Graduate School of Fundamental Science and Engineering
Waseda University

博　士　論　文　概　要
Doctoral Thesis Synopsis

論　文　題　目

Studies on Evaluation of Error Correction Coding Methodologies on 5G Wireless Communication

5G 無線通信における誤り訂正符号化方式の評価に関する研究

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For new era of wireless communications technology, fifth generation (5G) has evolved for filling the requirements of foregoing wireless network technologies and providing satisfactions of new mobile users. Providing very high data rates (typically of Gbps order) and extremely low latency is significant characteristic of 5G technology. The fifth generation (5G) communication systems are required to perform significantly better than the existing generation wireless network technologies in data rate, capacity, coverage, latency, energy consumption and cost. Hence, 5G needs to achieve considerable enhancements in the areas of bandwidth, spectral, energy, and signaling efficiencies and cost per bit and need to take some challenges that cannot be accommodated even by forth generation (4G).

In fifth generation wireless network, it becomes the critical challenge to offer high-bit rate data transmission and extensive networking services with low bit error rate (BER) performance. To achieve the requirements of 5G services, Orthogonal Frequency Division Multiplexing (OFDM) is a considerable technique for high quality communications. OFDM is able to mitigate the detrimental effects of multipath fading by partitioning a wideband fading channel into flat narrowband channels. However, a major drawback of OFDM systems is their large peak to average power ratio (PAPR).

As long as emerging of new applications of fifth generation wireless technology as well as Device to Device (D2D) communications, Machine to Machine (M2M), Internet of Things (IoT), Internet of Vehicles (IoV) and so on, achieving efficient and reliable high-bit rate data transmission and mitigating performance degradation becomes a critical challenge in 5G networks. These problems are evaluated in terms of error. Between the transmitter and receiver, information losses may be occurred because of some of causes, such as attenuation, intersymbol interference (ISI), Doppler shift, multipath fading, Internal processing of symbols and so on.

Therefore, researchers have been finding the optimal solution for the above mentioned problems. Firstly, error control scheme is considered as a vital part of modern digital wireless systems, enabling reliable transmission to be achieved over noisy channels. An also a combination of high rate data transmission with forward error correction techniques becomes a critical solution for future wireless environment.

In existing researches, many channel coding schemes have been applied for mitigating performance degradation and evaluated in terms of block error rate (BLER) or bit error rate (BER). Furthermore, the candidate coding schemes are investigated for the new data transmission in the 5G standard corresponding the activities in the third generation partnership project (3GPP). Turbo, low density parity check-code (LDPC), and polar codes are considered as the candidate schemes. These are investigated in terms of obtaining suitable rates, block lengths by proper design for a fair comparison.

According to logical thinking, it is a better way to understand the facts of causes or to understand the sources or the causes. In order to achieve efficient and reliable data transmissions and mitigate performance degradation, it is very important to study these errors from different perspectives. By studying the sources of causing errors, we can gain the knowledge of error patterns in terms of burst error sequences and the statistical properties of these errors in terms of numbers and distributions that can provide insights into the behavior of 5G wireless data transmissions. Modeling the error process is one of the best ways to find the optimal data transmission in future wireless technology by saving cost and time effectively.

On the other hand, data transmission is challenging due to the occurrence of burst errors and packet losses that are caused by multipath fading in multipath transmissions. To acquire more efficient and reliable data transmissions and to mitigate transmission medium degradation in 5G networks, it is important to study the error patterns or burst error sequences that can provide insights into the behavior of 5G wireless data transmissions.

In this research, we studied on 5G standard channel coding methods and we conducted two experiments as two parts of this research over proposed coded OFDM 5G simulation frame work and two states Markov based generative error model. Firstly, we conducted the study on channel coding methods in 5G environment. And then, we proposed two states Markov based generative error model for improving performance of 5G simulation by saving execution time and cause effectively. In our proposed system, we can divide two parts, coded OFDM 5G simulation frame work and two states Markov based generative error model.

