameters such parameters for setting maximum expected delay spread which is used for equalization, parameters for minimum and maximum output power used for output power control and parameters for target RSSI and signal to noise ratio (SNR) used for mobile station (MS) power control loop. Figure 4 shows an example of configuration parameters.

Students check the noise level and check whether uplink RSSI for MS is higher than noise level for at least 10 dB which was set by target SNR parameter.

It is further demonstrated that exists mutual influence of transmit and receive signal paths. This done by observing how noise levels change when transmit signal power is reduced and when antennas positions are changed.

2.2. Identification of GSM Users

Within Identification of GSM Users part of the laboratory exercise students get familiarized with numbers that are used for identification of mobile subscribers in GSM: IMSI (International Mobile Subscriber Identity), TMSI (Temporary Mobile Subscriber Identity), MSISDN (Mobile station ISDN Number), and IMEI (International Mobile Equipment Identity).

Concrete tasks comprise of checking the list of users that have requested interaction with openBTS. This list displays IMSI, TIMSI and IMEI numbers as well as paramether AUTH that denotes whether the users have been authenticated. Figure 5 shows an example of displayed parameters for users connected to openBTS system.

Students check IMSI and IMEI numbers by mobile phone application on the phone and compare it to the one reported by openBTS.

In order to be able to authenitficate users and register them with the openBTS GSM network, it is necessary to create entries in the database of subscriber information that replaces GSM Home Location Register (HLR) found in a conventional GSM. Students put the following entries in the database: user name, IMSI and MSISDN, and check whether the authentication has been successful.

2.3. Testing GSM Services

Within esting GSM Services part of the laboratory exercise, students get to test voice and SMS service.

After users are registered with the network, the services can be checked by dialing test numbers predefined in the Asterisk PBX.
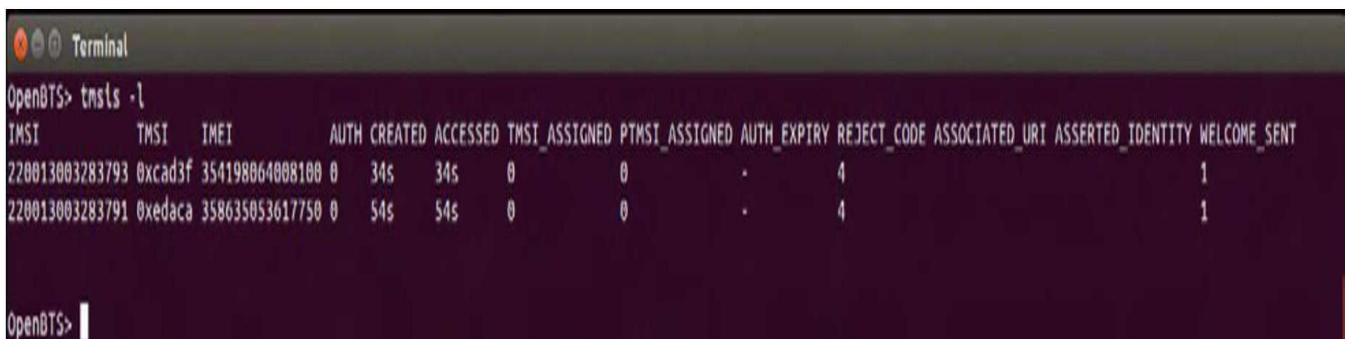

Figure 5. An example of display of users requests

Students send test message to 411 (predefined test number) and get, in a reply, IMSI and MSISDN numbers as parts of SMS, Figure 6.

