Energy efficient operation method of iterative channel decoder in wireless communication systems

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***Abstract*— In general, in a wireless communication system, iterative channel decoding such as an LDPC or turbo decoder is performed to improve performance according to a change in a wireless channel. If decoding is performed more iteratively, performance increases, but energy consumption also increases. This paper is about a method for operating Iteration (ITER) of channel decoding combined with AMC (Adaptive Modulation and Coding) technology in a receiver of wireless communication system in an energy-efficient manner.**

Keywords*— *Iterative Decoding, AMC, 5GNR

I. INTRODUCTION

When performing high-speed wireless communication for long-term special missions using unmanned drones, energy-efficient wireless communication technology is very important to reduce drone battery consumption[1]. And in this regard, in a wireless communication system, AMC (Adaptive Modulation and Coding) technology can be used in a way that properly combines a modulation method and a code rate of channel coding according to a change in a wireless channel[2]. In addition, iterative decoders such as LDPC (Low Density Parity Check Code) decoder and turbo decoder with excellent performance can be used to perform channel decoding according to channel change[3]. In general, when iterative decoding is performed, as the number of iterative decoding (ITER) increases, performance improves, but energy consumption also increases. Basically, the maximum number of ITER is applied as a fixed value to all AMC combinations of the receiver to achieve the maximum output data rate from the implementation point of view. However, when the number of decoding iterations is applied as a fixed value, energy consumption may increase because an excessive number of decoding iterations may be performed regardless of channel quality within the same AMC combination. Meanwhile, in the iterative decoding method, there is a method to reduce power consumption by performing early termination[4]. However, since the timing of early termination cannot be known with certainty, this method requires a complex structure from the implementation point of view, which increases complexity. Therefore, this paper is about a method of additionally applying ITER by further subdividing the existing AMC combination according to the quality of the received signal when the iterative decoder is operated in the receiver of the wireless communication system. In addition, this method has an effect of energy-efficiently performing channel decoding while satisfying target performance.

II. FRAME STRUCTURES AND SYSTEM PARAMETERS

First, the frame configuration is shown in Fig. 1. One frame consists of 10 subframes. One midframe consists of 2 subframes, one subframe consists of 7 slots, and one slot consists of 14 OFDM symbols. In addition, only the first slot in a frame has a control and data channels, and only data channels exist in the remaining slots.

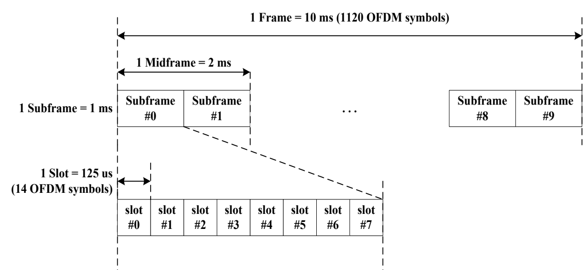

Fig. 1. Frame structure

Basic system parameters are shown in TABLE I. And CP (Cyclic Prefix) of 14 OFDM symbols in each slot occupies 0.29 usec. Modulation orders used for AMC combination are QPSK (Quadrature Phase Shift Keying), 16QAM (Quadrature Amplitude Modulation) and 64QAM, and the method used for channel encoding and decoding is LDPC.

TABLE I. SYSTEM PARAMETSERS

Parameters	Values
System bandwidth (MHz)	400
Frame duration (msec)	10
Sub-frame duration (msec)	1
Slot duration (msec)	0.125
FFT size	4096
CP length	288
Number of OFDM symbols per slot	14
Subcarrier spacing (KHz)	120
Channel encoder/decoder	LDPC
LDPC decoder iteration number (ITER)	4 ~8

III. THE PROPOSED METHOD

The method proposed in this paper is shown in Fig. 2. It is an energy-efficient AMC method combined with ITER. As shown in Fig. 2, the proposed method is described in the following order. First, after measuring CQI (Channel Quality Information) in DCB (Demodulator & Channel Decoder Block) of Rx, the measured value is transferred to MIDB (MCS & ITER Decision Block). And MIDB determines MCS and ITER using the delivered CQI. Afterwards, the MCS is transmitted to Tx to generate a transmission signal, and MCS and ITER are transmitted to DCB and used for demodulation and channel decoding.

In summary, in the conventional method, the receiver uses only the MCS in the DCB to satisfy the target performance using the CQI measured in the DCB, but in the method proposed in this paper, the DCB additionally uses ITER as well as the MCS.

