PERFORMANCE OF WIMAX PHYSICAL LAYER WITH VARIATIONS IN CHANNEL CODING AND DIGITAL MODULATION UNDER REALISTIC CHANNEL CONDITIONS

Md. Ashraful Islam and A.Z.M. Touhidul Islam

Department of Information and Communication Engineering
University of Rajshahi, Rajshahi-6205, Bangladesh
ras5615@gmail.com, touhid_ict_ru@yahoo.com

ABSTRUCT

The aim of this paper is to analyze the bit error rate (BER) performance of WiMAX physical layer with the implementation of different concatenated channel coding schemes under QAM and 16QAM digital modulations over realistic channel conditions (i.e. noise and multipath fading). In concatenated channel coding, the WiMAX system incorporates CRC-CC (Cyclic Redundancy Check and Convolutional) or RS-CC (Reed-Solomon and Convolutional) encoder over an additative white gaussian noise (AWGN) and other multipath fading (Raleigh and Rician) channels. A segment of synthetic data is used for the analysis. Computer simulation results based on BER and signal to noise ratio (SNR) demonstrate that the performance of concatenated CRC-CC coded WiMAX system under QAM modulation is better as compared to RS-CC coded system over noisy and fading environments.

KEYWORDS

Cyclic Redundancy Check code (CRC), Reed-Solomon code (RS), Convolutional code (CC), Concatenated codes, CRC-CC code, RS-CC code, WiMAX Physical layer, AWGN, Fading Channels.

1. INTRODUCTION

Wireless communications are an emerging field that has experienced a significant development over the last several years [1]. The availability of broadband networks offers high performance connectivity to over a billion of internet users around the world. Development of new wireless broadband standards and technologies is essential to increase wireless coverage rapidly. The demand for mobile data services and broadband network connectivity continues to increase. Conventional high-speed broadband services are based on wired-access technologies such as digital subscriber line (DSL). However this service is difficult to deploy in remote rural areas and it lacks support for terminal mobility. Mobile Broadband Wireless Access can be used as an alternative in such problematic situations in order to obtain a flexible and cost-effective solution [2].

The IEEE WiMAX/802.16 standard for broadband wireless metropolitan area networks (WMANs) can deliver high throughput over long distances, support different qualities of services, offers a wireless backhaul network that enables high speed internet access to residential, small

DOI : 10.5121/ijist.2012.2404

and medium business customers. This promising and cost-effective technology can also support internet access for WiFi hot spots and cellular base stations through their respective access points [3]. A number of broadband technologies can exist in the same wireless segment and compete each other to get last mile infra structures. In cases where it is very difficult to get such structures with other technologies, WiMAX will become an excellent solution [4]. The original WiMAX standard only supplied for fixed and Nomadic services. It is reviewed to address full mobility applications in mobile WiMAX standard under the IEEE 802.16e specification. Mobile WiMAX is a rapidly growing novel technology for full mobility wireless access and supports nomadic and fixed access as well as both the point-to-point and point-to- multipoint connections [5, 6].

The performance of WiMAX physical layer is commonly determined by BER. Noise in transmission medium disturbs the information signal and causes data corruptions. In general, SNR is inversely proportional with BER which means the quality of a communication system becomes better at lower BER and at higher SNR values. In order to improve the BER performance of a wireless communication system it is necessary to reduce burst error as much as possible. Forward error correction techniques use error-correcting codes such as RS, CC, and CRC and so on for dealing with burst error. By concatenating two different codes the effect of improving the total BER of WiMAX system can be realized.

The objective of this study is to develop a simulator for the WiMAX physical layer using Matlab R2009a and to evaluate the performance of WiMAX physical layer utilizing different concatenated channel encoding and digital modulation schemes over AWGN, Rayleigh and Rician fading channels.