By calling the test number 2602 students check the reception of the test tone. It is clearly heard in the case of good quality of communication channel. The loss of information can be heard as tone interruptions.
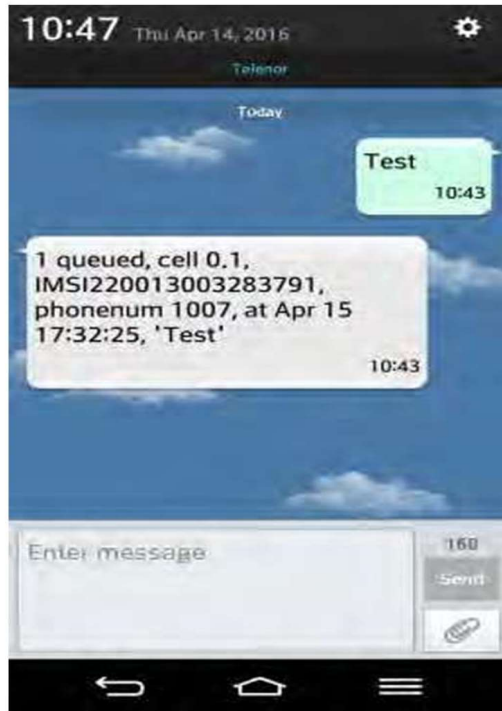
Figure 6. SMS reply message to dialling test number 411

Figure 7. Results when users are close to BS

Figure 8. Results when users are one floor apart

Figure 9. Results when users are one floor apart

Students further perform echo call test in order to check both uplink and downlink connection. In an echo call test the voice message that has been sent by MS in the uplink channel is sent back to MS on the downlink channel.

2.4. Measuring Signal Quality
Within "Measuring Signal Quality part of the laboratory exercise, students get familiarized with signal quality measures such as SNR and Bit Error Rate (BER) in GSM.

In this part of the exercise students make a two party call and examine what channels are used and what are their characteristics. They also examine the change of the characteristics of the links as the users are increasing distance from the base station.

Figure 7 shows the results for the call established between the two users when both users and base station are in the same room.

The parameters that are identified are the following: the users use two channels (TN1 and TN2) which are full rate traffic channels on time slots 1 and 2 of the C0 ARFCN. Transmit power (TXPWR) for both users is 5dBm. RSSI for user with IMSI 22013003283793 is -23 dB and for user with IMSI 22013003283791 is -37 dB. BER is zero percent.

Figure 8 shows the results when the user with IMSI number 22013003283793 is in another room. It can be seen from Figure 8 that by increasing distance of the MS from the base station, the MS transmission power is increasing from 5 to 13 dBm, in order to maintain target RSSI at -50dB. At the same time SNR has decreased and the BER is increased to 1.03 percent.

Figure 9 Shows the results when the user with IMSI 22013003283793 is one floor below base station. Further degradation of SNR and BER can be observed.

3. Results of Student Survey

One of the main reasons for introducing this laboratory excersise was to motivate students to learn about complextechnologies used in contemporary mobile communications. In order to examine students overall experience with the newly introduced laboratory excesise questionary has been created. The questionary has been filled in by 33 students. The questionary consists of ten questions grouped in three categories.

The first category of questions ask students to evaluate their knowledge of SDR and GSM before and after GSM laboratory class. Majority of students have answered that their understanding of GSM and SDR systems has improved after attending laboratory class.

The second group of questions reffers to evaluating complexity of the examined system and the complexity of the laboratory excersise. Majority of students have evaluated complexity of laboratory excersise as moderate.

The third group of questions evaluates student oppinion on how the excersise contributes to understanding of SDR and GSM concepts, and wheteher it inspires furhter interest in studing wireles/mobile communication systems.
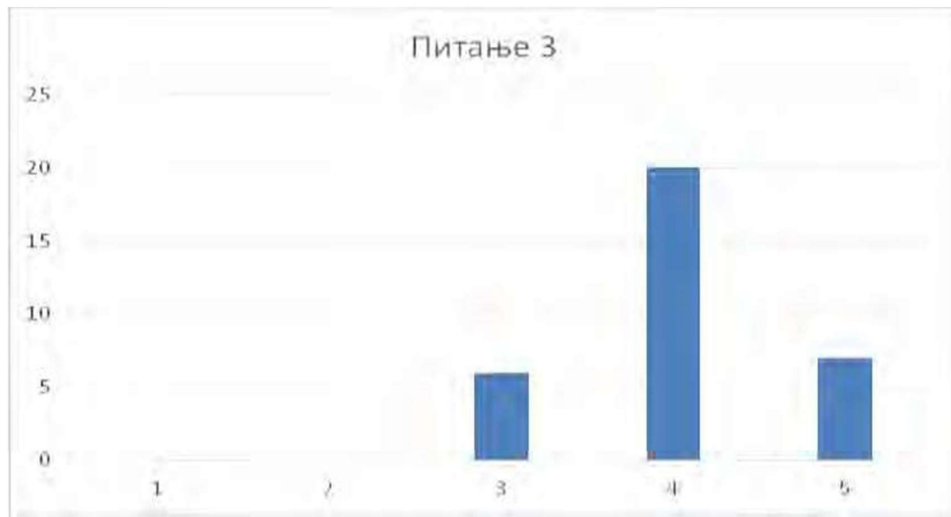

