Adaptive Scheduling Scheme for Multicast Service in Multiuser OFDM System

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***Abstract*— These Wireless communication systems have been developed to support users' various requirements. Multicast scheme is proposed for various types of service. Basically, the group Modulation and Coding Scheme (MCS) level for multicast transmission depends on the instantaneous worst channel user to provide reliable communication. However, this causes the low bandwidth efficiency for overall system. In order to overcome this problem, the proposed algorithm considers not only MCS efficiency of groups but also available overall system resources. The performance evaluation shows that proposed algorithm reduce the overall blocking probability and improve the throughput and revenue compared with traditional minimal and Proportional Fair (PF) based schemes.**

Keywords- Multicast, MCS efficiency, OFDM, Scheduling.

I. INTRODUCTION

Since wireless access technology and end user device, such as mobile, laptops, have been developed, user behavior is not restricted to using voice service by wireless device. As user who requests various multimedia broadcasting and streaming such as Internet Protocol Television (IPTV) increase, it is important to allocate resource efficiently [1]. Wireless multicast transmission can be a good solution to reduce the resource consumption for delivering the same contents to user who interested in certain group [2].

The major wireless multicast technologies used in various 3G/4G deployment models are Multicast Broadcast Service (MBS) [3] by WiMAX-The Worldwide Interoperability for Microwave Access, Multimedia Broadcast Multicast Service (MBMS) [4] by 3GPP, and Broadcast and Multicast Services (BCMCS) [5] by 3GPP2. These technologies commonly use Orthogonal Frequency Division Multiplexing (OFDM) technology with Adaptive Modulation Coding (AMC) in order to provide high bit rate and efficiently utilize the downlink bandwidth. By independently managing the each user, AMC can provide high bandwidth efficiency in unicast transmission. However in multicast transmission, it is not efficient since the multicast group MCS level is adjusted by only a user who has worst channel condition in a group [2]. Therefore, capacity saturation can be happened as the number of users increase because of depending on the instantaneous worst channel user in multicast transmission [6].

In order to cope with this problem, many researchers have proposed schemes especially considering throughput. Koh and Kim suggest the PF Scheduling for multicast service [7]. Kang and Cho suggest the dynamic packet scheduling for multicast [8]. Gopala and Gamal suggest the policy based scheduling for multicast [9]. Although these schemes can enhance system throughput by selecting maximal MCS level, it has low cell edge performance and causes high blocking probability. Therefore, there is no way to serve cell edge users and it will be a fatal problem if multicast is not provided to some static users. Xu Ning and Viver Guilame [10] concentrate to guarantee service of users in cell edge by handling PF parameter. In order to analyzing performance, we just focus on the PF scheduling algorithm since PF scheduling algorithm is one prominent example of compromise between fairness and high system throughput [7]. However, the proposed scheme is not restricted by PF algorithm. In this paper, we propose the adaptive scheduling based on MCS efficiency of groups and available overall system resources for multicast service. It improves not only cell edge performance but also increase the overall throughput. Finally, we compare the proposed scheme with the conventional scheme in wireless OFDM systems. We also analyze and compare the system performance of PF scheduling based multicast transmission scheme in terms of overall blocking probability, throughput and revenue. The rest of this paper is organized as follows. In Section II, proposed transmission scheme is described, and then In Section III, we develop the system model for analyzing blocking probability. The system performance between proposed scheme and conventional scheme are compared, and the system performance of the proposed scheme is evaluated in Section IV. Finally, conclusions are presented in Section V.

II. Proposed Transmission Scheme

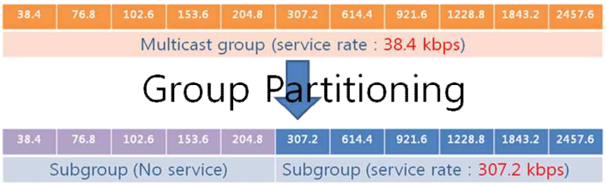


Figure 1. Multicast group partitioning (No service vs. service)

In this section, we describe a problem of the conventional transmission schemes for multicast and propose an adaptive scheduling scheme.

