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Performance Evaluation of AMC in Clustered OFDM System

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ABSTRACT

Adaptive modulation and coding (AMC), which has a number of variation levels in accordance with the fading channel variation, is a promising technique for communication systems. In this paper, we present an AMC method using the cluster in OFDM system for bandwidth efficiency and performance improvement. The AMC schemes applied into each cluster or some clusters are determined by the minimum or the average SNR value among all the subcarriers within the corresponding cluster. It is important to find the optimal information on cluster because AMC performance can be varied according to the number and position of cluster. It is shown by computer simulation that the AMC method outperforms the fixed modulation in terms of bandwidth efficiency and its performance can be determined by the position and number of clusters.

Keywords: Adaptive modulation and coding, Cluster, OFDM

1. INTRODUCTION

There has been a great deal of demands for multimedia communication in wireless personal communication systems. In order to realize such wireless multimedia communications, it is indispensable to achieve high-bit-rate transmission by employing higher modulation level or higher symbol rate transmission. Orthogonal Frequency Division Multiplexing (OFDM) technique has received considerable attention especially in the field of wired and wireless communication systems for its efficient usage of frequency bandwidth and robustness to frequency selective fading. Although the OFDM technique can provide better bit error rate (BER) performance under frequency selective fading as compared to the conventional single carrier transmission technique, the instantaneous BER performance for each OFDM subcarrier will be fluctuated over a wide range according to the fading condition of each subcarrier. In the conventional OFDM system, the lowest order modulation scheme has to be employed for all subcarriers so as to keep the overall objective BER performance. This is the problem encountered in realizing the higher data rate systems under multi-path fading environments[1].

OFDM system in conjunction with adaptive modulation (AM) technique is well known as one of the methods to solve the above problems. To improve noise and interference immunity, we use an AM technique that controls the modulation level and symbol rate according to the channel conditions[2]. In the OFDM system with AM technique, the optimum modulation scheme is assigned for each subcarrier according to its instantaneous fading characteristics. In that scheme, a number of feedback channel information bits for AM would be directly proportional to the number of subcarrier in one OFDM symbol. Therefore, the increase of AM information bits will lead to degradation of

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overall system performance and unnecessary increase of both frequency bandwidth and transmission power. To solve this problem, in this paper, we use the cluster, which combines a number of subcarriers in the frequency domain, for OFDM system.

J. Campello proposed an algorithm having the optimal performance by feedback of channel information of every subcarriers and selection of appropriate modulation method to each subcarrier[3]. However, it is impossible to feedback the channel information of every subcarrier by the limited control channel of the uplink. Therefore, in order to overcome this problem, it is efficient to feedback a number of channel information with a little information. T. Keller and L. Hanzo proposed the method which information for subcarriers is applied into a block unit so as to reduce the feedback information[4]. And R.Grunheid proposed a simple block-wise loading algorithm (SBLA), using the channel information with block unit, for HIPERLAN/2 system[5].

Within the system considered in this paper, we use the uplink feedback channel (UFCH) to send the adaptive modulation and coding (AMC) information for downlink (D/L) transmission. Using cluster concept, we can reduce the amount of AMC bits at a cost of slight decrease of channel capacity. Simulation results show how we can use the limited bits of UFCH for efficient AMC method and obtain the optimal position and number of clusters for best AMC performance. For the analysis of the presented method, we apply the same AMC scheme to the subcarriers included in a cluster or subcarriers in some cluster groups. The AMC scheme applied by each cluster or some clusters is determined by the minimum signal to noise ratio (SNR) or the average SNR value among all the subcarriers within the corresponding cluster.

The remainder of this paper is organized as follows. In Section 2, we briefly describe the system model, parameters and channels considered in this paper. Section 3 represents the AMC method for OFDM system using cluster. And Section 4 shows and analyzes the simulation performances of the presented AMC scheme by outage probability and bandwidth efficiency. Finally, in section 5, we conclude the results of this paper and present the future works.

