Scheduling Performance of Real Time Service in Multiuser OFDM system

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***Abstract*-In multiuser OFDMA system, multiuser diversity gain can be achieved by channel aware subcarrier and power allocation, and most work in this field is foucsed on the none-real time service. For Real Time (RT) service, not only the data rate, but also the packet delay should be guaranteed. In this paper, the multiuser subcarrier allocation is investigated for real time service. By exploiting the queue status information and Channel State Information (CSI), the delay sensitive service is expected to be served well. In this paper, Modified Largest Weighted Delay First (M-LWDF), Quality Guaranteed (QG) scheduling algorithms based on channel and queue aware are proposed for real time service in multiuser OFDMA system, and compared with Packet Loss Ratio (PLR) algorithm. From the simulation results, these algorithms almost have the same performance when system load is low, when the radio resource is enough to offer service for video users; when the system load increases, the performance difference becomes larger. The modified M-LWDF has the best performance, while QG has a better system throughput than PLR, but a worse user drop ratio.**

Key Words: OFDM, Multiuser Diversity, M-LWDF, PLR,QG

I. INTRODUCTION

OFDM is very suitable for high data rate transmission in wide band wireless channel for the excellent capability to mitigate the frequency selective fading and inter-symbol interference (ISI) [1]. The adaptive modulation and coding (AMC) on every subcarrier and adaptive frequency domain scheduling can provide high spectrum efficiency. Meanwhile, the implementation of OFDM is very convenient by IFFT/FFT. All these features make OFDM very competitive and promising for B3G system, which has been adopted in IEEE 802.16e [2] and 3GPP long term evolution.

Furthermore, by dynamical subcarrier allocation based on channel status information, multiuser diversity gain can be exploited to improve the cell throughput in OFDMA system. On OFDMA subcarrier and bit allocation, most work is focused on maximizing the system throughput when the scheduler is channel aware [3] [4]. However, for different packet service, the burst characteristic of the packets varies much and influences the system throughput much. For Unconstrained Delay Data (UDD) service, the delay of the packet is not serious, but for Real Time service, the packet with delay exceeding the pre-defined value will be dropped, which leads to bad user experience. So for real time service, usually the user data rate and packet delay should both be guaranteed. Obviously, if the packet status in queue is monitored and the packets can be transmitted in time, then QoS can be guaranteed. In [5], the queue aware scheduling is considered in OFDMA, and QoS can be guaranteed.

In this paper, the channel and queue aware scheduling for OFDMA is investigated, and a novel Quality Guaranteed (QG) and a modified M-LWDF [6] algorithm are proposed and compared with PLR algorithm [7] for RT service. From the simulation results, these algorithms almost have the same performance when system load is low, and the radio resource is enough to offer video service; however, when the system load increases, the performance difference becomes larger and larger among these algorithms. The modified M-LWDF has the best performance, while QG has a better system throughput than PLR, but a worse user drop ratio than PLR.

The organization of this paper is as follows. The system model is introduced in section II; a novel QG and a modified M-LDWF are introduced in section III; the simulation parameters and results are presented in section IV, and conclusions are drawn in section V.

II. SYSTEM MODEL AND PROPOSED ALGORITHM

For multiuser OFDMA system, with the constraint of total power, multiuser power and subcarrier allocation can be modeled as:

$$\begin{aligned}&\underset{z_{n,k},p_{n,k}}{Max}\sum_{n=1}^{N}\sum_{k=1}^{K} z_{n,k}\log_2\left(\frac{\left|H_{n,k}\right|^2 p_{n,k}}{\left|w_{n,k}\right|^2}\right)\\&\sum_{n=1}^{N}\sum_{k=1}^{K} p_{n,k}\le P, \qquad (1)\\&s.t.\sum_{k=1}^{K} z_{n,k}=1\end{aligned}$$

Where $z_{n,k}$ is the subcarrier allocation indicator, and

$$z_{n,k}=\begin{cases}1, \textit{subcarrier } n \textit{ allocated to user } k\\ 0, \textit{subcarrier } n \textit{ allocated to other user}\end{cases}$$

$p_{n,k}$ is the power of user k allocated on subcarrier n, and $p_{n,k}=0$ if subcarrier n is not allocated to user k. P is the system power constraint. $\left|H_{n,k}\right|^2$ is the channel gain of user k on subcarrier n, and $\left|w_{n,k}\right|^2$ is the noise power of k on subcarrier n.

The optimal solution for the above problem can be obtained by iterative multiuser waterfilling [8]. For the

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discrete modulation, it can be obtained by multiuser discrete bit loading.

If every user's data rate is constrained, the above problem can be changed as:

$$\min_{z_{n,k}} \sum_{n=1}^{N}\sum_{k=1}^{K} z_{n,k} p_{n,k},$$
$$s.t. \sum_{n=1}^{N} z_{n,k} m_{n,k} \geq M_k \qquad (2)$$
$$\sum_{k=1}^{K} z_{n,k} = 1$$

Where M_k is the minimum data rate required by user k.