A. Problem statement

According to AMC, in unicast service, high spectral efficiency can be achieved by selecting the highest modulation and coding rate with a given acceptable Bit Error Rate (BER) constraint. However, in the multicast case the transmission rate must be the minimum value of a multicast group. This makes system throughput performance degrade extremely since the overall system capacity is limited by the worst channel user. One possible way to improve the system throughput is to split the multicast group into two subgroups and to serve the better channel subgroup only [6-9]. Fig. 1 shows the example how the partitioning method can improve the system throughput.

Although splitting the multicast group can enhance the throughput, the cell-edge users are sacrificed. Therefore, it is important how to increase the throughput with minimizing cell-edge blocking probability. In this respect, it is our contribution to propose the efficient adaptive scheduling scheme for the multicast user group with considering group MCS efficiency and available radio resources in a cell.

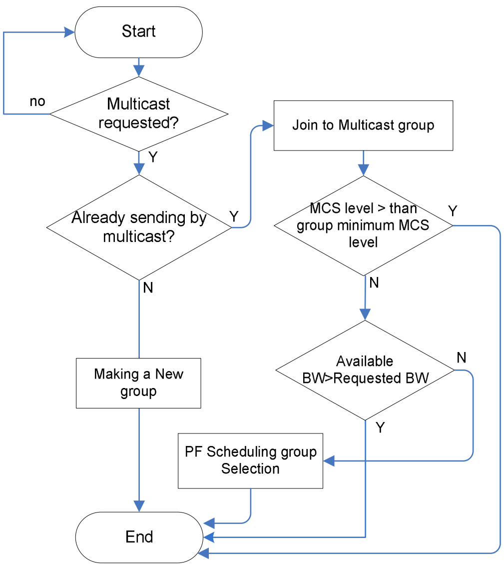


Figure 2. Proposed transmission scheme procedure

B. Proposed adaptive scheduling scheme

In this section, we address the proposed adaptive scheduling scheme. The proposed transmission scheme is involved with two cases : sparse phase and dense phase. The sparse phase means that the system has enough bandwidth to support the worst channel users in multicast groups. On the other hands, the dense phase, the system has not enough bandwidth to support the worst channel users because many groups are located in a cell. Fig. 2. expresses the overall procedure for proposed transmission scheme.

1) Select a transmission scheme

if available bandwidth size < requested bandwidth size

- dense mode is executed
- PF Scheduling group selection.

Else if

- Sparse mode is executed

2) Evaluate the group MCS level in dense mode

Measure the current Signal to Noise ratio (SNR) values of multicast users

- Measure the current average rate $R_k(t)$ of user k from SNR values at time frame t which updates as follows

$$R_k(t+1) = \frac{(T-1)\cdot R_k(t) + r_k^{\min}(t+1)}{T}, \quad if, \; k \in U_S$$

$$\frac{(T-1)\cdot R_k(t)}{T}, \quad elsewhere \; [7] \qquad (1)$$

It is known that a proportionally fair allocation should maximize the sum of logarithmic average user rates [2]. Therefore, PF scheduler maximizes sum of $R_k(t)$ by the property of PF allocation.

- Select and save a group MCS level for multicast group i: [7]

$$\therefore l^* = \arg\max_l \left\{ \prod_{k\in\{i|r_i(t)\ge r^l\}} \left(1+\frac{r^l}{(T-1)\cdot R_k(t)}\right)\right\} \qquad (2)$$

From above index l*, we can extract MCS[i] as a group MCS level for multicast group i.

To reduce overall blocking probability in the system, PF scheduling group selection procedure is executed. BN is the number of blocking user in group i, it affects the overall blocking probability in the system. Finally, we consider BN value to choose PF scheduling group by following below algorithm..

for (i=1:the number of group(N))

for (k=1:multicast group users in group I (U_s))

$$if \;\; MCS[i][k] < MCS[i]$$
$$BN_i ++ \qquad (3)$$
end
end

$$G_{PF,i} = \min\{BN_1, BN_2, ..., BN_N\} \qquad (4)$$

Since we select PF scheduling group by adopting G_{PF}, we can execute PF scheduling algorithm to group $G_{PF,i}$ which has minimum number of blocking users.