2. RELATED WORKS

The WiMAX physical layer specified in IEEE 802.16-2004 over space-time coding for more than one transmit antennas and a maximum ratio combining diversity scheme to allow performance investigations in various MIMO scenarios is studied in [7], where they showed that a gain of 3 dB in the channel SNR appears in the BER curves when two antennas are used at the receiver instead of at the transmitter. A final contribution in this paper is the performance evaluation of the AMC scheme where the proposed scheme has been shown to be effective from approximately 7 dB of channel SNR onwards; an enormous increase in the throughput of the system is achieved with the use of the AMC scheme. In [8], performance of Interleaved CRC encoded QPSK based wireless communication system are analyzed and shown that interleaved CRC encoded QPSK based system provides unique performance in proper identification and retrieval of transmitted color image. Authors further concluded that it is possible to transmit color image with lower value of the transmitted power and the performance of OFDM based WiMAX communication system can be increased using suitable error correction code such as interleaved RS code (255,239,8) with 1/2-rated Convolutional code [9]. Md. Zahid Hassan *et al.* [10] shown that the performance of the WiMAX system in digital image transmission over AWGN channel is comparatively better as compared to Rayleigh and Rician fading channels. The concatenated channel coding scheme with low-density parity-check and convolutional codes in OFDM based system is very much effective in proper identification and retrieval of transmitted digital image in noisy and fading environment [11]. Simulation of WiMAX Physical layer using Simulink and Matlab is described in [12]. The model used 5/6- rated convolutional code with QPSK digital modulation and the system performance can be evaluated under different data rates, coding schemes and channel conditions. M.A. Hasan [13] showed the performance of WiMAX physical layer over SUI-1, SUI-2 and SUI-3 channels. The performance of the proposed system was also evaluated under different modulations and channel coding schemes. It was observed that FEC improves the BER performance by almost 6dB at BER level of 10^{-3}. The performance improvement due to RS codec on different modulation and coding profiles has been also observed on SUI-3 channel model.

3. CONCATENATED CHANNEL CODING

Cyclic Redundancy Check codes (CRC), Reed-Solomon codes (RS) and Convolutional codes (CC) have distinguishing features in handling errors. Concatenation of these codes provides better BER performance compared to the use of individual code. A Convolution encoder consists of a shift register and exclusive-OR logic circuits. The shift register provides temporary storage as well as shifting operation for the input bits while the logic circuit generate coded output from the bits currently held in the shift register [14].

In Reed-Solomon (RS) Coding, the message to be send is mapped to a polynomial and the codeword is defined by evaluating it at several points. The RS code is used to to add redundancy to the data sequence which helps in correcting block errors that occur during transmission of the signal. RS encoder encapsulates data with coding blocks which are helpful in dealing with the burst errors. The supported compressed and punctured code of the encoder used to facilitate variable block sizes and variable error correction capability.

Cyclic Redundancy Check (CRC) codes satisfy the cyclic shift property from which the codes possess a great deal of structure exploited to greatly simplify the encoding and decoding operation [15]. In CRC coding a generator polynomial is used as the divisor, the input data as the dividend and the remainder is considered as the result.

The Convolutional codes (CC) is best suited for correcting random errors in a noisy channel while the RS code can combat burst errors caused by convolutional decoder. The concatenated RS-CC scheme can be employed to reduce the overall error rate as compared to using single coding scheme. In RS-CC coding, the RS code is used as the outer code while the convolutional code as the inner code. On the other hand, CRC codes are single-burst-error-detecting cyclic code used to detect errors without correction them. The employment of a serially concatenated cyclic redundancy check (CRC) code along with a convolutional code (CC) is effective in discarding erroneous packets after CC decoding. In concatenated CRC-CC coding, CRC and CC codes are used as the outer code and inner code respectively.

4. SIMULATION MODEL

The block diagram of transmitter and receiver sections of the WiMAX Physical layer are shown in Figure 1. We have implemented only the mandatory features of the physical layer of WiMAX air interface, while leaving the implementation of optional features for future work. At the transmission section, at first, we have generated a random data stream of length 61184 bit as our input binary data using Matlab R2009a. Then randomization process has been carried out to scramble the data in order to convert long sequences of 0's or 1's in a random sequence to improve the coding performance. After that, we have performed Reed-Solomon (RS) encoding with the parameters (N = 255, K = 239, T = 8) or Cyclic Redundancy Check (CRC) encoding. 2/3 rated convolutional encoding is also implemented separately on the RS encoded or CRC encoded data. The encoding section was completed by interleaving the encoded data. Various digital modulation techniques, as specified in WiMAX Physical layer namely QAM and 16QAM are then used to modulate the encoded data. The modulated data in the frequency domain is then converted into time domain data by performing IFFT on it. For reducing inter-symbol interference (ISI) cyclic prefix has been added with the time domain data. Finally the modulated parallel data were converted into serial data stream and transmitted through different communication channels. Matlab built-in functions, "awgn", "rayleighchan" and "ricianchan" are used to generate AWGN, Rayleigh and Rician channels, respectively. At the receiving section, the reverse procedures have been performed at the transmission section. The performance of the simulated WiMAX PHY layer is evaluated for different channel coding and digital modulations under AWGN, Rayleigh and Rician channels. Bit Error Rate (BER) calculation against different Signal-to-Noise ratio (SNR) is adopted to evaluate the system performance.