2. SYSTEM MODEL

This section presents the system parameter, fading channel model and some frame arrangement in this paper. In a system model, user equipment (UE) checks the states of each subcarriers periodically and determines the applicable AMC level to send the feedback information to base station. Table 1 shows the system parameter and channel model used in this paper. OFDM/FDD system with 20MHz bandwidth in D/L is considered and the number of UE is 8. Cell radius is 10km and cell environment for simulation is considered as one cell. Also, path loss is assumed to have a Gaussian distribution according to distance.

The increase of AM information bits will lead to degradation of overall system performance and unnecessary increase of both frequency bandwidth and transmission power. To solve this problem, we use the cluster which represents the group of several subcarriers in the frequency domain. The subcarriers included in one cluster or subcarriers in some clusters can use the same modulation level and coding method. Using cluster concept, we can reduce the amount of AMC bits at a cost of slight decrease of channel capacity. Within the system considered in this paper, we use the UFCH to send the AMC information for D/L transmission. In the uplink frame structure, the time of of a frame, T_{frame}, is 20ms and the time for an uplink traffic packet (UTP) is 1ms. Among channels included in a UTP, the time interval of UFCH, T_{UFCH} is 0.2ms and 16 bits are assigned for this channel within a frame. Fig. 1 shows the partial frame arrangement relating to U/L frame structure.

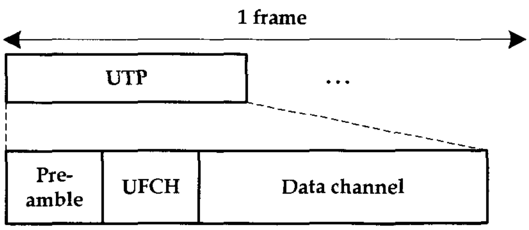

Fig. 1. Partial frame arrangement in the U/L.

3. AN ADAPTIVE MODULATION METHOD FOR OFDM SYSTEM USING CLUSTER

6 kinds of configurable cluster allocation, 1, 2, 3, 4, 6 and 12 clusters, are considered in this paper and the performances of 4, 6 and 12 clusters are especially compared by the simulation. In case the number of cluster (NoC) is 1, 2 and 3, overall used numbers of bits (NoB) are 4, 8 and 12, respectively. Because of the limited 16 bits of UFCH, it is important to arrange the clusters effectively for efficient AMC information assignment. For example, if NoC is 3 and AMC level is 16, 512 subcarriers per one cluster are used and overall bits are 12 bits ($3\times4=12$). In this case, the residual 4 (16-12) bits can be considered an inefficient bits regarding the channel structure. Above example could be also applied to NoC = 1 and 2 cases, and 1536 and 728 subcarriers per cluster in each case are assigned, respectively.

A maximum of 32 AMC levels are considered in this paper. If the 32 and 16 AMC levels are applied, then the 5 and 4 bits for AMC information are needed for a cluster or cluster group, respectively. Therefore, in order to keep the defined 16 bits of UFCH, we should group the overall clusters into maximum 4 cluster group (CG) in case of 16 AMC levels because the allocation bits per cluster is 4. And, we actually require 2 bits for each AMC process because we use the 4 AMC levels as written in Table 1. So we assume the residual bits except 2 bits among UFCH bits are null bits. For example, when 4 bits for AMC information are needed for cluster or CG and 4 CG are applied, in each CG, each 2 bits are recognized null bits. In Table 4, option 1 represents that 12 clusters are used and these clusters are grouped by 4 CG. Like the clustered OFDM system[6], we restrict the CG as a group of contiguous subcarriers. That is, only adjacent subcarriers are included in a cluster or CG as illustrated in Fig. 2.

