Proportional fair scheduling method with QoS for the coexistence system of GFDM and OFDM

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Abstract: Future 5th generation (5G) mobile system is required to accommodate a huge amount of mobile data traffic with different quality of services (QoS) in a large number of devices. To realize 5G system, a new waveform such as generalized frequency division multiplexing (GFDM) has been researched. In this paper, we propose a proportional fair (PF) scheduling method considering the delay budget of users for the coexistence system of GFDM and orthogonal frequency division multiplexing (OFDM). From computer simulation, we show that the proposed method can improve the average delay time for users of small delay budget without large degradation of system throughput.

Keywords: 5G, GFDM, OFDM, scheduling method, QoS

Classification: Wireless Communication Technologies

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1 Introduction

Future 5th generation (5G) mobile communication system is required to accommodate a huge amount of mobile data traffic with different quality of services (QoS) in a large number of devices. To realize 5G system, a new waveform such as generalized frequency division multiplexing (GFDM) has been researched [1, 2, 3, 4, 5, 6]. In the future, if GFDM is adopted in 5G system, the coexistence system of GFDM and orthogonal frequency division multiplexing (OFDM) on the same system band can be considered. Since GFDM has the lower side-lobe by applying pulse shaping filter for each subcarrier, GFDM signal can be allocated to OFDM guard band. Additionally, GFDM can expect to improve the system throughput since it is flexibly available of empty resource including OFDM guard band by changing the subcarrier spacing or the number of subcarriers.

In this paper, we propose a proportional fair (PF) scheduling method considering the delay budget of each user for the coexistence system of GFDM and OFDM. The proposed method can adjust the effect of delay the budget in calculating PF metric depending on operational scenario such as the traffic amount or type of connected users. From computer simulation, we show that the proposed method can improve the average delay time for users with small delay budget without large degradation of system throughput.

2 The coexistence system of GFDM and OFDM

In 5G system, there is an amount of mobile data traffic with diversified QoS since the massive devices such as smart phones, robots and sensors are connected to the same network. In this paper, we focus on the coexistence system of GFDM and OFDM. Fig. 1 shows the allocation scenario in bandwidth of 1.4 MHz. By using GFDM, these traffics can be allocated to empty resources including guard band on the OFDM system band as shown in Fig. 1. Therefore, this system can improve the system throughput compared with the conventional OFDM system.

Fig. 1. Allocation scenario at BW = 1.4 MHz of LTE.

3 Proposed scheduling method

The resource scheduler for 5G system is required not only allocating fairness between users, but also allocating based on QoS such as the delay budget. For allocation fairness, PF scheduling has been designed for 3G and 4G system [7]. In this paper, for allocation based on QoS, we propose a new PF scheduling method considering the delay budget of users for the coexistence system of GFDM and OFDM. Proposed scheduler allocates the user x_{alloc} who has the largest PF metric to the allocation block n . The PF metric $PF(t, n, x)$ is calculated as the ratio of achievable instantaneous throughput $TP_{inst}(t, n)$ at a time t and an allocation block n to average throughput $TP_{average}(t)$ with correction term of the delay budget $T_{delay}(x)$ as follows:

$$PF(t, n, x) = \left(\frac{TP_{inst}(t, n)}{TP_{average}(t)} \right) \cdot \frac{1}{1 + \alpha \cdot (T_{delay}(x))^\beta}, \quad (1)$$

$$x_{alloc}(t, n) = \arg \max_{X \in \{x_0, x_1, \dots, x_m\}} \{PF(t, n, x)\}, \quad (2)$$

where m is the number of candidate users for allocation, α and β are the weighting factors for $T_{delay}(x)$. The achievable instantaneous throughput can be calculated as follow:

$$TP_{inst}(t, n) = BW_{alloc}(n) \cdot \log_2(1 + SINR(t, n)), \quad (3)$$

where $BW_{alloc}(n)$ is the allocated bandwidth of n , $SINR(t, n)$ is measured signal to interference and noise power ratio (SINR) at t and n . In the proposed method, the weighting factors α and β can adjust the effect of $T_{delay}(x)$ depending on operational scenario as the traffic amount or the type of the connected users.

4 Performance evaluation

In this section, the average delay time and the system throughput for the proposed scheduling method are evaluated by computer simulation with the parameters and

Table I. Simulation parameters.