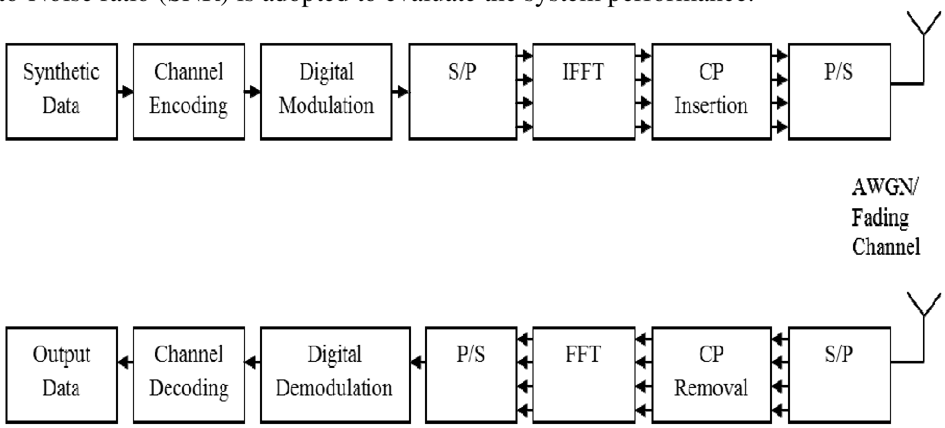

Figure 1. Block diagram of WiMAX Physical Layer with concatenated channel coding.

Simulation for the WiMAX physical layer was done using Matlab R2009a. The simulation Parameters used in the present study are shown in Table 1.

Table 1. Simulation Parameters.

Parameters	**Values**
Nominal channel bandwidth	2.5 MHz
Number of Subscriber	200
FFT size	256
CP	1/8
Modulation	QAM, 16QAM
RS code	(255,239,8)
Convolution code	2/3 rated
CRC code	(3,2)
SNR	0-25
Noisy Channel	AWGN, Rayleigh, Rician
Number of bit to be transmitted and received	61184

5. SIMULATION RESULTS

Figures 2 through 4 show the BER performance graphs for the simulated WiMAX physical layer with the implementation of RS-CC and CRC-CC concatenated channel coding under QAM and 16 QAM digital modulation schemes over AWGN noisy, Rayleigh and Rician multipath fading channels. In all simulation plots, it is realized that the BER performance of WiMAX communication system degrades with the increase of noise power.

As seen from Fig. 3, the BER performance of concatenated coded WiMAX physical layer under AWGN channel improves with the decrease of the order of modulation and the best result comes for QAM modulation. At lower SNR up to 4dB RS-CC code shows better performance, however, above that SNR value CRC-CC shows outperformance than RS-CC code. The CRC-CC curve shows less flattening than RS-CC code. The CRC-CC curve also has a better slope than RS-CC code. For a typical SNR value of 6dB, the BER value for CRC-CC and RS-CC concatenated coding under QAM modulation are 0.000343 and 0.001548 respectively, which implies that the system performance with CRC-CC coding is about 4.5 dB better than that of the system with RS-CC channel code over AWGN noisy channel.

