Collaborative Simulation-Based Methodology for Teaching Mobile Communication Systems

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Abstract

This paper presents a collaborative simulation-based learning strategy as an educational method for teaching mobile communication systems in the communication engineering curriculum. In this methodology, senior-level undergraduate students will have to implement a simulator based on its standard (IS-95) and use it in educational activities; when used in this manner, it can provide students with an educational method that helps them effectively understand the theory of mobile communication technologies. This methodology may be particularly useful when access to actual mobile communication system is limited. An evaluation based on learners' satisfaction achievement shows the effectiveness of the methodology to enhance the teaching/learning process.

I. INTRODUCTION

Recently, mobile communication technology has become related to our lives through the development of wireless communication technology and the wide release of cellular phones. This has enabled us to access various services such as internet, music, and online shopping using a portable mobile device. We can also enjoy chatting with friends, watching TV, and finding the route to a destination. Wireless communication technology significantly helps to create valuable services. Since the introduction of analog wireless communication 20 years ago, it has made considerable progress, from voice communication and simple messaging service to video/voice communication and multimedia service. Since the second generation of communication technology was introduced in 1996, the CDMA has been the world`s first commercialization in Korea. It plays a crucial role in making local mobile phones into the world's best product. This technology has contributed significantly to the development of CDMA and its related equipment, as well as to associated devices and software programs.

Presently, wireless communication technology has been split into asynchronous and synchronous. The former was focused on the WCDMA in Europe and Japan and the latter was focused on the CDMA 2000 in the USA [1]. However, both technologies were based on the CDMA technology. It is therefore necessary to understand the IS-95 CDMA system clearly in order to learn about the new third generation CDMA system. While we clearly need to understand CDMA technology for both present and future wireless communication technology, most communication engineering curriculums are based on theoretical methodology that lacks practical and clear experiments, due to the lack of relevant material. To overcome this issue, we must develop a simulator for the CDMA wireless communication system that is costless but very important to help the students to understand CDMA by themselves. The purpose of this paper is to present the development of an IS-95 simulator of the physical layer of the CDMA system, and to demonstrate its use in the classroom as an educational method that can be extended to other modern wireless and mobile communication technologies. Using this collaborative approach, the understanding and experience gained by the students who design the simulator yield skills and experience that can easily be shared with other students, both by using the simulator itself and with the associated documentation[2],[3].

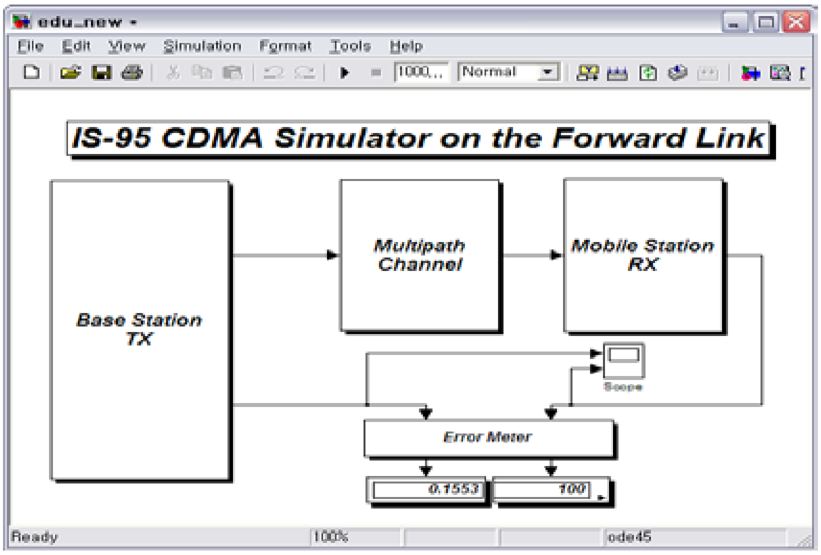
This paper is organized as follows. In Section II, we present the theoretical background of collaborative simulation-based methodology. The implementation and usage of the collaborative learning methodology is described in Section III. In Section IV, we evaluate this methodology within the mobile communication engineering curriculum and analyze the evaluation results. Finally, the conclusions of this paper and some possible avenues for future research are provided in Section V

II. COLLABORATIVE SIMULATION-BASED METHODOLOGY

A. Overview of CSBM

The CSBM (collaborative simulation-based methodology) aims to help senior undergraduate students better understand the subject of theoretical communication engineering, as well as to motivate them to learn it. To accomplish this, we implemented the use of a simulator in the classroom by using MATLAB/SIMULLINK, a basic development tool that students are familiar with. In this paper, we discuss the development of the IS-95 CDMA simulator and describe how used it to teach the subjects covering mobile communication. Figure 1 shows a simulator for the IS-95 CDMA system on the forward link.