In first part of this research, we proposed coded OFDM 5G simulation frame work by implementing two 5G standard coding methods in 5GTF specification. Then, we conduct the analysis on two standard channel coding methods in multipath fading environment of 5G network. In this research, we consider LDPC and turbo code as a backward compatibility of LTE, 4G and 3G according to 5G specifications of Verizon 5G Technology Forum released test plan. This proposed simulation frame work provides two reference error sequences for error generation process. For experiment and evaluation, three modulation methods are implemented including, including QPSK, 16QAM and 64QAM.Moreover, we do the analysis the abilities of coded OFDM 5G simulation over different FFT sizes. According to our experimental results, we found that our coded OFDM in 5G network outperforms uncoded OFDM in 5G network. Moreover, Turbo coded OFDM with 5G specification achieve better performance with smaller BER than the LDPC coded Multipath OFDM in 5G network. Finally, we approve that the coded OFDM simulation have better results in both coding methods by comparing standard Monte Carlo and theatrical simulations results. That finding motivates to select Turbo codes as 5G channel coding resulting in cost savings because of backward compatibility to 3G and 4G.

In second part of this research, we proposed a two-state Markov-based 5G error generative model for modeling the different statistical characteristics of the underlying error process in the 5G network. The underlying 5G reference error sequences are obtained from our 5G wireless simulation. The binary error sequences are generated by referencing two reference error sequences and using two-state Markov model. For estimating the error model, the Baum-Welch algorithm is used. Then the error probability and run-length distribution, error gap and error burst, of the generated error sequences are compared with original error sequence. By comparing the burst or gap error statistics of the reference error sequences from the 5G wireless simulations and those of the generated error sequences from the two-state Markov error model, we show that the error behaviors of coded OFDM 5G simulations can be adequately modeled by using the two-state Markov error model. Finally, we can approve that proposed two-state Markov-based generative error model have the accurate estimated channel model and generate exact error sequences that is mostly symmetric with original sequences by comparing theoretical Gilbert Elliot model. Our proposed two-state Markov-based generative error model can help to provide a more thorough understanding of the error process in 5G wireless communications and to evaluate the error control strategies with less computational complexity and shorter simulation times.

The contributions of this research are;

Firstly, analysis simulation framework for coding methods in 5G environments was proposed. And then, we do analysis on proposed model for difference error patterns over three different kinds of modulation methods, including QPSK, 16QAM and 64QAM. As main contribution of this research two state Markov based error generative model was proposed which can call two reference error model, by using two different error sequences form different coding schemes in 5G environment.

As an additional contribution, we do studying the error patterns and the statistical characteristics of burst error sequences that can provide insights into the behavior of 5G wireless data transmissions and model of the underlying error process in the 5G network. Finally, we proposed a robust generative error models aim to produce any error sequences by using only two reference error sequences obtained from a reference transmission system which include two different coding methods, LDPC and Turbo in different multipath scenario.

We aim to overcome the implementation difficulty of channel coding methods in OFDM frame work by conforming 5G specifications. And then we consider cost savings because of backward compatibility to 3G and 4G. We aim to study the statistical characteristics of the underlying error process in the 5G network. Furthermore, we desire to assist the finding the optimal solution for reliable and effective high bit data transmission, to provide a more thorough understanding of the error process in 5G wireless communications and to evaluate the error control strategies with less computational complexity and shorter simulation times.

早稲田大学　博士（工学）　学位申請　研究業績書

(List of research achievements for application of doctorate (Dr. of Engineering), Waseda University)

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Articles in Refereed Journals	○ [1] Modeling and Analysis of Error Process in 5G Wireless Communication Using Two-State Markov Chain, IEEE Access, 10.1109/ACCESS.2019.2892051, Vol.7, Jan 11 2019, **M. San Hlaing**, Keping YU and T.sato, [2] Overload Pattern Classification for Server Overload Detection, International Journal of Information & Network Security (IJINS), Vol.2, No.3, (ISSN: 2089-3299), June 2013, **M. San Hlaing**. [3] Data Center Resource Demand Prediction, Internal Journal of Information Engineering Research Institute IERI, lecture Notes in Information Technology (ISSN:2070-(1918)), December 2013, **M. San Hlaing** and Thandar Thein.
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