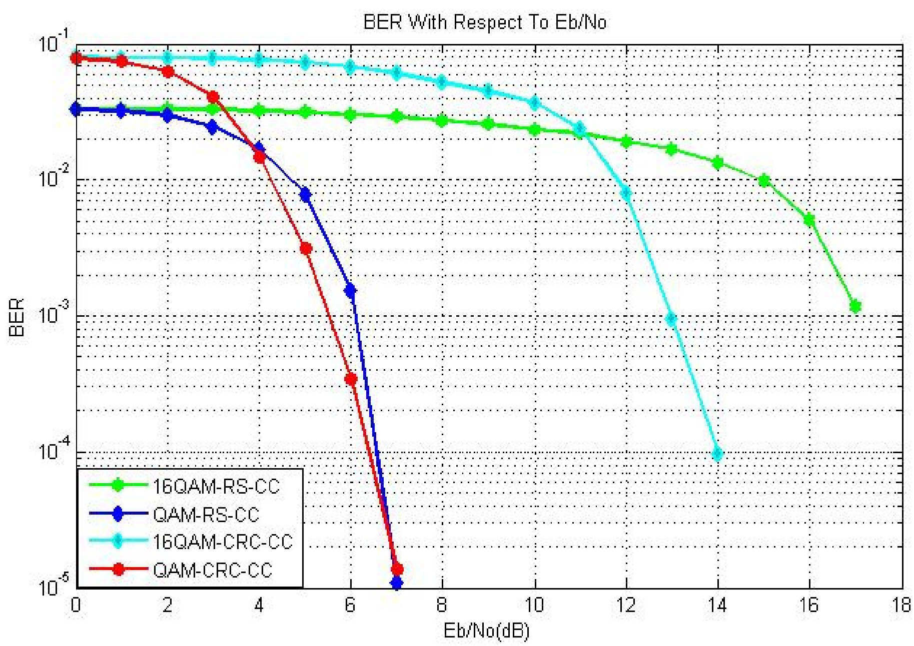

Figure 2. BER of WiMAX Physical layer for different channel coding and modulation in AWGN channel.

Figure 3 shows the BER performance of WiMAX physical layer over Rayleigh channel. It is apparent that the system performance deviates due to the incorporation of multipath fading environment; system with 16QAM modulation is more influenced by the Doppler frequency shift and its performance degrades. The WiMAX system outperforms with CRC-CC code while shows worst performance with RS-CC coding under QAM modulation scheme. The BER value for CRC-CC and RS-CC concatenated coding under QAM modulation are 0.000061 and 0.001149 respectively for a typical SNR value of 10dB. The absolute BER system performance with CRC-CC code is about 12.8 dB better than RS-CC code.

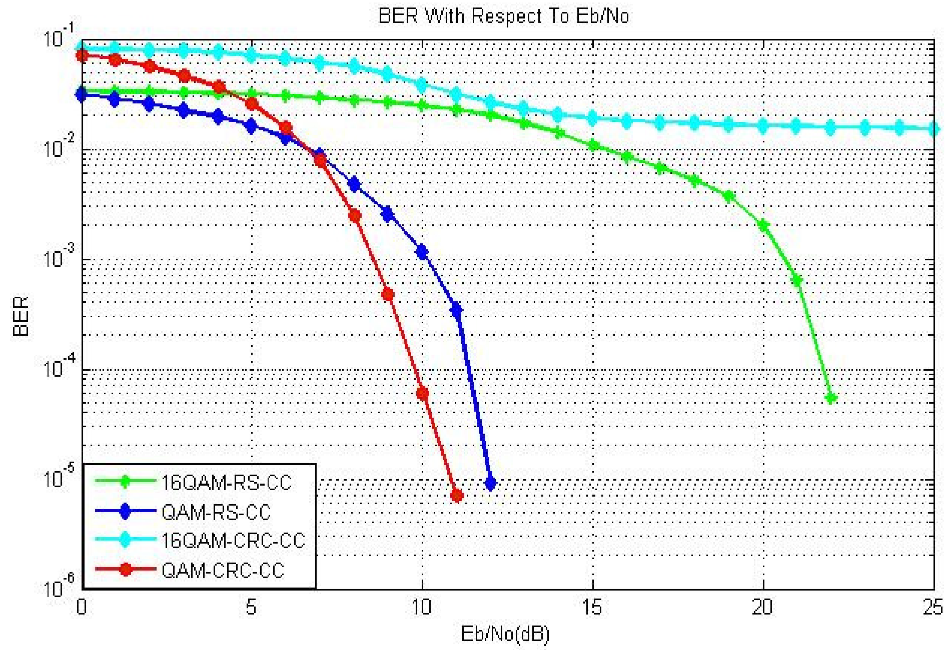

Figure 3. BER of WiMAX Physical layer for different channel coding and modulation in Rayleigh channel.

Figure 4 compares the BER performance of WiMAX physical layer over Rician channel. The system provides satisfactory performance with QAM modulation and the performance undergoes significant degradation at 16QAM modulation due to presence of multipath fading effect. For a typical SNR value of 10dB, the BER value for CRC-CC and RS-CC concatenated coding under QAM modulation are 0.000239 and 0.000885 respectively which implies that the system performance with CRC-CC coding is improved by 5.7dB than that of the system with RS-CC channel code over Rician fading channel.