In Table 2, the allocated bits for a CG, which is the combination of some clusters, are 5. For example, in option 1, 5 bits for the cluster group 1 (CG1), which includes the clusters 1, 2, 3 and 4, are assigned and the total 15 ($3\times5=15$)bits for option 1 are allocated. Also, cluster group 2 (CG2) and CG3 are made up of the clusters 5 - 8 and 9 - 12, respectively. In Tables 2 - 4, PoC represents the position of cluster and 1/(A, B, C) means that the representative 4 or 5 bits for AMC are transmitted by obtaining minimum or average SNR value of the cluster A, B and C, which are the elements of a CG. In these tables, a number of allocated bits per a CG increase in proportion as the number of clusters in (A, .. ,Z) becomes larger. And the performances of AMC schemes tend to be deteriorated according as the allocated bits per a CG

Table 1. System parameter and channel model.

Parameter	Value	
Bandwidth	20MHz (D/L)	
Carrier frequency	2GHz	
Number of FFT	2048	
Used subcarriers	1536	
	1344(data)	512(pilot)
No. of virtual carrier	512	
Guard interval	18.08 μs	
Symbol duration	81.92 μs	
Symbol # per packet	10	
Modulation	QPSK, 16QAM, 64QAM	
Coding	1/2 rate convolution code (k=7)	
Fading channel model		
Fading Ch. model	ITU-R channel (Ped. A & B)	
Path loss model	Category B model	

or a cluster increase. Though the frequency hopping is considered in the frame structure, the frequency hopping is not applied actually to show the performance in this paper. Because the overall performance of system can be varied by how the clusters are allocated, we should select carefully the optimal number of clusters considering the trade-off between performance and simplicity.

The AMC scheme applied by each cluster or some clusters is decided by the minimum signal to noise ratio (SNR) or the average SNR value among all the subcarriers within the corresponding cluster. When we use the minimum SNR value, we compare the SNR value of each subcarrier in a cluster or each CG and the final minimum SNR value are applied into the rest of a cluster or a CG. For example, in Fig. 2 (a), the minimum SNR value of CG1 is obtained by the comparison of minimum SNR values of cluster 1 (C1), C2 and C3. And in this case, subcarriers per each cluster and a CG are 128 and 384, respectively. Similar to Fig. 2 (a), the 256 subcarriers for CG3 and CG4 are assigned in Fig. 2 (b). If the frequency hopping is not considered, Figs. 2 (a) and (c) have the same AMC performance because the 384 subcarriers are allocated for each CG. So, in this paper, we omit the simulation performance for the Fig. 2 (a). And 512 virtual carriers are used in Figs. 2 (b) and (c) as shown in Table 1.For example, in Fig. 2 (b), the 512 subcarriers are inserted between C3 and C4. In Table 3, T4O5 means the option 5 of Table 4. These options are the representative parts of the cluster positions can be considered in T4O5.

Table 2. Example of NoC, PoC and NoB. (Bits for AMC info. : 5)

Option	NoC	PoC	NoB
1	12	1/(1,2,3,4), 1/(5,6,7,8), 1/(9,10,11,12)	15
2		1/(1,2,3,4,5,6), 1/(7,8,9,10,11,12) 1/(1,2,3,4), 1/(7,8,9,10)	10
3		1/(1,2,3,4,5,6,7,8,9,10,11,12)	5
4	6	1/(1,2), 1/(3,4), 1/(5,6)	15
5		1/(1,2,3), 1/(4,5,6), 1/(1,2), 1/(4,5)	10
6		1/(1,2,3,4,5,6)	5

Table 3. 5 Cases of PoC for T4O5.