Figure 1. IS-95 CDMA Simulator



The implementation items of the simulator based on the IS-95 specification and main contents are CDMA Tx part (base-station), wireless communication channel part, CDMA Rx part (mobile-station), and BER meter for the evaluation of the system's performance. In a classroom, students can easily understand these through theoretical learning and the implementation of the simulator. Moreover, they can apply mobile communication theory from simple to complicated one using the same simulator. The CSBM will be a more effective method for understanding the theory of mobile communication technologies when students are limited in their ability to access actual mobile communication systems for their experiments. Students who enroll in this course must have a background in analog and digital communications as well as computer networks. In order to improve the teaching-learning process in the mobile communication course, a simulation-based methodology has been employed.

B. Contents of IS-95 CDMA Simulator

We developed a simulator of the CDMA mobile communication system for senior-level undergraduate students who have difficulty learning about theoretical subjects. The main development content is as follows. The CDMA mobile communication Tx part consists of numerous blocks; each block is closely connected with the next block. Detailed discussions of these blocks are beyond the scope of this paper; however, some basic aspects will be discussed here.

<u>CDMA mobile communication Tx (base-station) implementation</u>

- Random data generator
- Digital modulation: BPSK, QPSK
- Convolutional encoder
- PN code generator
- PN spreader
- Multi-user combiner
- Walsh code multiplier

In this simulator, we used five sets of voice data as our source data. The voice source block generates the voice data of the user as a binary. The convolutional encoder block was built in a MATLAB/SIMULINK library. An orthogonal property of the Walsh multiplier block was used to distinguish each user's binary data from the entire received signal. The short PN block is used to distinguish the base-station. A signal was spread by the short PN. A signal from the base-station arrived at the end user equipment through a multipath channel. This multipath channel changed from the original base-station signal to a distorted signal. In the section regarding the implementation of the wireless communication channel, we consider three parameters that have the Hata model as a path loss model, along with the AWGN channel and a Rayleigh fading model. This can be explained as follows:

Wireless communication channel implementation

- Path loss model: Hata model
- AWGN channel
- Multipath fading: Rayleigh fading, three-path ray model

The CDMA mobile communication Rx (Mobile) implementation part consists of the following five parts:
CDMA wireless communication Rx (Mobile) implementation

- PN de-spreader
- Digital integration
- SNR calculator
- Digital demodulation: BPSK, QPSK
- Viterbi decoder

In the PN de-spreader, this block parameter will always set the same value of PN spreader in TX part. Digital demodulation block has a function of BPSK, QPSK. Here, we use a Viterbi decoder in MATLAB/SIMULINK library. The results of those lead to the bit error rate (BER).
Evaluation of system performance implementation

- BER meter

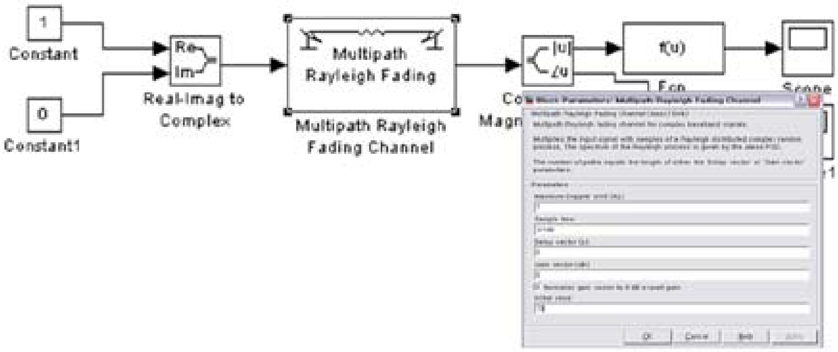
III. IMPLEMENTATION AND USE OF COLLABORATIVE LEARNING

At Korea University of Technology and Education (KUT), the IS-95 simulator is used to support class lectures and to allow students to practice several topics. In this paper, we present two such topics due to the limitation on the paper's length: multipath Rayleigh fading and spreading/despreading block. The teaching process is based on the CSBM, which was mentioned above. During the class, the teacher first introduces the general aspects of the technology and then the students interact with the simulator through the IS-95 CDMA system. The IS-95 system of mathematical model is developed based on the standard of EIA/TIA/IS-95 and the fundamental theory presented in reference [4].