From the above simulation results it is obvious that the BER performance CRC-CC coded WiMAX system with QAM modulation is much better than that of the system with RS-CC concatenated coding scheme. The flattening result of the curve decreases from RS-CC curve towards the CRC-CC curve in different channel environments. Finally, we have evaluated approximate SNR value in dB at 10^{-4} BER level for the simulated WiMAX system for different coding and modulation techniques under AWGN and multipath fading (Rayleigh and Rician) channels as shown in table-2. It can be seen that, in all channel conditions, the performance of CRC-CC coded WiMAX system with QAM modulation reaches a specific BER level at considerably lower SNR value than that of the system with RS-CC coding.

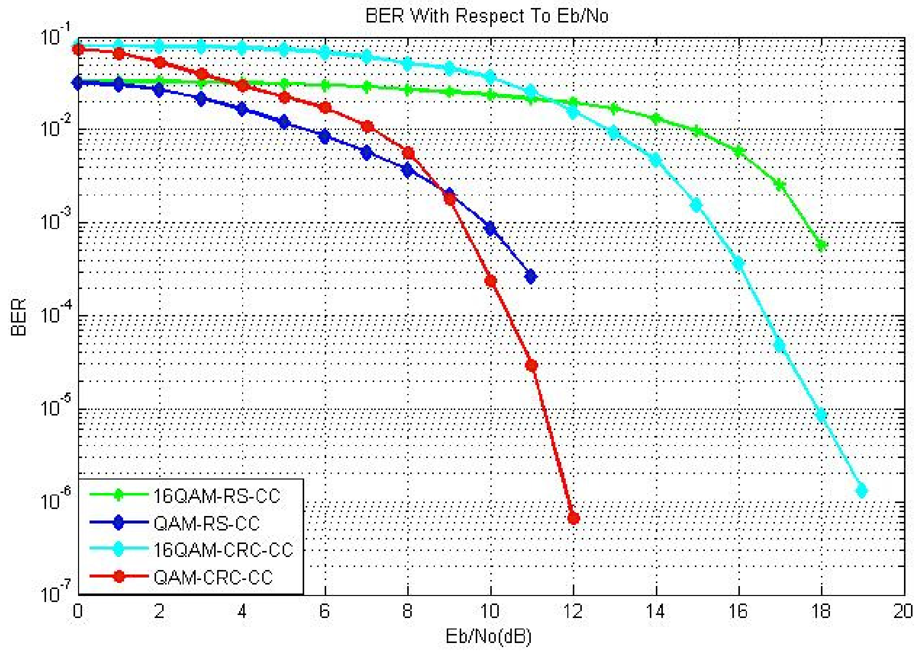

Figure 4. BER of WiMAX Physical layer for different channel coding and modulation in Rician channel.

Table 2. WiMAX Physical layer Performance for different channel coding and modulation under AWGN, Rayleigh and Rician Channels.

AWGN Channel				
Coding	RS-CC		CC-CRC	
Modulation	QAM	16QAM	QAM	16QAM
SNR in dB at BER of 10^{-4}	6.6	17	6.4	16.9
Rayleigh Channel				
Coding	RS-CC		CC-CRC	
Modulation	QAM	16QAM	QAM	16QAM
SNR in dB at BER of 10^{-4}	12	22	9.7	25
Rician Channel				
Coding	RS-CC		CC-CRC	
Modulation	QAM	16QAM	QAM	16QAM
SNR in dB at BER of 10^{-4}	11	18	10.5	16.5

6. CONCLUSIONS

In this paper, we have analyzed the bit error rate performance of WiMAX Physical layer with the implementation of different concatenated channel coding schemes under various digital modulations over realistic channel conditions. Computer simulation results demonstrate the outperformance of the concatenated CRC-CC code when compared to RS-CC code and the proposed WiMAX system achieves good error rate performance under QAM modulation technique in AWGN, Rayleigh and Rician fading channels. From the present simulation based study it can be concluded that the utilization of concatenated CRC-CC code in WiMAX wireless communication system under QAM modulation is very much effective to combat inherent interferences under the noisy and multipath fading realistic channel environments.