No. of Case	PoC
1	1/(1), 1/(6), 1/(2,3), 1/(4,5)
2	1/(3), 1/(4), 1/(1,2), 1/(5,6)
3	1/(1), 1/(2), 1/(3,4), 1/(5,6)
4	1/(1), 1/(4), 1/(2,3), 1/(5,6)
5	1/(5), 1/(6), 1/(1,2), 1/(3,4)

Table 4. Example of NoC, PoC and NoB. (Bits for AMC info. : 4)

Option	NoC	PoC	NoB
1	12	1/(1,2,3),1/(4,5,6),1/(7,8,9), 1/(10,11,12)	16
2		1/(1,2,3,4),1/(5,6,7,8),1/(9,10,11,12)	12
3		1/(1,2,3,4,5,6), 1/(7,8,9,10,11,12)	8
4		1/(1,2,3,4,5,6,7,8,9,10,11,12)	4
5	6	1/(1,2), 1/(3,4), (5), (6)	16
6		1/(1,2), 1/(3,4), 1/(5,6)	12
7		1/(1,2,3), 1/(4,5,6)	8
8		1/(1,2,3,4,5,6)	4
9	4	(1), (2), (3), (4)	16
10		1/(1,2), (3), (4)	12
11		1/(1,2), 1/(3,4)	8
12		1/(1,2,3,4)	4

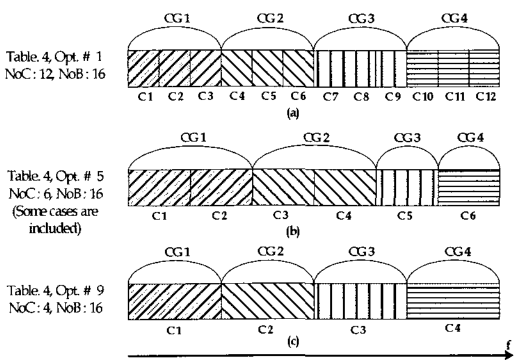

Fig. 2. Concept of cluster allocation in Table 4.

4. SIMULATION RESULTS

Here we present the simulation results of OFDM system using cluster under ITU-R Pedestrian channel environments and evaluate the performance of the presented method described in a previous section. Table 5 and 6 show the delay profiles of ITU-R Pedestrian A and B channels and main parameters for the simulation, respectively. And the applied mobile speed in simulation is based on the standard speed of ITU-R channel model.

Performances of the presented AMC scheme for OFDM system are analyzed by outage probability and bandwidth efficiency results. The outage is defined as follows. Outage = $N_{Packet\ error\ \#} / N_{Packet\ trans\ \#} + P_{unsatisfying\ packets\ of\ constant\ bit\ rate\ 3.84Mbps}$, where $N_{packet\_error\ \#}$ is the total number of received packets incorrectly and $N_{packet\_trans\#}$ is the total number of transmitted packets. Outage is averaged over 10000 OFDM blocks and bandwidth efficiency is defined as

Table 5. Delay profiles of ITU-R Pedestrian A and B channels.

Tap	ITU Pedestrian A		ITU Pedestrian B	
	Relative delay(ns)	Average Power(dB)	Relative delay(ns)	Average Power(dB)
1	0	0	0	0
2	310	-1.0	200	-0.9
3	710	-9.0	800	-4.9
4	1090	-10.0	1200	-8.0
5	1730	-15.0	2300	-7.8
6	2510	-20.0	3700	-23.9

Table 6. Main simulation parameters.

Cell radius	10 Km
Power Control	No
BS transmission power	Cell edge outage prob. = 1 & 10%
Received SNR measurement	Perfect
Channel estimation	Perfect
Synchronization (freq. & time)	Perfect

$$BW\ efficiency = Allocated\ bits\ in\ one\ frame\ /\ (N \times symbols\ in\ frame)$$