The problem above is a NP problem, which can be solved by linear programming. In [9], a suboptimal solution is proposed, and the subcarrier and power allocation is performed in two steps, subcarrier allocation and power allocation respectively.

In a multi-cell scenario, since the inter-cell interference should be taken into account in the subcarrier and power allocation, multi-cell coordination is necessary for the central algorithm, which will lead to a complex system architecture and heavy signaling overhead. In this paper, the distributed control is considered, and no multi-cell coordination is necessary. The power of Node B is allocated uniformly on every subcarrier, and thus the problem is simplified as multiuser subcarrier allocation.

A. M-LWDF algorithm

For real time service, Modified Largest Weighted Delay First (M-LWDF) [6] is regarded as the optimal scheduling for real time service in CDMA system. For multiuser OFDMA system, it is modified further to adopt the multi-channel allocation simultaneously. The scheduling of M-LWDF takes into account the maximum service delay $W_i(t)$ and channel status information of user i .The user priority function for subcarrier n is defined as:

$$\mu_{i,n}(t) = b_i W_i(t) \frac{r_{i,n}(t)}{\overline{r}_i} \qquad (3)$$

Where $W_i(t)$ is the delay of the first packet in the queue of user i . $b_i = -(\log \sigma_i)/W^i_{Max}$, σ_i is the maximum probability of $W_i(t)$ exceeds W^i_{Max} , $\Pr\{W_i(t) > W^i_{Max}\} < \sigma_i$. $r_{i,n}(t)$ is the transmission capability of user i on subcarrier n at time t , $\overline{r}_i$ is the average data rate of user i . $r_{i,k}(t)$ and $\overline{r}_i$ vary with time and are decided by the modulation and channel condition. The user with the highest priority value $\mu_{i,n}(t)$ obtains the chance to transmit on subcarrier n . If all services are the same type, and have the same QoS, then W^i_{Max} and σ_i are the same for all user, and the priority can be simplified as:

$$\mu_{i,n}(t) = W_i(t) \frac{r_{i,n}(t)}{\overline{r}_i} \qquad (4)$$

B. PLR algorithm

[7] has proposed a Packet Loss Ratio (PLR) algorithm for real time service. It calculates a priority for every user on every subcarrier, and allocates the subcarrier according to the user's priority, and the subcarrier is allocated to the user with highest priority value. The priority calculation takes into account the user packet delay $W_i(t)$, channel status $r_{i,n}(t)$, the user average throughput in past $\overline{r}_i$, and the user packet loss ratio $PLR_i(t)$. The priority function on subcarrier n is defined as:

$$\mu_{i,n}(t) = \begin{cases} W_i(t) \dfrac{r_{i,n}(t)}{\overline{r}_i} \dfrac{PLR^i_{\max}}{PLR_i(t)}, & if\ PLR_i(t) > PLR^i_{\max} \\ W_i(t) \dfrac{r_{i,n}(t)}{\overline{r}_i} \dfrac{k}{PLR^i_{\max}}, & if\ PLR_i(t) < k \leq PLR^i_{\max} \\ W_i(t) \dfrac{r_{i,n}(t)}{\overline{r}_i} \dfrac{PLR_i(t)}{PLR^i_{\max}}, & otherwise \end{cases} \qquad (5)$$

Where $PLR^i_{\max}$ is the maximum packet loss ratio defined the user,, k is a none-zero constant which is far smaller than $PLR^i_{\max}$.

C. QG Algorithm

For real time service, the service has a strict constraint on delay, but permits some packet drop ratio. To maximize the user number serving by the system, system may permit every user has a small packet drop ratio less than the pre-defined one. So we proposed the QG scheduling algorithm for RT service, the user priority is defined as:

$$\mu_i(t) = \frac{r_i(t)}{\overline{r}_i} \times f(PLR_i, W_i(t)) \qquad (6)$$

Where,

$$f(PLR_i, W_i(t)) = \begin{cases} 10^{W_i(t)/W_{Max}} \times 10^{PLR_i/PLR_{Max}}, \\ \quad if\ PLR_{Max} \geq PLR_i \\ 10^{W_i(t)/W_{Max}} \times 10^{(2PLR_{Max} - PLR_i)/PLR_{Max}}, \\ \quad if\ PLR_{Max} < PLR_i \end{cases} \qquad (7)$$

When PLR_i is small, the priority value of QG is less than that of proportional fairness; when PLR_i approaches PLR_{Max} , the priority increases fast; when PLR_i exceeds PLR_{Max} , the priority is decreased to avoid wasting on the limited radio resource by the user with bad channel condition. Figure 1 is an example of the priority function.