A. Multipath Rayleigh Fading

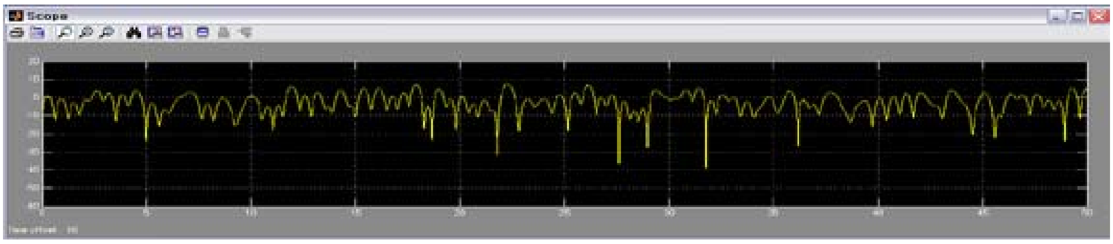
Due to reflection by obstacles such as buildings, there are many propagation paths with different delays and different amplitudes. The multipath Rayleigh fading is referred to as being frequency selective if multiple resolvable paths exist. It is assumed that each resolvable propagation path suffers from the same attenuation according to the distance and the same shadowing [5]. In Figure 2, we assume that as a constant value input to the IS-95 system for the fading channel, the multipath Rayleigh fading block receives complex numbers as input signals in the simulator. Finally, to teach the effects associated with the radio channel, the lecturer analyzes with the students the changes in the system's performance due to those in the radio channel parameters.

Figure 2. Test model for Rayleigh fading



As a result, we confirmed that variable of the signal's shape was changed according to fading envelop. Figure 3 shows the level of attenuation that can occur due to the multipath Rayleigh fading channel. The relative phase of multiple reflected signals can cause constructive or destructive interference at the receiver. If some channel elements move, it might make the channel fade more or less rapidly.

Figure 3. A result of multipath Rayleigh fading



B. Spreading/Despreading

Figure 4 shows a test of the spreading and despreading process that can reject interference/jamming signals that are introduced to the signal in the channel. When the interference signal is despread at the receiver, the effect of PN code multiplication "spreads" the interference, while the original transmitted signal is obtained. When the signal is passed through data-detection, the jamming effects have already been reduced, which leads to more reliable signal detection. This also provides privacy to the signal because it is difficult to decode a signal without knowing the code that is used to spread it [6].

Figure 4. Test block for spreading and despreading

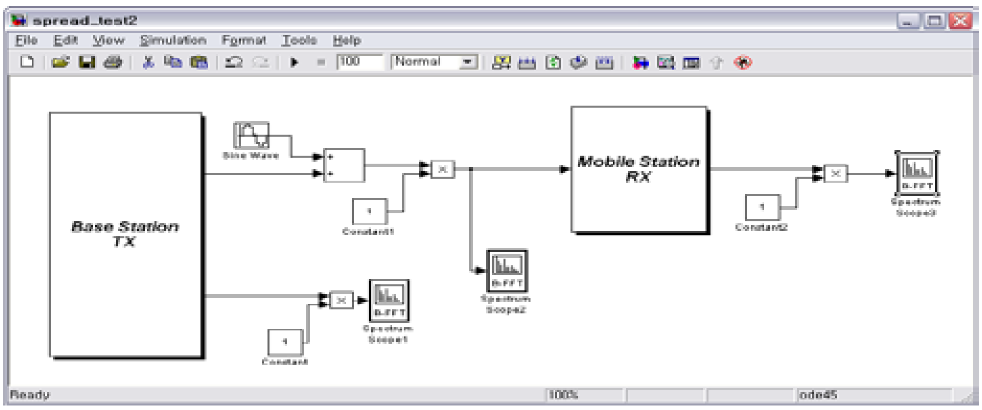


Figure 5 (a) shows the Tx source signal, 5 (b) shows the spread source signal with the interference signal as a 30-Hz sine-wave, and 5 (c) shows the source signal after despreading and spread interference signal. As a result, we verified that tone interference in a narrow band was spread in the despreading process.

IV. EVALUATION OF THE METHODOLOGY

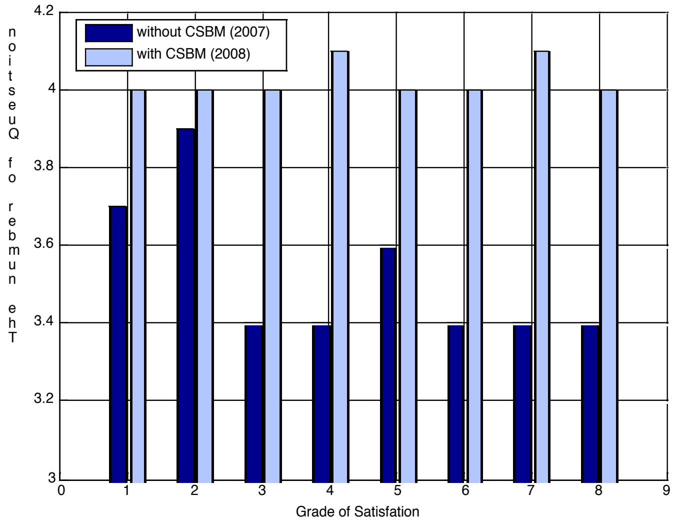
The total number of students per class is 26; we compared the satisfaction levels of students in the mobile communication classroom sessions between 2007 and 2008. Regarding learning skills, the student batch in 2007 was different from that in 2008; however, we can consider that students' levels of understanding of the class are alike assuming the existence of similar education trends. From this result, we confirmed that students' understand of the subjects was better when the classroom sessions used the collaborative simulation-based methodology. In the survey that was carried out after class, the students answered the questions listed in Table 1. The answers were favorable toward students' satisfaction with the mobile communication subject when the IS-95 CDMA system simulator was used, and about the usefulness of the simulation for educational purposes.

