International Journal of u- and e- Service, Science and Technology
Vol.8, No. 8 (2015), pp.323-332
http://dx.doi.org/10.14257/ijunesst.2015.8.8.33

Channel Coding-Aided Multi-Purpose Wireless Chip Modules for Throughput Enhancement

Inchul Hwang[1] and Hanho Wang[2]

[1] *Sangmyung University, Dept. of Information and Telecommunications Engineering, Cheonan, Korea*
[1] *ichwang@smu.ac.kr*
[2] *Sangmyung University, Dept. of Information and Telecommunications Engineering, Cheonan, Korea*
[2] *hhwang@smu.ac.kr*
(Corresponding Author)

Abstract

Many kinds of multi-purpose wireless communication chips exist. However, their transmission power, throughput and error correction schemes are fixed. It is hard to apply them to various wireless applications with various quality-of-service. However, bit error occurs frequently in that transmission speed, which results in corrupted digital image when we use the chip module for image transmission. Unfortunately, this chip module does not have any error correction functionality. Hence, transmission speed should be reduced for reliable wireless data transmission. In this paper, a channel coding scheme is adopted outside of the chip module. Especially, the convolutional code is adopted as an error correction code. When the channel coding is adopted, frame error probability is analyzed considering practical chip setup parameters. By using the channel coding added outside of the chip module, reliable image transmission becomes available. Using multiple chip modules and channel coding together, throughput enhancement with trusted wireless transmission can be implemented.

Keywords: *Dual-Polarization Antennas, Scheduling*

1. Introduction

There are many kinds of multi-purpose wireless communication chip modules (CCM). Their throughput is limited and transmission power is very small. Although there are many kinds of wireless applications requiring various throughputs and delay constraints, conventional communication chip modules have too limited functionalities to support that various wireless applications' quality of service (QoS) [1, 2]. Hence, in this paper, let us consider how to adapt the conventional communication chips to various wireless applications. Especially, we are focusing on reliable wireless communications where an error correction functionality is added to the conventional wireless communication chip modules [3-5].

The conventional chip modules are operated with a micro processor unit (MCU). There are several interfaces for communication between CCM and MCU. There could be transmission errors at interfaces [6]. Communication coverage of MCC is very small. Due to lack of received signal strength, bit errors could occur in wireless channels [8-9]. We do not know where errors occur. Even, we cannot modify the functionalities of MCC. Therefore, resultant errors from MCU output are our target to correct. If encoding information is shared at both a transmitter and receiver, error correction function can be added outside of MCU [4, 5].

ISSN: 2005-4246 IJUNESST

In this paper, an error correction scheme is implemented and added to MCU. Considering practical setup parameters applied to the conventional wireless communication chips, a frame error probability and application data failure probability are mathematically derived and analyzed. Based on the analysis, it is shown that service coverage and communication reliability can be improved via both theoretical and practical implementation approaches. Channel encoding requires small computing power [10]. Hence, the encoding process is performed at the transmitter MCU. However, decoding process is computationally complicated. Hence, the decoding process is implemented outside of MCU. This proposed platform is applied to wireless image transmissions. Using this platform, a digital image is successfully transmitted when the transmission speed is the maximum.

