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Wireless Transmission System for the Improved Reliability in the Flying Ad-hoc Network

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ABSTRACT
Unmanned aerial vehicle (UAV) has unlimited availability not only in war but in various fields such as reconnaissance, observation, exploration. The wireless communication system between UAVs is very important and is known as flying ad-hoc network (FANET). The reason is that the FANET for UAV transfers data such as the information on mission accomplishment, collision prevention, etc. Therefore, the FANETs require the robust and spectral efficient communication scheme in the fading channel. Due to the high-mobility of the UAVs, these channels are very dynamic and time varying channel. In a dynamic channel environment, the adaptive modulation and coding (AMC) scheme is necessary to provide a reliable communication. This paper provides the improved wireless communication scheme applied with the AMC scheme. The proposed scheme uses the modulation and coding according to the channel state information (CSI) in the FANETs. The receiver obtains the CSI by using the channel estimation and transmits the feedback information to the transmitter. And then, the transmitter confirms the channel conditions via the CSI and adaptively uses the modulation scheme and code rate according to the channel conditions. Because the proposed scheme provides the reliable wireless communication, it does not require unnecessary re-transmission.
Keywords: AMC, channel state information, flying-ad-hoc network, 802.11p

I. INTRODUCTION

Recently, the development of the UAV has made enormous progress thanks to a rising demand, not only in military applications, but especially thanks to new civilian applications, both scientific and commercial. The UAV communication system can be classified into communication between the control center and the UAV, communication between the UAVs, communication between the UAV and the unmanned ground vehicle (UGV), etc.
Figure 1 shows the cases of the wireless communication systems. Case 1 is communication between the control center and the UAV. When the control center transfers the data such as velocity, attitude, position etc., this communication is used. Case 2 is communication between the UAVs. Case 3 is communication between the UAV and the UGV. Case 2 and case 3 are used for the information exchange such as the information on mission accomplishment, collision prevention, etc. between UAV and UGV.

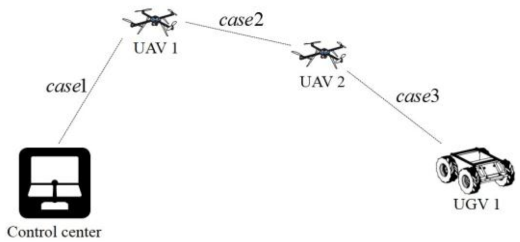

Fig 1: Cases of the wireless communication Systems

In the FANET, the communication between UAVs undergoes the serious performance degradation due to the high-mobility of the UAVs. Additionally, the communication between UAVs requires the wide coverage of the wireless communication. In the FANET, IEEE 802.11p is considered as a communication method between UAVs. IEEE 802.11p can support the communication in a high-mobility environment and the wide coverage of the wireless communication. The physical layer is originally adopted from IEEE 802.11a standard. Because IEEE 802.11a is the standard for stationary indoor environments, IEEE 802.11p has

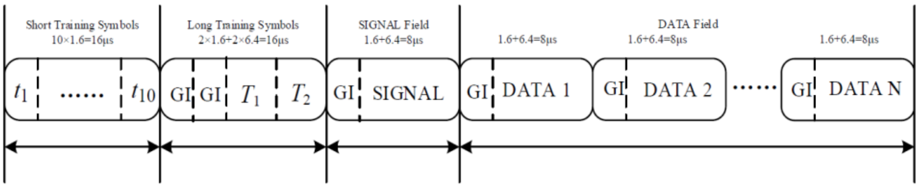

Fig 2: 802.11p packet preamble structure

Table 1: Comparision of physical layer parameters of IEEE 802.11a and IEEE 802.11p

Parameters	**IEEE 802.11a**	**IEEE 802.11p**
Bit rate (Mbps)	6, 9, 12, 18, 24, 36, 48, 54	3, 4.5, 6, 9, 12, 18, 24, 27
Modulation mode	BPSK, QPSK, 16QAM, 64QAM	BPSK, QPSK, 16QAM, 64QAM
Code rate	1/2, 2/3, 3/4	1/2, 2/3, 3/4
Number of subcarriers	52	52
Symbol duration	4 μm	8 μm
Guard time	0.8 μm	1.6 μm
FFT period	3.2 μm	6.4 μm
Preamble duration	16 μm	32 μm
Subcarrier spacing	0.3125 MHz	0.15625 MHz

several issues in high-mobility, fast time varying wireless communication environments. Because the FANET has very dynamic channel, AMC scheme is necessary to provide a reliable communication**.** The AMC scheme is one of the solutions that solve the performance degradation due to the fading channel effect.

This paper is organized as follows. The section 2 explains the physical layer of IEEE 802.11p standard for FANET communication. Next, the section 3 explains the AMC scheme for FANET communication. The section 4 explains the proposed scheme in detail. In the section 5, the simulation results are explained. Finally, the section 6 is the conclusion.