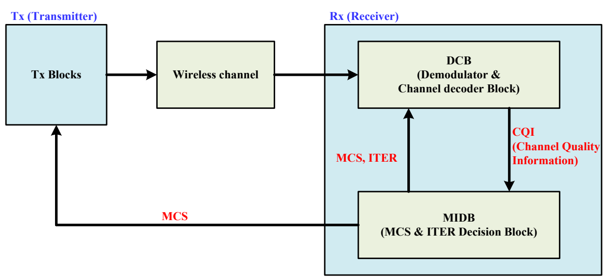

Fig. 2. Energy-efficient AMC method combined with iterative number of decoding (ITER)

IV. SIMULATION ENVIRONMENTS AND RESULTS

A. Simulation Environments

Fig. 3 shows the simulation block diagram of this paper. First, in the Data Generation block, it is a block that randomly generates transmission data in unit of slot. As shown in Table II, the MCS setting is a block that sets the modulation method and code rate used in simulation. The LDPC Encoder is a block that encodes in the LDPC standard supported by 5G-NR[5]. The Modulator is a block that performs modulation with QPSK, 16QAM and 64QAM. The IFFT is an Inverse Fourier Transform block that converts a signal in the frequency domain to a signal in the time domain. The AWGN is a block that adds Additive White Gaussian Noise to the transmission signal. And the FFT of the receiver is a block that converts a time domain signal into a frequency domain signal. The demodulator is a block that performs equalization after performing channel estimation and demodulation suitable for QPSK, 16QAM and 64QAM. The LDPC decoder is a block that performs the LDPC decoding function corresponding to the LDPC encoder of the transmitter. The CRC check is a block that determines whether there is an error through CRC checking of decoding data. Finally, in the BLER calculation block, the Block Error Rate is calculated to extract the simulation performance.

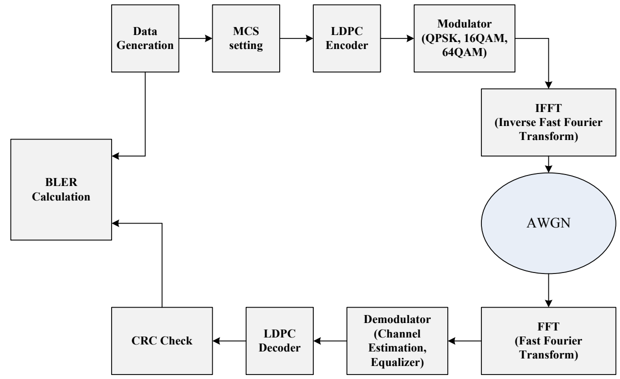

Fig. 3. Simulation Block Diagram

TABLE II. MCS SETTING

MCS (Modulation and Coding Set)	Setting Parameters
MCS0 (MCS=0)	Modulation order = QPSK Code rate = 251/1024
MCS1 (MCS=1)	Modulation order = QPSK Code rate = 526/1024
MCS2 (MCS=2)	Modulation order = 16QAM Code rate = 434/1024
MCS3 (MCS=3)	Modulation order = 16QAM Code rate = 616/1024
MCS4 (MCS=4)	Modulation order = 64QAM Code rate = 466/1024
MCS5 (MCS=5)	Modulation order = 64QAM Code rate = 772/1024

B. Simulation Results

As shown in Fig. 4, Target-BLER has the value of BLER less than 0.01. The main input parameters are SNR (Signal to Noise Ratio), ITER (4~8) and MCS (2~5). The simulation results are divided into cases of MCS4/MCS5 and MCS2/MCS3.

First, Fig. 4 shows the BLER performance results while the ITER changes from 4 to 8 in the range of MCS4 and MCS5.

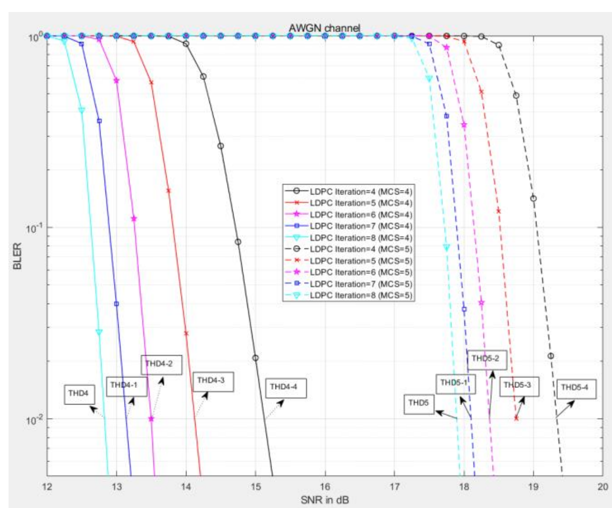

Fig. 4. Simulation Result (MCS4/MCS5)

Threshold values THD4-4, THD4-5, THD4-6, THD4-7 and THD4-8 are the SNR values at the point where the BLER performance results and Target-BLER(0.01) meet when each ITER is 4 to 8 in MCS4. And THD5-4, THD5-5, THD5-6, THD5-7, and THD5-8 are the SNR values at the point where the BLER performance results and Target-BLER = 0.01 meet when each ITER is 4 to 8 in MCS5. These values from simulation results are the criteria for judging MCS and ITER. If the energy-efficient AMC operation is explained based on the block diagram in Fig. 2 using the performance results in Fig. 4, First, after measuring SNR (CQI) in DCB of Rx, it is transmitted to MIDB, and MIDB uses the transferred SNR to determine MCS and ITER as in TABLE III.