2. System Model

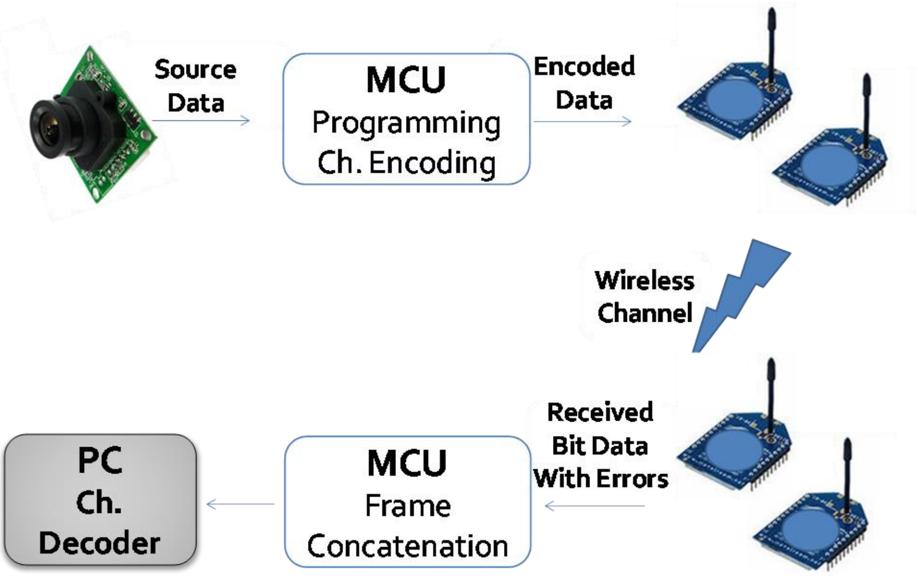

Figure 1. DPA Antenna System and Rotation Angle

System model is illustrated in Figure 1. Source data is generated by a digital camera. This case can be applied to wireless surveillance systems or drone camera systems. Source data is separated into several transmission frames, which are transmitted via CCMs. Each frame carries channel-encoded data. In this paper, a convolutional encoder with code rate 1/2 is used.

Transmitted signal might be faded and received in CCMS of a receiver with background thermal noise. In this stage, if the received signal strength is not enough, bit error occurs. After that, bit data is sent to MCU via SPI or USART interface. In the MCU of the receiver, frame concatenation is performed. The concatenated frame includes several bit errors, which results in partial image corruption. MCU can set up the transmission speed of CCMs. Usually, if the transmission speed increases, bit error rate also increases or communication available distance decreases. This system model and experimental results were partly presented in [11]

Retransmission protocol can be programmed at MCUs at the transmitter and receiver. Frames are numbered. A timer begins just after a frame transmitted. Personal computer (PC) is connected to the receiver's MCU. Computing power of the PC is strong enough to execute the decoding algorithm for the convolutional code.

3. Frame Error Rate Analysis

In order to evaluate the error performance of a wireless communication system, the received signal strength (RSS) is a most representative performance metric. Especially, signal-to-noise ratio (SNR) should be measured to evaluate the error performance statistically. RSS is basically a function of a transmission power and a path loss directly related to a propagation distance. RSS can be calculated as [12]:

$$r = p_T \cdot d^{-\alpha}, \tag{1}$$

Where r, p_T, d, and α are RSS, a transmission power, a propagation distance, and the path loss exponent, respectively. For example, in IEEE 802.15.4, the transmission power P_T is 10mW corresponding to 10dBm in 2.4 Ghz frequency band. The path loss exponent usually has values between 2.5 and 4. If there is a line-of-sight (LoS) channel between a transmitter and a receiver, the path loss exponent value might be below 3. However, the path loss exponent value increases as the carrier frequency increases or the LoS component of the channel decreases.

Next, we need to calculate the SNR. SNR is directly related to the wireless link capacity of a digital communication system according to the Shannon capacity theorem. In order to calculate the SNR, a received signal should be defined as [13]:

$$y = \sqrt{r \cdot G_p \cdot G_c} + n, \tag{2}$$

Where y, G_P, G_C, n are the received signal, the processing gain, the coding gain, and the background noise at the receiver. Using this received signal, we can calculate the post-SNR processed by the channel decoder. A direct sequence spread spectrum scheme or symbol repetition are adopted in IEEE 802.15.4. Hence, the processing gain is considered. The coding gain varies depending on what channel code and constraint length are used. From (2), the SNR can be calculated as:

$$SNR = \frac{r \cdot G_p \cdot G_c}{N}, \tag{3}$$

Where N is the channel bandwidth-considered a noise power.

From (3), we can calculate the bit error rate (BER) when the modulation scheme is given. BER is calculated for the QPSK modulation in Rayleigh fading channel as [14]:

$$BER = \frac{1}{2} \cdot \left(1 - \sqrt{\frac{SNR}{1 + SNR}}\right) \tag{4}$$

System model is illustrated in Figure 1. Source data is generated by a digital camera. This case can be applied to wireless surveillance systems or drone camera systems. Source data is separated into several transmission frames, which are transmitted via CCMs. Each frame carries channel-encoded data. In this paper, a convolutional encoder with code rate 1/2 is used.