II. IEEE 802.11P FOR FANET

The IEEE 802.11p physical layer is based on orthogonal frequency division multiplexing (OFDM) which is a widely implemented wireless technique to improve spectrum efficiency and mitigate the effect of multipath channel fading by transmitting parallel data streams on a number of orthogonal subcarriers [4][5]. The preamble includes the short training symbols and the long training symbols. The short training symbols are used for coarse synchronization and the long training symbols are used for fine synchronization and channel estimation. The SIGNAL field conveys information about the type of modulation, the coding rate, etc. The DATA field is mainly consist of the transmitted data.

Table 1 shows the comparison of the parameters of IEEE 802.11a and IEEE 802.11p. IEEE 802.11p physical layer uses the 64 OFDM subcarriers. 48 OFDM subcarriers of 64 OFDM subcarriers are used as data subcarriers. 4 OFDM subcarriers are used as pilot subcarriers. The remaining OFDM subcarriers are used as virtual subcarriers. IEEE 802.11p uses the half of bandwidth used by IEEE 802.11a. The symbol period of IEEE 802.11p is twice the symbol period of IEEE 802.11a. Therefore, the period of the guard interval (GI) is extended. The longer GI period minigates the large delay spread of the channel and offers increased robustness for outdoor operation.

III. ADAPTIVE MODULATION AND CODING FOR FANET COMMUNICATION

The high modulation schemes such as 16-QAM, 64-QAM provide a high data rate in order to handle the large amounts of data. However, the high modulation scheme must have good channel

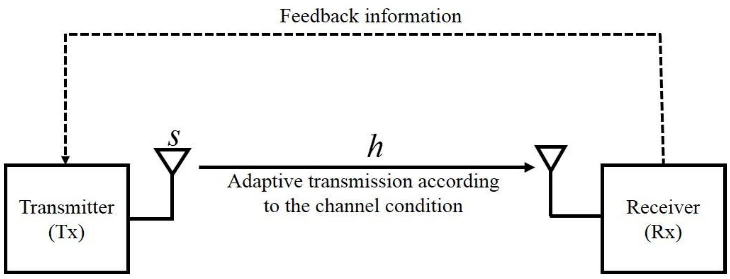

Fig 3: System model of the AMC scheme

Table 2: Transmission types

Transmission type	Modulation scheme	Code rate	Data rate (Mbps)
1	BPSK	1/2	3
2	BPSK	3/4	4.5
3	QPSK	1/2	6
4	QPSK	3/4	9
5	16-QAM	1/2	12
6	16-QAM	3/4	18
7	64-QAM	2/3	24
8	64-QAM	3/4	27

conditions in order to provide a reliable wireless communication. On the other hand, the low modulation schemes such as BPSK and QPSK provide a high reliability, but cannot provide a high data rate. The low modulation schemes can provide a reliable wireless communication in poor channel conditions. The AMC scheme uses adaptively the code rate of the channel coding and modulation according to channel conditions. Therefore, the AMC scheme is one of the solutions that solve the performance degradation due to the fading channel effect. The AMC scheme provides more flexible reliability and throughput than existing schemes [2]. Figure 3 shows the system model of the AMC scheme. In the AMC scheme, the receiver should exactly estimate the channel condition and transmit the feedback information to the transmitter. The channel conditions can be determined by using the signal to noise ratio (SNR) of the received signal [3].

IV. PROPOSED SCHEME

This section explains the proposed scheme in detail. The proposed scheme uses the AMC scheme in order to provide the flexible performance in the FANET. Because the FANET has the very dynamic channel, the AMC scheme is necessary to provide a reliable communication.

IEEE 802.11p is considered as a communication method between UAVs. The conventional scheme cannot provide the appropriate performance of the systems according to the channel conditions. Because the conventional scheme cannot provide the reliability, it should use the unnecessary re-transmission in the poor channel condition. On the other hand, the proposed scheme that uses the AMC scheme does not use the unnecessary re-transmission. Table 2 shows the transmission types of the proposed scheme. Because FANET generally has high-mobility of the UAV, it is a time-varying channel. If the UAV does not have high-mobility, the FANET is time invariant channel. The time invariant channel has better channel condition than time varying channel. Because the proposed scheme should provide the reliable communication, the target data rate of the proposed scheme assumes 10Mbps in the time varying channel. Therefore, transmission type 5 is used in the best channel condition and transmission type 1 is used in the worst channel condition. All transmission type can be used in the time invariant channel.

The FANET is divided into three cases. Figure 4 shows the cases of the FANET. All cases are the time varying channel. Case 1 means the condition that the distance between UAVs is close. Case 1 has the line of sight (LOS). If the LOS is present, the system can obtain the high SNR. This case has good channel condition. Therefore, the proposed scheme uses the transmission type 5. Case 2 means condition that the distance between UAVs is far. However, case 2 has the LOS. Therefore, the proposed scheme uses the transmission type 1 to 4.