3) Evaluate the group MCS level in sparse mode [6].
- Measure the current MCS values of multicast users
- Select and save the lowest MCS value among U_s multicast users:

$$\therefore C_M = \min\{MCS_1, MCS_2, ..., MCS_{Us}\} \qquad (5)$$

Therefore, in proposed adaptive scheduling scheme for multicast service, we concentrate to enhance multicast traffic efficiency.

III. Analysis of Transmission Scheme

To analyze the proposed transmission scheme, we can model our proposal with $M^x/M/C/C$ for OFDM subcarrier allocation system [11][12]. From the viewpoint of analytical purpose, we may obtain statistical average number of used sub-channel in MCS level. Every subcarrier has the same average data rate. The number of sub-channel C generally denotes the system capacity in an NG cell. Because sub-channel is contained 28 subcarriers, the cell has in total $28CR_b$ rate resources, where R_b represents the average data rate per subcarrier. In our model, minimal data requests limited by sub-channel not subcarriers which depend on real service. Therefore, a multicast service (call) can request multiple sub-channels to fulfill its transmission requirement. Hence, this case is considered as a batch (group;bulk) arrival.

TABLE I. Notations For Numerical Analysis

Notations	Explanation
C	System capacity (The maximum number of sub-channel).
X_k	The number of requested sub-channel in PF.
x_k	The number of requested sub-channel in Minimum.
$\pi(k)$	State probability of state k.
Ω_{block}	Call Blocking probability for Adaptive PF.
$\Omega_{pf-block}$	Blocking probability when PF is used and fully blocked
$\Omega_{pf-non-block}$	Blocking probability when PF is used and not fully blocked.
γ	Throughput in multicast service.
µ	Average service rate of multicast stream.
P_{PF}	average blocking probability of PF algorithm

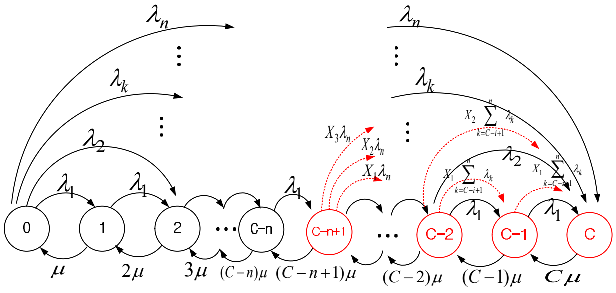


Figure 3. State-transition-rate diagram of $M^x/M/C/C$ for the OFDM sub-channel allocation system in adaptive PF algorithm

Assume the customers arrive in groups following a Poisson process with the mean group-arrival rate λ. The service times (call holding times) are independently exponentially distributed with the parameter µ. The system propability sequence $\{x_k\}$ and $\{X_k\}$ means the probability of requesting k sub-channel based on traditional minimal and PF scheduling based environment. Let λ_k denote the batch arrival rate where $\lambda_k = x_k\lambda$.

$$\sum_{k=1}^{n} x_k = 1, \;\; where, \;\; 1 \le k \le n \le C \qquad (6)$$

The model is equivalent to the standard Erlang loss system [11]. Fig. 3 depicts the state-transition-rate diagram of the model. Red circle means that there is possibility of PF algorithm due to lack of available bandwidth. Finally, red dotted line shows the PF transition rate when requested sub-channel is higher than available sub-channel in multicast environment. The equilibrium (steady-state) equations written below are run to obtain the steady-state probabilities of the model.

i) m=0;

$$\lambda\pi(0) = \mu\pi(1), \;\; where \;\; 1 \le n \le C \;\; and \;\; \lambda = \sum_{k=1}^{n} \lambda_k \qquad (7)$$

ii) $1 \le m \le C-n$

$$(m\mu + \sum_{k=1}^{n} \lambda_k)\pi(m) = \sum_{k=1}^{min(m,n)} \lambda_k \pi(m-k) + (m+1)\mu\pi(m+1) \qquad (8)$$

iii) $C-n+1 \le m \le C$

$$(m\mu + \sum_{k=1}^{\min(n-1,C-m)} \lambda_k + \sum_{k=1}^{\min(n-1,C-m)} (X_k \sum_{k=C-m+1}^{n} \lambda_k))\pi(m)$$
$$= \sum_{k=1}^{\min(m,n)} \lambda_k \pi(m-k) + \sum_{k=1}^{m-(C-n+1)} \pi(m-k) X_k \sum_{j=C-(m-k)+1}^{n} \lambda_j$$
$$+ (m+1)\mu\pi(m+1) \qquad (9)$$