User pattern name	GFDM only	OFDM only	GFDM/OFDM
Number of GFDM user	20	0	10
Number of OFDM user	0	20	10
Scheduling method	Proposed PF		
PF metric updating period [ms]	0.5 (scenario1), 1.0 (scenario2)		
Allocation BW [kHz/user]	180 (scenario1), 90 (scenario2)		
Weighting factor α	0.1~3		
Weighting factor β	0.1~3		
Packet generation period [ms]	1.0 (scenario1,2)		
Traffic type	Full buffer		
Delay budget [ms] [8]	50 (QCI no. = 3), 100 (QCI no. = 1)		
System bandwidth [MHz]	1.4		
Number of subcarrier	128		
Subcarrier spacing [kHz]	15 (OFDM, GFDM)		
GI length [μ s]	5.2 (OFDM, GFDM), 4.7 (OFDM)		
Sampling frequency [MHz]	1.92		
Channel model	AWGN		
Hybrid ARQ	OFF		
ICIC (for GFDM)	ON (Double sided SIC [9])		
AMC	ON		
Moduration	QPSK, 16QAM, 64QAM		
FEC	Turbo Code rate 0.117~0.921		
Number of iteration	8		

allocation scenarios shown in Table I and Fig. 1. We evaluate three situations that the number of OFDM users are changed. The delay time is defined as the processing time from the generation timing of a packet to the deletion timing of same packet per each user. In each user pattern of Table I, the 50% of users have the 50 ms delay budget, and the other users have the 100 ms delay budget. As shown in Fig. 1(a), scenario1 allows the allocation up to two users per 1.0 ms at each allocation block by updating the PF metric every 0.5 ms. Additionally, it allows the allocation up to 10 users in 1.4 MHz because one user is allocated per 180 kHz. On the other hand, as shown in Fig. 1(b), scenario2 allows the allocation up to one user per 1.0 ms at each allocation block by updating the PF metric every 1.0 ms. In addition, it allows the allocation up to 20 users in 1.4 MHz because of one user allocation per 90 kHz. Therefore, each scenario are able to allocate up to 20 users at 1.0 ms period.

Fig. 2(a-b) shows the weighting factors α and β versus delay time for GFDM only pattern at scenario1. In Fig. 2(a-b), Y axis is averaged value of transmitted packets and users with same delay budget in all SNR. In Fig. 2(a), the difference of delay time between users with 50 ms delay budget and users with 100 ms delay budget is increasing in large α . On the other hand, in Fig. 2(b), the difference of delay time between users with 50 ms delay budget and users with 100 ms delay

Fig. 2. Evaluation of delay time and system throughput ((a-c): for GFDM only pattern, (d): for each user pattern).

budget has the maximum value in $\beta \leq 1$. Therefore, the proposed method can adjust the effect of delay budget by changing the values of α and β . In the scenario has the higher priority for the smaller delay budget, large α and small β have to be set.

Fig. 2(c) shows the SNR versus delay time for GFDM only pattern in $\alpha = \beta = 1$. In Fig. 2(c), Y axis is averaged value of packets and users with same delay budget in each SNR. The delay time of scenario1 is smaller than scenario2 since scenario1 allows the allocation up to two users per 1.0 ms. Meanwhile, the delay time of users with 50 ms delay budget is smaller than users with 100 ms delay budget. Consequently, the proposed method can preferentially allocate frequency resource to users with the small delay budget, and can improve the average delay time for these users.

Fig. 2(d) shows the SNR versus system throughput for each scenario in $\alpha = \beta = 1$. As shown in this figure, the system throughputs of GFDM/OFDM and GFDM only pattern at scenario2 increase about 1.0 Mbps (27%) and 1.1 Mbps (29%) at SNR = 12 dB compared with the OFDM only pattern, respectively. In addition, the system throughputs of GFDM/OFDM and GFDM only pattern at scenario1 increase about 1.0 Mbps (27%) and 1.4 Mbps (34%) compared with the OFDM only pattern. These improvements come from the guard band utilization by GFDM users.

As the above results, the proposed method can improve the average delay time for users with small delay budget without large degradation of system throughput in the same user pattern.

5 Conclusion

This paper proposed the PF scheduling method considering the delay budget of each user for the coexistence system of GFDM and OFDM. The proposed method can adjust the effect of delay budget by the weighting factors α and β depending on operational scenario such as the traffic amount or type of connected users. From computer simulation, we showed that the proposed method in the GFDM and OFDM coexistence system improves the average delay time for users with small delay budget without large degradation of system throughput in the coexistence system of GFDM and OFDM.

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