Let us think about frame transmissions. In wireless communications, data encoded binary bits is transmitted via a transmission frame including multiple data bits. Using a multi-purpose communication chips, maximum data bits carried in a frame are a few hundred bits. When M bits take on a transmission frame, the probability that a frame is successfully transmitted without any bit error can be calculated as:

$$P_S = (1 - BER)^M \tag{5}$$

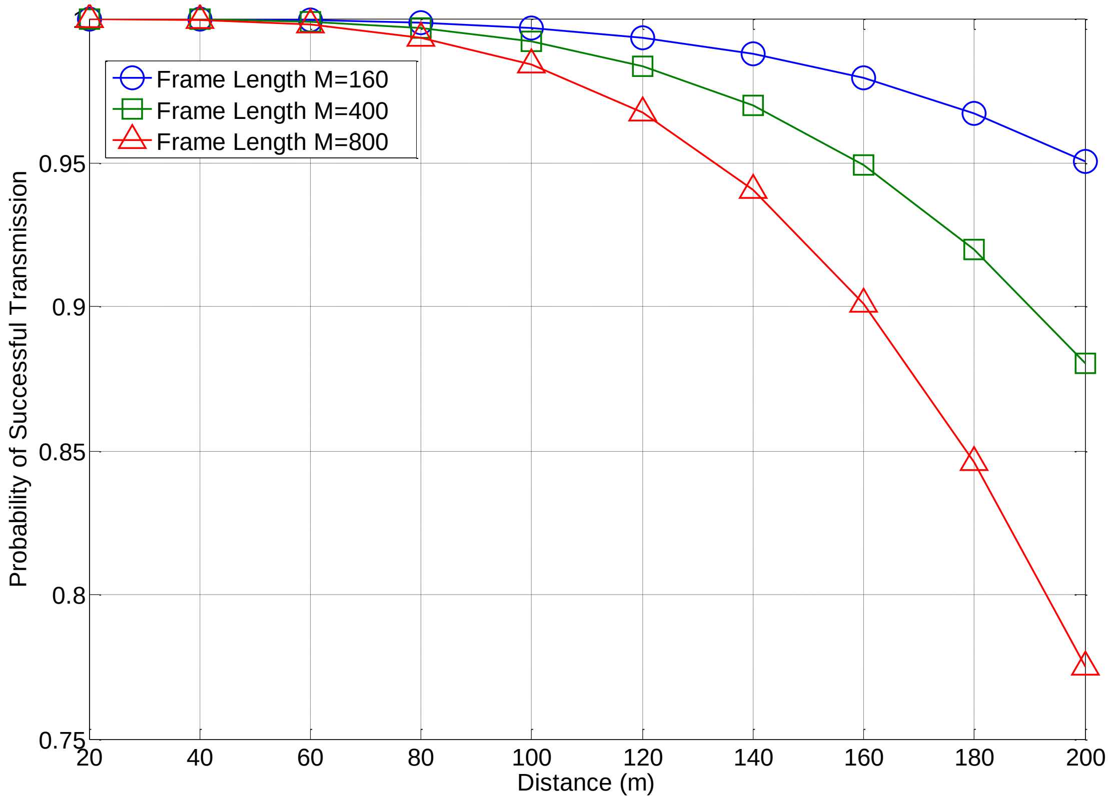

Figure 2. Probability of Successful Frame Transmission

The probability that a transmission frame is successfully transmitted in (5) is plotted in Figure 2. In this result, the path loss exponent is 4 which is generally used value when LoS channel rarely exists. Observing Figure 2, the successful transmission probability decreases as the frame length and the distance increases. As the distance increases, the path loss is getting larger, hence, received SNR decreases. The probability in (5) is a monotonically decreasing function with respect to M . Accordingly, the longer the frame length is, the more frame error occurs.

A retransmission protocol is implemented in a wireless chip if there are bit errors in a transmitted frame. The maximum number of retransmissions for a successful frame transmission is pre-determined, which is K in this paper. The probability that a successful frame transmission can be made during the limited number of retransmissions can be calculated as:

$$P_{R\_S} = 1-(1-P_S)^K \tag{6}$$

This probability can be exactly derived as the equation (6) by subtracting probability that K tries all fail and from one.