Reforming (1) and (2) yields

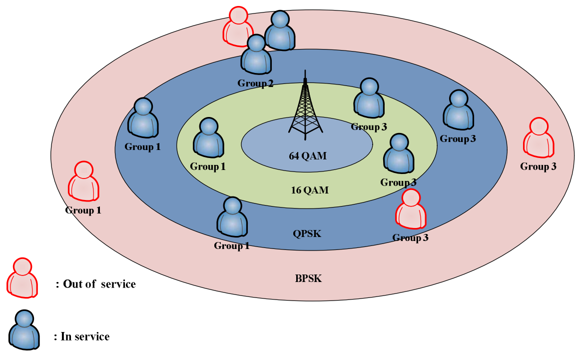


Figure 4. Mobile terminal distribution example

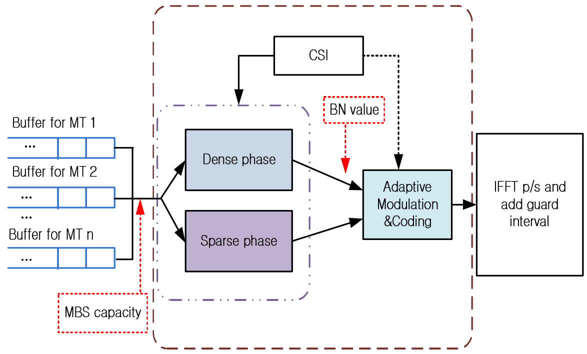


Figure 5. System model for adaptive scheduling scheme

$$\pi(1) = \pi(0)\lambda / \mu \quad (10)$$

$$\pi(m+1) = \frac{(m\mu + \sum_{k=1}^{n} \lambda_k)\pi(m) - \sum_{k=1}^{min(m,n)} \lambda_k \pi(m-k)}{(m+1)\mu} \quad (11)$$

Where, $1 \le m \le C-n$.

$$\pi(m+1) = [(m\mu + \sum_{k=1}^{\min(C-m,n)} \lambda_k + \sum_{k=1}^{\min(n-1,C-m)} (X_k \sum_{k=C-m+1}^{n} \lambda_k))\pi(m)$$

$$- \sum_{k=1}^{\min(m,n)} \lambda_k \pi(m-k) - \sum_{k=1}^{\min(m-(C-n+1),n)} \pi(m-k) X_k \sum_{j=C-(m-k)+1}^{n} \lambda_j]$$

$$/(m+1)\mu \quad (12)$$

Where, $C-n+1 \le m \le C$.

Recursive programs cannot always solve the equations, owing to overabundant recursive levels for large C. Therefore, an iterative procedure is adopted to solve the equilibrium equations. Let initial value P_0^*=1; then other steady state probability value can be extracted by global balance equation. According to the normalizing condition (summation of steady state probability equals one) the equilibrium probabilities of all states are written as follows:

$$\pi(m) = \pi(m)^* / \sum_{i=0}^{C} \pi(i)^*, where \ \ 0 \le m \le C. \quad (13)$$

The Call Blocking Probability (CBP) of the model is explained in the following. Basically, PF algorithm contains static blocking probability that means rates of blocking users who don't satisfy determined MCS level. This probability is expressed as P_{PF}. Sometimes, available bandwidth can't satisfy determined bandwidth which is extracted from PF algorithm, it is fully blocked. Finally, the CBP can contain two blocking cases : Fully block and Static block. Thus, the CBP can be expressed as

$$\Omega_{block} = \Omega_{pf-block} + \Omega_{pf-non-block} \quad (14)$$

$\Omega_{pf-block}$ expresses the blocking probability of fully block case. $\Omega_{pf-non-block}$ expresses the blocking probability of static block case. Equations for both cases contain $P_{min\text{-}out}$, because, when available bandwidth can't satisfy minimal scheme, PF scheduling will be conducted. Finally two cases can be differentiated by $P_{PF\text{-}out}$ and $P_{PF\text{-}nonout}$.