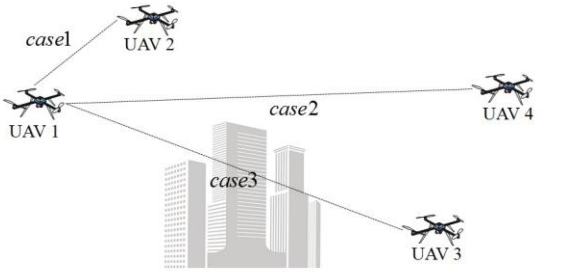

Fig 4: Various cases of the FANET

Because the case 2 has not best channel condition, it cannot use the transmission type 5. Case 3 means condition that the distance between UAVs is far. Additionally, this case does not have LOS. This channel has the worst channel condition. Therefore, the proposed scheme uses the transmission type 1.

In the proposed scheme, the steps of the system operation are as follows. First, the transmitter determines threshold in consideration of the performance that the system requires. Second, the receiver estimates the channel condition and transmits the feedback information to the transmitter. The transmitter can know the channel condition through the feedback information. There are many methods to determine the condition of the channel. The proposed scheme determines the channel condition according to the SNR of the received signal. Third, the transmitter obtains the channel condition through the feedback information. Furth, the transmitter selects the modulation scheme and the code rate according to the threshold and the channel condition.

V. SIMULATION RESULTS

This section explains the simulation results of the proposed scheme. Table 2 is the parameters of the simulation [6]. This simulation environment is the time varying channel.

Table 2: Simulation parameters of is the time varying channel

Tap power (dB)	0, -10, -17.8, -21.1, -26.3
Delay value (ns)	0, 100, 200, 300, 400
Fading Doppler(Hz)	284, 871, 166, 908, 723

This simulation has the multi-path channel. Tap power means the reduction of the transmission power. Delay value means the time delay of the received signals. Fading Doppler means the value of Doppler frequency induced by high-mobility. Figure 5 shows the BER of the proposed scheme in time varying channel. The proposed scheme can adaptively use the transmission. Figure 6 shows the throughput of the proposed scheme in time varying channel. Figure 5 and Figure 6 show that the proposed scheme provides the high data rate according to the SNR.

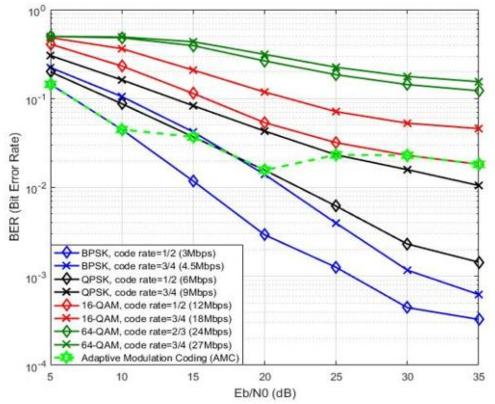

Fig 5: BER of the proposed scheme in time varying channel

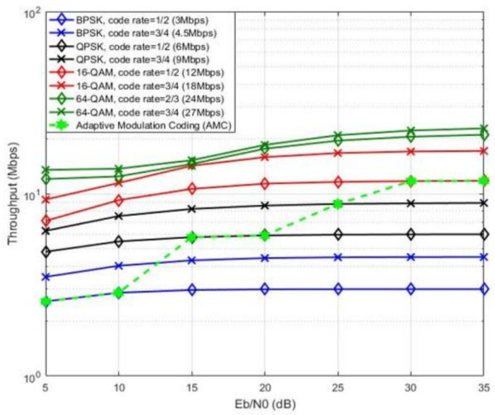

Fig 6: Throughput of the proposed scheme in time varying channel

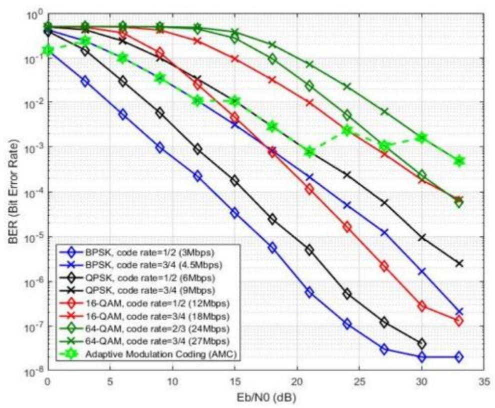

Fig 7: BER of the proposed scheme in time invariant channel

Figure 7 shows the BER of the proposed scheme in time invariant channel. The time invariant channel has better channel condition than time varying channel. Therefore, all transmission type can be used in the proposed scheme. Thus, the transmission type 1 is used in the worst channel condition and the transmission type 8 is used in the best channel condition.

VI. CONCLUSION

The proposed scheme uses the modulation and coding according to the CSI. The proposed scheme can provide the appropriate performance of the FANET. Because the proposed scheme provides the appropriate performance of the systems according to the channel conditions, it can be usefully used in the dynamic channel environment. The simulation results show that the proposed scheme can provide the appropriate performance according to the channel condition.

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