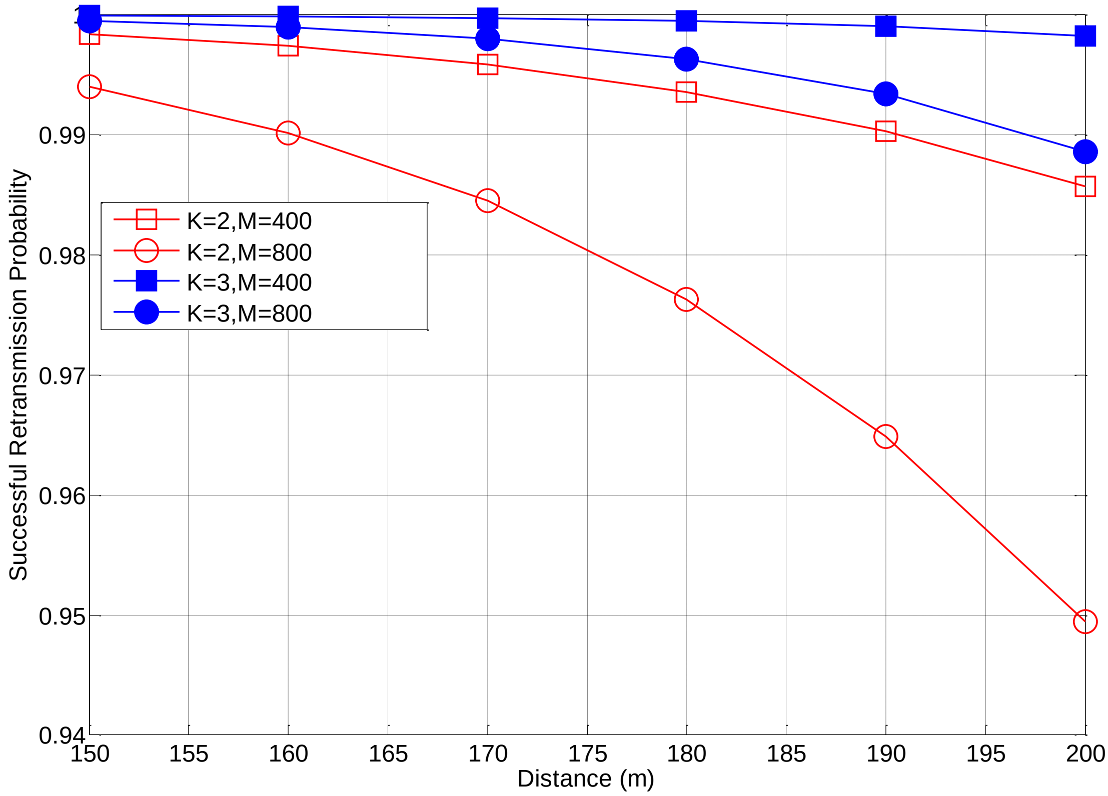

Figure 3. Successful Retransmission Probability

As we can see in Figure 3, successful transmission probability increases when the retransmission scheme is adopted. When the frame length is 400 and triple transmissions are granted for the transmission error, we can achieve 99.9% successful frame transmission even though the distance is 200 meters far. However, if only one retransmission is granted for the 800-bit frame, our wireless applications are ready to suffer from 5% of frame error when the communication distance is 200 meters. The probability in (6) reflects the successful event of only one data frame. Unfortunately, data sizes made by wireless applications might be much larger than those that one data frame can carry.

For example, let us assume a jpeg photo file with 100 kilo bytes made by a digital camera. 100 kilo bytes are 800,000 bits. If the 800-bit long frame in Figure 3 is used, 1,000 frames should be successfully transmitted to load the image without any corruption. If the total number of frames to be transmitted for an application data is L, the probability that the application data cannot1- be successfully received and loaded can be calculated as:

$$P_{A\_F} = 1 - P_{R\_S}^{L} \tag{7}$$

As seen in (7), if the application data size is larger, the application data failure probability should increase. In the following result, the 800-bit long frame size is assumed. Practically, many Zigbee chips support 100-byte long data frame in maximum. The maximum number of transmissions for a data frame is assumed to be 3 and 4. Let us observe the application data failure rate in Figure 4.