$$\Omega_{pf-block} = \sum_{m=C-n+2}^{C} \pi(m) \cdot P_{\min-out} \cdot P_{PF-out} \quad (15)$$

$$\Omega_{pf-non-block} = \sum_{m=C-n+1}^{C} \pi(m) \cdot P_{\min-out} \cdot P_{PF-nonout} \cdot P_{PF} \quad (16)$$

$$where, \ P_{PF-out} = 1 - \sum_{k=1}^{\min(n-1,C-m)} X_k, \ P_{\min-out} = \sum_{k=C-m+1}^{n} x_k$$

$$P_{PF-nonout} = \sum_{k=1}^{\min(n-1,C-m)} X_k \quad (17)$$

And, Throughput equation follows Erlang's Loss Formula.

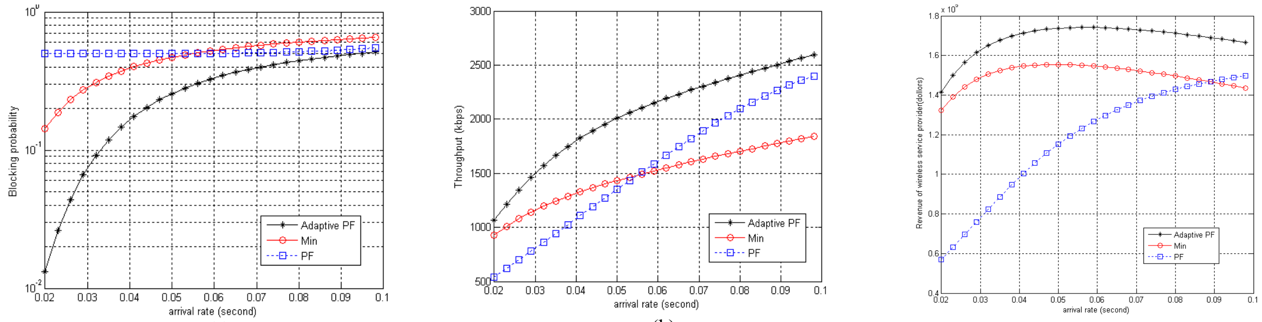
Next, we introduce the service provider's reward/penalty cost model to expect service providers' revenue. We assumed that when the base station successfully serves the multicast service without blocking, the service provider receives a reward value of R. On the other hand, if a user is rejected, we assume that the service provider loses a value of L immediately [2].

In prior art under the resource allocation policy, for example, if the system on average services N client per unit time and reject M client per unit time, then the system revenue is

$$\sum N \cdot R - \sum M \cdot L \quad (18)$$

Finally, we define the total system revenue as follow:

$$revenue = \sum_{m=1}^{C} m\mu\pi(m) \times R - \lambda\Omega_{block} \times L \quad (19)$$



(a) (b) (c)

Figure 6. Results with performance comparison for (a) blocking probability (b) throughput (c) revenue between Adaptive PF, Min and PF

IV. PERFORMANCE EVALUATION

Fig 4 shows the mobile terminal (MT) distribution example. MTs are directly mapping the MCS level by considering path loss in large scale fading. In this case, each MT requests the multicast service from BS. After requesting the service, each packet goes to the BS. Fig 5 illustrates the adaptive scheduling scheme for a packet-switched OFDM system. We focus on downlink transmission of multicast data traffic. Therefore, base station (BS) that makes scheduling decisions for packet transmission based on MBS capacity. BS can choose two scheduling method based on MBS capacity adaptively. At Media Access Control (MAC) layer, upon each packet arrival, the BS puts the packet into its corresponding buffer which is assumed to have infinite space. At Physical (PHY) layer, we assume perfect channel state information (CSI). With this CSI, the BS can implement AMC to maximize the throughput on each subcarrier [13]. In performance evaluation, we measure distribution of MCS level in worst channel user in multicast transmission and PF scheduling based multicast transmission. In this case, we consider the arrival rate has a discrete uniform distribution and arrival multicast user has MCS level which is uniformly distributed from 1 to 10. We simulate uniform distributed user in cell to execute min based algorithm and PF based algorithm. Finally, we extract P_{PF} which is static blocking probability when PF algorithm used. Whole simulation procedure follows:

Step1. Each user has their MCS level depend on channel condition. We just consider path loss in large scale fading.