The simulation results are explained in terms of energy efficiency as follows. In Fig. 4, in the conventional AMC method, if the SNR value measured at the receiver is 15dB, This value is in the range of THD4<SNR<THD5 at BLER value is 0.01, AMC operates with MCS4 (ITER=8). However, when using the method proposed in this paper, the received SNR (15dB) is in the range of THD4-3<SNR<THD4-4, and since it operates with MCS4-3 (ITER=5), energy consumption in the receiver can be reduced.

TABLE III. MCS & ITER DECISION (MCS4/MCS5)

Measured SNR (CQI)	Determined MCS/ITER
THD4-8 < SNR < THD4-7	MCS=4, ITER=8
THD4-7 < SNR < THD4-6	MCS=4, ITER=7
THD4-6 < SNR < THD4-5	MCS=4, ITER=6
THD4-5 < SNR < THD4-4	MCS=4, ITER=5
THD4-4 < SNR < THD4-8	MCS=4, ITER=4
THD5-8 < SNR < THD4-7	MCS=5, ITER=8
THD5-7 < SNR < THD4-6	MCS=5, ITER=7
THD5-6 < SNR < THD4-5	MCS=5, ITER=6
THD5-5 < SNR < THD4-4	MCS=5, ITER=5
THD5-4 < SNR	MCS=5, ITER=4

Simulation performance results and MCS/ITER DECISION process in the case of MCS2 and MCS3 are shown in Fig. 5 and TABLE IV. Threshold values THD2-4, THD2-5, THD2-6, THD2-7 and THD2-8 are the SNR values at the point where the BLER performance results and Target-BLER(0.01) meet when each ITER is 4 to 8 in MCS2. And THD3-4, THD3-5, THD3-6, THD3-7, and THD3-8 are the SNR values at the point where the BLER performance results and Target-BLER(=0.01) meet when each ITER is 4 to 8 in MCS3. These values from simulation results are also the criteria for judging MCS and ITER in MCS2 and MCS3.

V. CONCLUSIONS

Conventional AMC operation uses only fixed-value ITER in MCS combinations. In this paper, when operating channel decoding in the iterative decoding method in the receiver of a wireless communication system, energy consumption can be reduced by further subdividing the conventional AMC combination interval and selecting and using ITER suitable for the target performance. Additionally, this method has the advantage of being implemented in the receiver regardless of standards related to AMC operation.

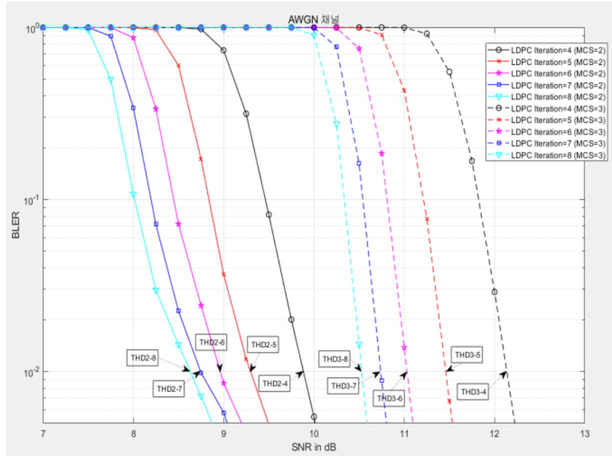

Fig. 5. Simulation Result (MCS2/MCS3)

TABLE IV. MCS & ITER DECISION (MCS2/MCS3)

Measured SNR (CQI)	Determined MCS/ITER
THD2-8 < SNR < THD2-7	MCS=2, ITER=8
THD2-7 < SNR < THD2-6	MCS=2, ITER=7
THD2-6 < SNR < THD2-5	MCS=2, ITER=6
THD2-5 < SNR < THD2-4	MCS=2, ITER=5
THD2-4 < SNR < THD3-8	MCS=2, ITER=4
THD3-8 < SNR < THD3-7	MCS=3, ITER=8
THD3-7 < SNR < THD3-6	MCS=3, ITER=7
THD3-6 < SNR < THD3-5	MCS=3, ITER=6
THD3-5 < SNR < THD3-4	MCS=3, ITER=5
THD3-4 < SNR	MCS=3, ITER=4

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