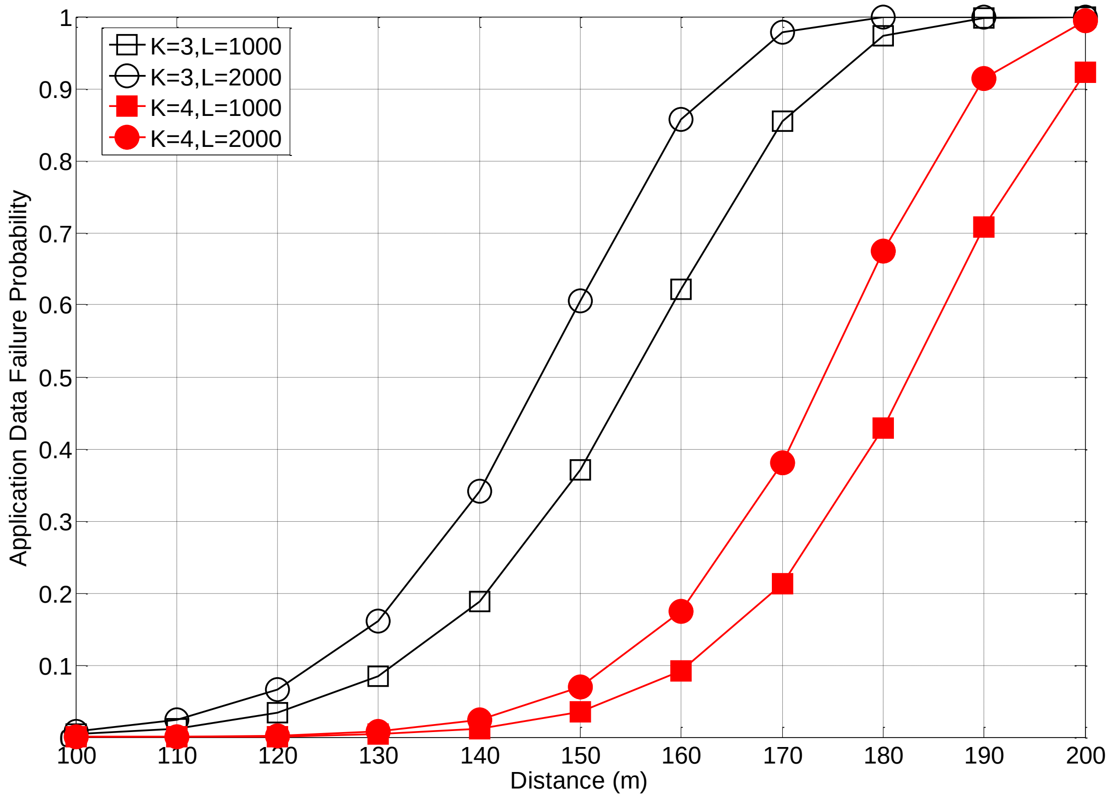

Figure 4. Application Data Failure Probability

For the case of K =3, when the communication distance is 150 meters, 38 % and 60% of jpeg image files will be corrupted for the cases of file size 100 and 200 kilo bytes, respectively. If we want 90% perfect image files received in the wireless channel, the communication distance is limited below 120 meters. The case of K =4 is also plotted. If the retransmission opportunities increase, the application data failure probability dramatically decreases. However, 4 times transmission for one successful data frame transmission is rarely supported in usual Zigbee chips. Using this chip, there is no way to expand the communication distance. If more retransmissions are granted up to three times, the communication distance expands to 150 meters. Therefore, this chip is not appropriate for large data size application requiring over 100 meters coverage.

Let us recall the equation (3). The coding gain is mainly focused. The conventional chip does not have inherent channel coding schemes for the forward error correction. Hence, micro-processor units (MCU) which has high computing power are need for both transmitter and receiver sides. We now utilize a convolutional code with shift register length C and coding rate 1/2 by adopting additional MCUs. Upper bound of the coding gain can be given as:

$$G_c \leq 0.5 \cdot (C+2) \tag{8}$$

Let us apply the coding gain in (8) to results in Figure (5). We use the convolutional code with coding rate 1/2 and shift register lengths C =3, 7, 9 which correspond coding gains 3.97, 6.99 and 7.78 dB, respectively.