In general, simulation results based on main options of Table 2~4 show that we can get a better outage performance and bandwidth efficiency by reporting the average SNR value more than the minimum SNR value to UFCH information in pedestrian channel environment. Also, in the same table, we can see that the performance can be differentiated by the other positions of clusters. For example, in option 5 of Table 4, there are 5 main cases classified by different cluster allocation. Comparing with the performances of these 5 cases and fixed QPSK modulation, we can see that fixed modulation method outperforms the 5 cases of Table 3, which are based on Fig. 2 (b), in terms of outage performance. However, AMC shows the better characteristic than the fixed modulation when it comes to bandwidth efficiency. And, based on the simulation result of Table 3, we can see that 5 cases have different performance curves due to the distance among clusters even though they are in the same option. That is, the distance among clusters can be varied according to cases in Table 2 and 4 because 512 virtual carriers are inserted between C3 and C4. In Figs. 3~6, T2 and T4 represent the Table 2 and 4, respectively, and the O5 and O9 mean the option 5 and 9, respectively. For example, T4O5C1 implies the case 1 of option 5 in Table 4. Fig. 3 demonstrates the outages of the AMC with different NoCs and the fixed modulation under ITU-R pedestrian A & B channels. In Fig. 3, outage probability is 1% and E_s/N_o is 220 dB and SNR value for decision of AMC level is minimum SNR value. The transmitting power of Base-Station (BS) is determined by $P_{1/2\text{-}QPSK} > \text{received SNR of cell boundary users} < 0.01$. In this simulation, the tx power of BS is 220 dB. Compared with the results of Pedestrian

A channel, the outages of Pedestrian B channel show about $0.5 \times 10^{-2} - 2 \times 10^{-2}$ degradation at 5km, except for T4O5C5 and T2O4. And these constant gaps of performance are maintained under overall cell environment. Needless to say, outage performance of fixed QPSK modulation shows better one than that of AMC methods. Also, as mentioned before, 5 cases of T4O5 doesn't show the same performance owing to the distance among clusters. For the Ped. A and B channel under the same environments of Fig. 3, an over 2.5 improvement of bandwidth efficiency can be obtained by using AMCs instead of fixed QPSK modulation, as shown by Fig. 4. Compared with other AMC cases, the bandwidth efficiencies for T4O5C2, T4O9 and T4O5C3 are improved by about 0.2 ~ 0.5. As shown in Fig. 4, those 3 cases have much better performances than other schemes including QPSK in proportion to the cell radius. Based on the trade-off between outage and bandwidth efficiency results, in Ped. A channel, T4O9 is better than other AMC cases and fixed QPSK modulation. Also, in Ped. B channel, T4O5C5 and T4O5C3 outperform other cases in terms of outage and bandwidth efficiency, respectively. Simulation results in Ped. B channel are based on the distance effect among clusters. Fig. 5 shows the outages of AMCs and fixed QPSK modulation for the ITU-R Pedestrian B channel environment. In the Fig. 5, Outage probability is 1% and the E_s/N_0 is 220 dB. Also the SNR information for AMC level is determined by the minimum and average value. Fixed QPSK modulation shows the good performance with average SNR information around the middle position of entire cell and has the similar performances in other regions. The outages of every AMC cases with average SNR value are much smaller than those of AMC with minimum SNR values, consequently, compared with the latter, the outages for former schemes show about $1\times10^{-2}-5\times10^{-2}$ improvement when cell radius is more than 5km. Comparing the performances of different UFCH allocation bits us ing average SNR value, although the outage for T4O5C1 shows the least value about 1.25×10^{-4} at 2km, we can see that 2 cases of T4O5 and T4O9 have similar characteristics from 3 to 10km. Because the number of clusters in two AMC schemes are 4 and 6, there are no big differences between clusters and subcarriers per cluster. Hence, both the T4O5 and T4O9 with average SNR value are more robust to the channel delay profiles than those using minimum one. Fig. 6 shows the bandwidth efficiency under the same environment as Fig. 5. Like outages, compared with minimum SNR values, the bandwidth efficiency with average SNR shows about maximum 1.5 improvement. Furthermore, the bandwidth efficiencies for AMC using average SNR values are exactly same and