REFERENCES

[1] S. Sampei,“Applications of Digital Wireless Technologies to Global Wireless Communications,” Prentice Hall, 1st Edition, 1997.

[2] Mai Tran, George Zaggoulos, Andrew Nix and Angela Doufexi, “Mobile WiMAX: Performance Analysis and Comparison with Experimental Results,” 2nd IEEE International Symposium on Wireless Vehicular Communications, Calgary, Canada, 21 - 22 September 2008.

[3] J. El-Najjar, B. Jaumard, C. Assi, “Minimizing Interference in WiMax/802.16 based Mesh Networks with Centralized Sche duling,”Global Telecommunications Conference, pp.1-6 , 2008.

[4] Intel White Paper, Wi-Fi and WiMAX Solutions, “Understanding Wi-Fi and WiMAX as Metro-Access Solutions,” Intel Corporation, 2004.

[5] A. Yarali, B. Mbula, A. Tumula, “WiMAX: A Key to Bridging the Digital Divide,” IEEE Volume, pp.159-164, 2007.

[6] WiMAX Forum, “Fixed, Nomadic, Portable and Mobile Applications for 802.16-2004 and 802.16e WiMAX Networks,” November, 2005.

[7] Amalia Roca, “Implementation of a WiMAX simulator in Simulink,” Vienna, February 2007.

[8] Md. Golam Rashed, Hasnat Kabir, Sk. Enayet Ullah and Rubaiyat Yasmin,“Performance evaluation of CRC Interleaved QPSK based Wireless Communication System for Color Image Transmission,” Journal of Bangladesh Electronics Society (BES), Vol. 9, No. 1-2, pp. 151-159, December 2009.

[9] Md. Zahid Hasan, Mohammad Reaz Hossain, Md.Ashraful Islam, and Riaz Uddin Mondal, “Comparative Study of Different Guard Time Intervals to Improve the BER Performance of WiMAX Systems to Minimize the Effects of ISI and ICI under Adaptive Modulation Techniques over SUI-1 and AWGN Communication Channels,” International Journal of Computer Science and Information Security, IJCSIS, Vol. 6, No. 2, pp. 128-132, November 2009.

[10] Md. Zahid Hasan and Mohammad Reaz Hossain, “Performance Evaluation of a Concatenated FEC Scheme Based WiMAX System with Application to the Digital Image Transmission over White Guassian Noise and Fading Channels,” Asian Journal of Information Technology, Vol. 9, Issue: 2, pp.62-66, 2010.

[11] M. D. Haque, S. E. Ullah, M. M. Rahman, and M. Ahmed, “BER Performance Analysis of a Concatenated Low Density Parity Check Encoded OFDM System in AWGN and Fading Channels,” Journal of Scientific Research, JSR Publication. Vol. 2, No. 1, PP. 46-53, 2010.

[12] Muhammad Nadeem Khan, Sabir Ghauri, “The WiMAX 802.16e Physical Layer Model,” IET International Conference, pp. 117 -120, 2008.

[13] Mohhammod Azizul Hasan, “Performance Evaluation of WiMAX/IEEE 802.16 OFDM Physical Layer,” Espoo, June, 2007.

[14] Dennis Roddy, “Satellite Communcations,” Third edition, McGraw-Hill Telecom Engineering.

[15] Theodore S. Rapaport, “Wireless Communications Principles and Practice,” Prentice-Hall of India Private Limited, 2004

Authors

Md. Ashraful Islam received his Bachelor and Master degree in Information and Communication Engineering from University of Rajshahi, Bangladesh in 2006 and 2007, respectively. Now he is working as a Lecturer in the department of Information and Communication Engineering, University of Rajshahi, Bangladesh. He is also continuing research towards his MPhil degree in the same department of Information and Communication Engineering, University of Rajshahi, Bangladesh.

A. Z. M. Touhidul Islam received his Bachelor and Master degree in Applied Physics and Electronics from University of Rajshahi, Bangladesh in 1997 and 1998, respectively. He also received his PhD degree from Japan Advanced Institute of Science and Technology, Japan in 2009. Since June 2001, he has been with the faculty of the University of Rajshahi where he is currently working as Associate Professor in the department of Information and Communication Engineering. His research interests include Modeling, Simulation and Performance Analysis of Communication Systems for their Capacity and Quality of Service (QoS) enhancements.