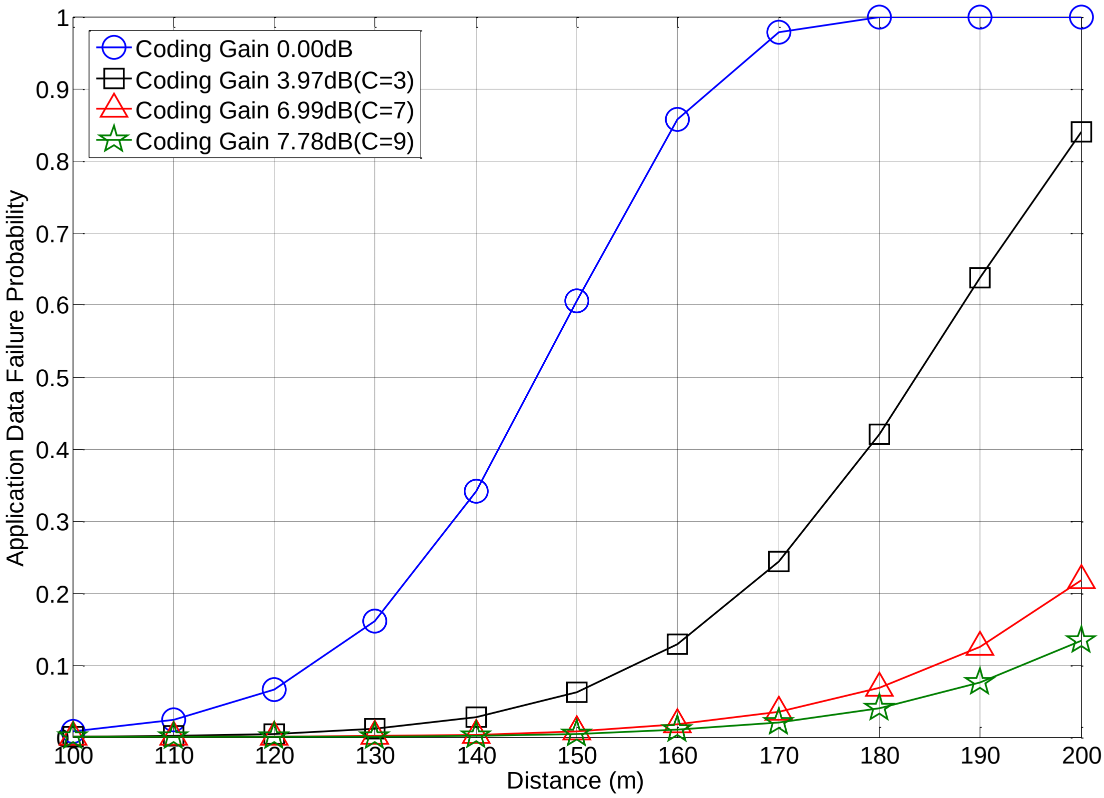

Figure 5. Application Data Failure Probability Improvement

In results in Figure 5, values of L and K are fixed at 2000 and 3, respectively. Only channel coding gains vary. Increasing the shift register length means that computational complexity increases. The coding rate is inversely proportional to the throughput or bandwidth. If the convolutional code with coding rate 1/2 is utilized, two times of bandwidth should be needed compared with the channel coding unutilized case. Although additional bandwidth and computational complexity are required, the application data failure probability is dramatically improved by adopting channel coding. Based on 10% data transmission failure, coverage is expanded from 120 to 190 meters if additional computing resource is invested. Implementing the channel coding outside the conventional communication chips, coverage, throughput and reliability can be improved.

If we want more coverage, we can select a convolutional code with coding rate 1/3. In such case, data bits increases three times. This means throughput decreases to 33%. To compensate this, we can use three communication chips simultaneously with MCU having more than 3 serial communication ports. Communication chips following the IEEE 802.15.4 standard provide more than 10 independent frequency channels. Hence, there is no technical problem to implement triple-chip-equipped wireless communication platform. This wireless communication platform is exactly what we want to propose.

4. Simulation and Results

As depicted in Figure 1, we made a two-chip-equipped platform in order to utilize a convolutional code with coding rate 1/2.