Figure 10. Students answers to question how much does this laboratory exercise contribute to your understanding of GSM

Figure 10 shows students answers to question: "How much does this laboratory exercise contribute to your understanding of GSM?" Majority of students (27 out of 33) have answered with scores 4 and 5 on the five point scale. Answers show that students have evaluated that this exercise has satisfactorily contributed to their understanding of GSM system.
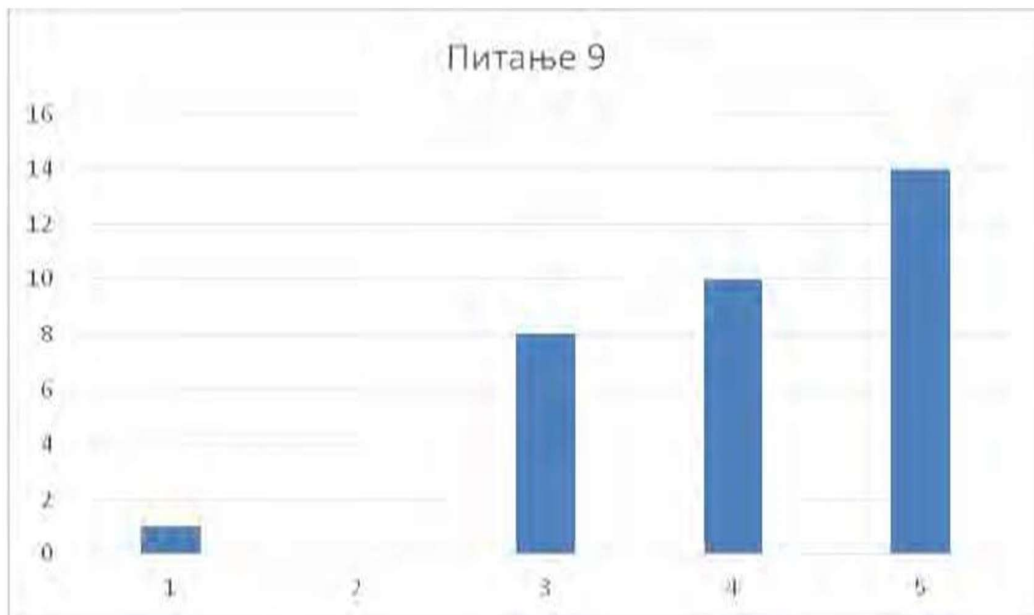

Figure 11. Students answers to question at what degree does this laboratory exercise inspires interest in studying GSM

Figure 11 shows students answers to question: "At what degree does this laboratory exercise inspires interest in studying GSM?" Majority of students (24 out of 33) have answered with scores 4 and 5 on the 5 point scale. Answers show that students have evaluated that laboratory exercise has motivated them to further study of GSM.

4. Conclusion

Laboratory excercise "GSM mobile technology with SDR and openBTS" significantly improves teaching of GSM by integrating the teaching of theory with the practical experience. Students get exposed to modern teaching tools used at world's top universities. Student survey results show that introduced laboratory class is well accepted. We plan to further advance the study of GSM in the future by using protocol analyzer software Wireshark and to introduce laboratory on UMTS.

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