Step2. We randomly group users as multicast group.

Step3. Apply two scheduling algorithm to each multicast group in same environment – PF algorithm and Min algorithm.

Step4. Extract blocking probability and MCS level distribution.

Finally, we assumed that total channel capacity C is 40 and multicast streaming is 300kbps. Service rate is 0.0055 since we just focus on ucc contents environment which have average 3 minutes (180 seconds) running time [12]. We analysis performance by using various parameters in simulation and numerical analysis in terms of blocking probability, throughput and revenue.

A. Call Blocking Probability by proposed adpative PF algorithm

Fig. 6 (a) shows the performance comparison among the adaptive PF, min and PF in terms of blocking probability as arrival rate increase from 0.02 to 0.1 [12]. In PF algorithm, although arrival rate is small, it can make blocking situation, because it determines MCS level. As arrival rate increase, PF algorithm is better than min algorithm because min algorithm saturate faster than PF algorithm due to choose worst channel user. In adaptive PF, when arrival rate is low (unused sub-channels are enough to support requested sub-channel), it doesn't use PF algorithm. After arrival rate is high, it uses PF algorithm to enhance multicast sub-channel efficiently. Finally, overall blocking probability patterns show that adaptive scheduling enhances user blocking rates by adaptively choosing algorithm. It also affects cell edge performance since most of blocking user might be cell edge user in large scale fading environment.

B. Throughput by proposed adaptive PF algorithm

Fig. 6 (b) shows the performance comparison among the adaptive PF, min and PF in terms of throughput as arrival rate increase from 0.02 to 0.1 [12]. As result of blocking

TABLE II. SYSTEM PARAMETERS IN OFDMA ENVIRONMENT

MCS Level	Modulation	Coding rates	Maximum Data rate (Mbps)	# of used Sub-channel by streaming (300kpbs)
1	QPSK	1/2, 6x	0.75	11
2	QPSK	4x	1.13	8
3	QPSK	2x	2.26	4
4	QPSK	1x	4.51	2
5	QPSK	3/4	6.77	2
6	16QAM	1/2	9.02	1
7	16QAM	3/4	13.54	1
8	64QAM	2/3	18.05	1
9	64QAM	3/4	20.30	1
10	64QAM	5/6	22.56	1

probability, throughput shows the bandwidth utilization of each case. Since throughput is depend on blocking probability, adaptive PF ensures higher bandwidth utilization than min and PF algorithm based multicast. Conventional PF is smaller than min algorithm when arrival rate is low. As arrival rate is increased, conventional PF is better than min algorithm as shown in Fig. 5.

C. *Revenue by proposed adaptive PF algorithm*

Now we evaluate revenue of each scheme in the aspect of wireless service provider. In this case, we assume that wireless service provider provide IPTV service. Fig. 6 (c) shows the result obtained by service providers' reward/penalty cost model. We assumed that is the base station successfully serves the multicast service without blocking, the system receives a reward value of R(=$10). On the other hand, if a user is rejected, we assume that the service provider loses a value of

L(=$5) immediately. This figure shows that as the arrival rate increase, the revenue of each algorithm is slightly decreasing because of its blocking probability of services. In this case, our proposed algorithm can offer higher revenue than others. And PF can't compensate within most of our observe point since PF algorithm contains static blocking probability.

II. CONCLUSION

Multicast transmission makes efficient utilization of sub-channel in wireless environment. Although conventional PF enhance multicast channel utilization in hot-spot situation, it is not suitable for low arrival rate situation as our analysis. In OFDM environment, since multicast part in OFDM is dedicated, unused multicast sub-channel in certain time slot means inefficient resource allocation. To enhance efficiency of resource allocation, our proposed scheme has been suggested. Our analysis have shown that adaptive scheduling scheme adaptively allocate sub-channel to multicast users depending on MBS channel capacity which is same as available bandwidth. As result of comparison, our proposed scheme guarantees more serviced users in certain time slot and more efficient bandwidth utilization. Since most of blocking users are in the cell edge, we can also enhance cell edge performance. Further work will extend the proposed scheme with considering weight factor of the number of users in multicast group and apply general scheduling algorithm.

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