Figure 6 depicts transmitted images with or without channel coding. Wireless image transmission has researched in other works [6]. In this experiment, we use Xbee-Pro wireless communication chip module. As seen in Figure 6, there is no bit error and image corruption when the channel coding is utilized.

In this example, we use a convolution code with code rate 1/2 and constraint length 3. For the fair comparison, transmission rates for the upper and lower images are set at 56

Kbps and 112 Kbps, respectively. Considering the code rate, data rates for two images are the same practically. Although the same transmission speed in wireless channel is applied, we can get a good image without any corruption by using the channel coding

Result in Figure 6 comes from a basic wireless image transmission scenario. Extending scenarios can include multiple CCMs' transmission and reception, communication environment-aware channel code rate adaptation, communication distance expansion, and so on. Using a CCM at 112Kbps mode seems not reliable. However, two CCMs at 112Kbps mode with channel coding with code rate 1/2 let the reliable wireless transmission possible.

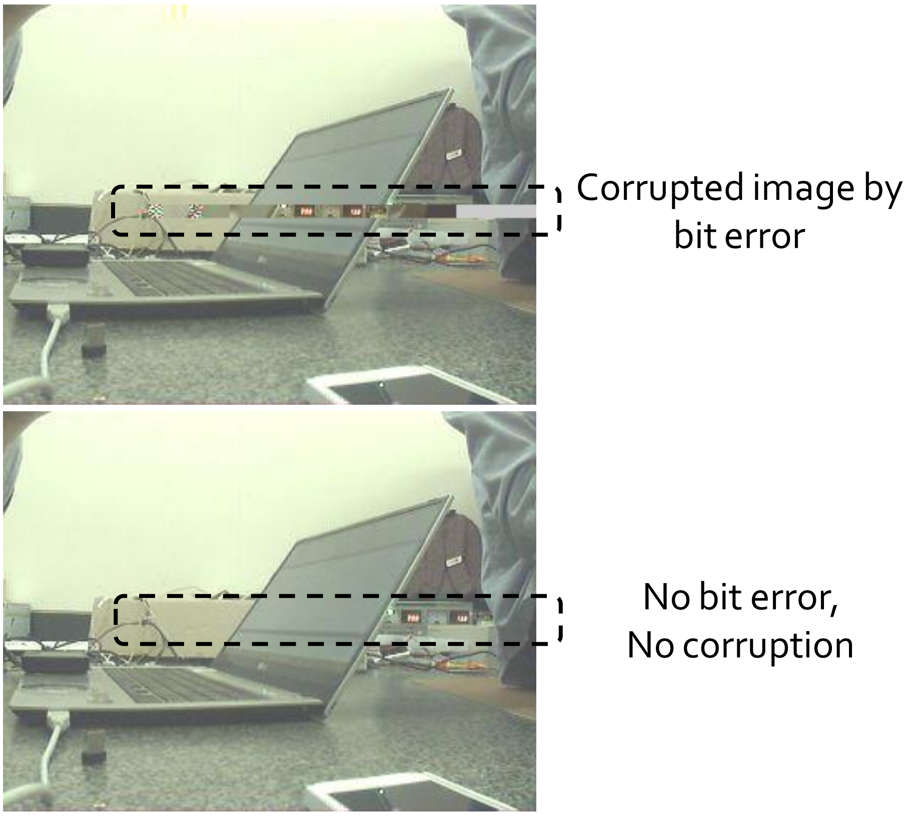

Figure 6. SINR Evaluation in a Single-Cell Scenario

5. Conclusion

Many kinds of multi-purpose wireless communication chips exist. However, their transmission power, throughput and error correction schemes are fixed. It is hard to apply them to various wireless applications with various quality-of-service. However, bit error occurs frequently in that transmission speed, which results in corrupted digital image when we use the chip module for image transmission. Unfortunately, this chip module does not have any error correction functionality. Hence, transmission speed should be reduced for reliable wireless data transmission. In this paper, a channel coding scheme was adopted outside of the chip module. Especially, the convolutional code is adopted as an error correction code. When the channel coding was adopted, frame error probability was analyzed considering practical chip setup parameters. By using the channel coding added outside of the chip module, reliable image transmission became available. Using multiple chip modules and channel coding together, throughput enhancement with trusted wireless transmission could be implemented.