Table 1. Questions in the student inquiry

NO	Questions
1	What is your level of satisfaction after taking the class?
2	Were you more interested in the class?
3	Would you recommend this class to other students?
4	Were the contents comprehensible?
5	Did the class process provide benefits to the student's level of knowledge?
6	Do you think that class motivation was appropriated to the students?
7	Did the lecturer introduce new technology and trends?
8	Do you think the materials were suitable?

A histogram of the responses is shown in Figure 6. The students agreed that the IS-95 CDMA system simulator is useful for gaining a better understanding of the fundamental concepts of the IS-95 CDMA system and asserted that they perform better when the class follows the collaborative simulation-based methodology. The results also indicate that students felt that they become familiar with the simulator fairly quickly and easily. These opinions show the importance of having a tool that students feel comfortable using in order to acquire the skills related to their topic. Thus, we confirmed that students were able to achieve the educational purpose of the IS-95 CDMA physical layer even if they have limited access to an actual mobile communication system. This result shows the importance of the collaborative simulation-based learning environment as a facilitator to help students understand the new concepts related to CDMA. The result also shows that this provides a useful experience to the senior undergraduate students who developed it. These students acquired a deep understanding of the communication processes involved in the operation of a complex communication technology that had already been implemented for commercial purposes.

Figure 6. Evaluation results of the CSBM



The distributions of the responses to the questions are shown in Figures 7 and 8. These results demonstrate that the students agreed that the use of CSBM was a more efficient way to learn about complex communication systems. The answers show that students were more motivated to learn IS-95 systems. In particular, the answers to questions 3, 4, 7, and 8 improved from 2007 to 2008 with the introduction of CSBM. These results demonstrate that students consider the use of a simulator to be a convenient way of studying complex communication systems when other laboratory equipment is not available and that the development of other simulators should be encouraged.

Figure 7. Evaluation results without CSBM in 2007

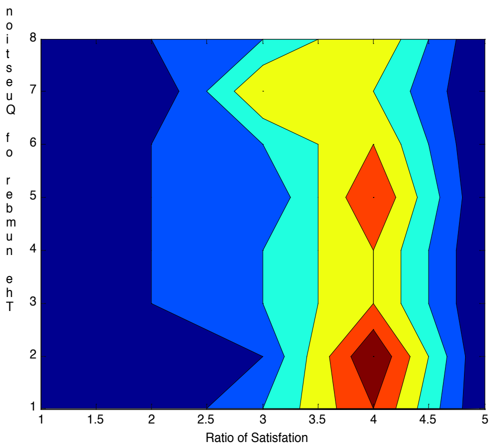
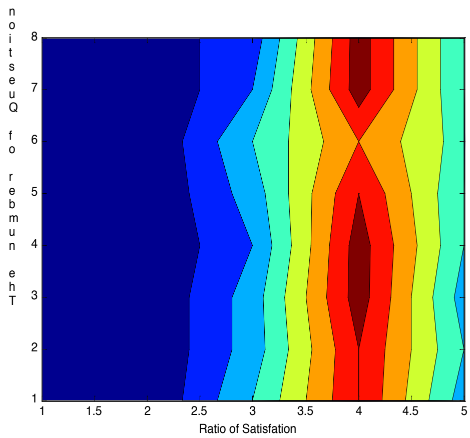


Figure 8. Evaluation results with CSBM in 2008



V. CONCLUSIONS

In this paper, we presented a collaborative simulation-based learning strategy as an educational method for teaching mobile communication in the communication engineering curriculum. The proposed methodology allows both teachers and students to interact more closely by means of simulation techniques. In this methodology, senior-level undergraduate students implement the simulator based on its standard (IS-95 CDMA system) and use the simulator in educational activities. It can thereby provide students with an educational method to effectively understand the theory of mobile communication technologies. This methodology is particularly useful when access to actual mobile communication systems is limited. The evaluation results based on learner satisfaction achievement shows the effectiveness of the methodology in enhancing the teaching/learning process. In other words, the students believe that the proposed methodology is a convenient way to study complex communication technologies. Additional future work includes the implementation of third and fourth generation mobile communication systems and the development of a CSBM.

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