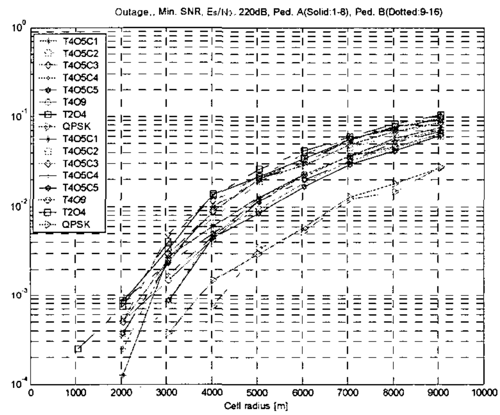

Fig. 3. Outage of AMC and fixed QPSK modulation for ITU-R Pedestrian A and B channel. (Outage prob. : 1%)

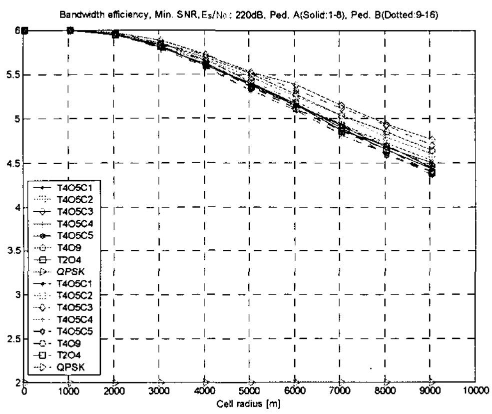

Fig. 4. Bandwidth efficiency of AMC and fixed QPSK modulation for ITU-R Pedestrian A and B channel. (Outage prob. : 1%)

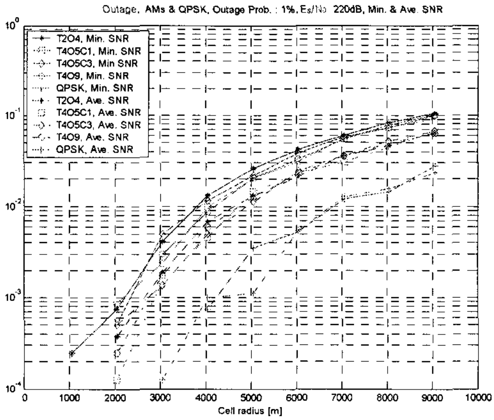

Fig. 5. Outage of AMC and fixed QPSK modulation with minimum and average SNR. (Outage prob. : 1%)

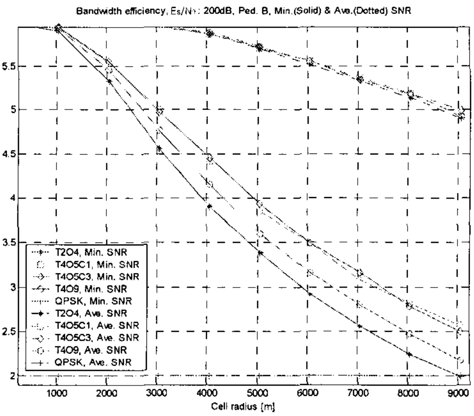

Fig. 6. Bandwidth efficiency of AMC and fixed QPSK modulation with minimum and average SNR. (Outage prob. : 1%)

so robust to channel delay profiles.

5. CONCLUSION

In this paper, we have evaluated the AMC method for OFDM system with cluster in pursuit of BW efficiency and performance improvement. It is demonstrated by computer simulation that AMC scheme with average SNR value for selecting AMC levels shows better performances than those of method using minimum SNR value. Generally, the simulation results under ITU-R Pedestrian A channel showed better characteristics than those of channel B. And, the performance of AMC method can be af fected by the position and number of clusters owing to the subcarriers within the corresponding cluster or CG as well as the distance among clusters. Also, T4O9 among AMC schemes can be considered as the optimal scheme in terms of outage and BW efficiencies for our system. That is, it is very important to how to determine the position and selection method of clusters in order to improve the overall AMC performance. In the future, to use the presented AMC scheme for our system in practice, we will analyze the overall system by using AMC, frequency hopping and other main techniques.

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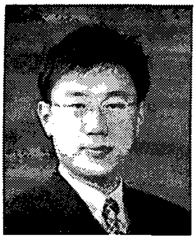

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