Acknowledgment

This research was supported by Basic Science Research Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Education (NRF-2014R1A1A2058985)

References

[1] J. Kim, J. Lee, J. Kim and J. Yun, “M2M Service Platforms: Survey, Issues, and Enabling Technologies”, IEEE Communications Surveys & Tutorials, vol. 16, no. 1, **(2014)**, pp. 61-76.
[2] M. Hasan, E. Hossain and D. Niyato, “Random access for machine-to-machine communication in LTE-advanced networks: issues and approaches”, IEEE Communications Magazine, vol. 51, no. 6, **(2013)**, pp. 86-93.
[3] Z. Fan, R. Haines and P. Kulkarni, “M2M communications for E-health and smart grid: an industry and standard perspective”, IEEE Wireless Communications, vol. 21, no. 1, **(2014)**, pp. 62-69.
[4] Y. Zhang, R. Yu, M. Nekovee, L. Yi, S. Xie and S. Gjessing, “Cognitive Maching-to-Machine Communications: Vision and Potential for the Smart Grid”, IEEE Network, vol. 26, no. 3, **(2012)** June, pp. 6-13.
[5] H. Chang and K. Chen, “Cognitive Spectrum Sharing Economy for Heterogeneous Wireless Networks”, Proceedings of IEEE GLOBECOM, **(2011)** December 5-9, Houston, USA.
[6] C. Yu, C. Ho and C Huang, “Energy-Efficient Algorithms and Evaluations for Massive Access Management in Cellular Based Machine to Machine Communications”, Proceedings of IEEE VTC Fall, **(2011)** September 5-8, San Francisco, USA.
[7] H. Chao, Y. Chen and J. Wu, “Power Saving for Machine to Machine Communications in Cellular Networks”, Proceedings of IEEE GLOBECOM, **(2011)** December 5-9, Houston, USA.
[8] J. Matamoros and C. Anton-Haro, “Opportunistic Sampling for Random Field Estimation with M2M Capillary Networks”, European Wireless Conference, **(2011)** April 27-29, Vienna, Austria.
[9] R. Harikrishnan, “An Integrated Xbee Arduino and Differential Evolution Approach for Localization in Wireless Sensor Networks”, Procedia Computer Science, vol. 48, **(2015)**, pp. 447-453.
[10] C. Pham, “Low cost Wireless Image Sensor Networks for visual surveillance and intrusion detection applications”, IEEE on Networking, Sensing and Control, **(2015)**, pp. 376-381.
[11] I. Hwang and H. Wang, “Throughput enhancement of multipurpose wireless chip modules by suing channel coding”, Proceedings of Advanced Science and Technology Letters, **(2015)** August 19-21, Jeju, Korea.
[12] A. Giordano and A. Levesque, “Digital Communications BER Performance in AWGN and Fading”, Wiley, **(2015)**.
[13] B. Sklar, 2nd edition, “Digital Communications Fundamentals and Applications”, Prentice Hall, New Jersey, **(2001)**.
[14] H. S. Nalwa, Editor, “Magnetic Nanostructures”, American Scientific Publishers, Los Angeles, **(2003)**.

Authors

Inchul Hwang, is currently a senior student in Information and Telecommunications Engineering of Sangmyung University. He has studied microprocessor board designs and computer programming. He is currently interested in wireless communications. Since 2013, he has participated in technical projects which are dual-polarization antenna capacity analysis supported by ETRI and multi-rate and multi-hop wireless communication platform development supported by national research foundation of Korea (NRF). He is also co-working as a main programmer to build the 5th-generation cellular system level simulator with Yonsei University and SK Telecom.

Hanho Wang, He received the B.S. and Ph.D. degrees from the School of Electrical and Electronic Engineering, Yonsei University, Seoul, Korea, in 2004 and 2010, respectively. He worked in Korea

Intellectual Property Office (KIPO), Daejeon, Korea from 2010 to 2011. He is an assistant professor in Information and Telecommunications Engineering of Sangmyung University, Cheonan, Korea. His current research interests are in physical layer in wireless communication, cooperative communications and cognitive radio networks.