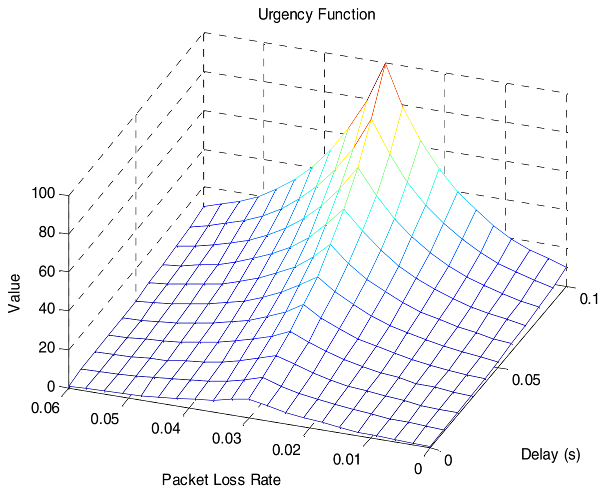

Figure 1 user priority function vs. PLR_i and packet delay

III. SIMULATION PARAMETER

In the simulation, Modulation and Coding Scheme (MCS) adopted is given in Table 1, the convolution coding are combined with QPSK, 16QAM to create 5 MCS. No H-ARQ is considered in link level simulation, but the chase combining is adopted in system level simulation. The suitable MCS is selected from the Table 1 to transmit data symbol on every subcarrier. The SNR threshold for MCS as Table 1 is obtained.

TABLE 1 THE MCS AND THE SNR THRESHOLD

MCS	Mod	Code Ratio	data bits	SNR threshold
1	QPSK	1/3	2/3	0.5dB
2	QPSK	1/2	1	3.7dB
3	QPSK	3/4	3/2	6.3dB
4	16QAM	1/2	2	10dB
5	16QAM	3/4	3	15.2dB

To avoid the heavy signaling loading, every continuous 8 subcarriers are combined together as a basic resource unit, named as a sub-channel, in which the same modulation and coding scheme is used for all subcarriers. One sub-channel is assigned to one user according to the algorithms we proposed in section II. The power of a Node B is uniformly allocated on all the subcarriers. A soft frequency reuse scheme [11][12] is adopted. The same frame structure of LTE TDD [10] is adopted in our work.

In this paper we consider video traffic model, and the 500kbps video is defined as Table 2.

If the user has 5% packets are dropped during the communication, then the user is regarded as unsatisfied. The other system simulation parameters are as Table 3.

TABLE 2 TRAFFIC MODEL PARAMETERS

Video Stream model	Value
Inter-arrival time between the beginning of each video-frame	100ms
Number of video-packet in a frame	8
Video packet size	400byte
Inter-arrival between video-packets in a video frame	Truncated Pareto *K*=2.5 alpha = 1.2 *M*= 12.5ms
Video packet max delay time	200ms
Video average data rate Video minimum data rate	500kbit/s 128kbit/s
Video length	120s

TABLE 3. SYSTEM PARAMETERS

Parameter		Assumption
Carrier Frequency		2GHz
Band width		10MHz
Sample Frequency		15.36 MHz
Sub-carrier spacing		15 kHz
CP length(μs/samples)		7.29/14
FFT Size		1024
Occupied Subcarriers number		601
Subcarrier Group number		75
Inter-site distance		2Km
Cell number		27 (9 clusters)
Distance-dependent path loss		L=128.1 + 37.6log10(R)
Shadowing standard deviation		8 dB
Correlation distance of Shadowing		50 m
Shadowing correlation	Between cells	0.5
	Between sectors	1.0
Penetration Loss		20dB
Channel model		Typical Urban (TU)
Total BS TX power (Ptotal)		43dBm
Minimum distance between UE and cell		>= 35 meters
User data rate		500Mbps
H-ARQ		Chase combining

IV. SIMULATION RESULTS

In this section, the simulation results of the modified M-LWDF, PLR and QG scheduling algorithms for real time service are presented as Figure 2, Figure 3 and Figure 4.

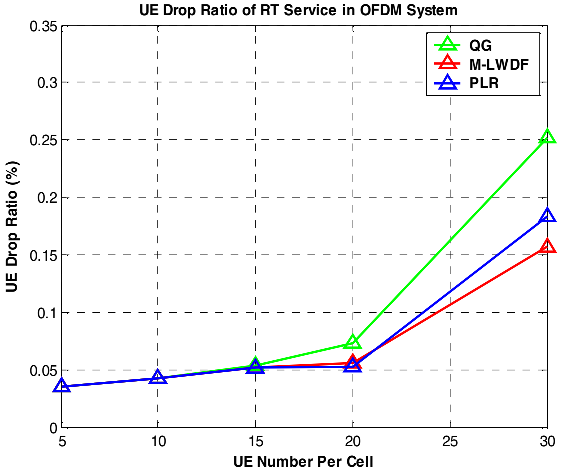

Figure 2 user number vs. drop ratio

From the simulation results, three algorithms almost have the same performance when system load is low, and the radio resource is enough to offer service for video service; however when the system load increases, the performance gap becomes larger. M-LWDF has the best performance since it can maximize the packet waiting time and thus leads to a lower drop ratio. QG and PLR take into account the user packet drop ratio and packet delay. Although they permit some dropped packet, they also consider the drop ratio and may define higher priority for users with higher packet drop ratio but bad channel condition and thus lead to inefficient resource utilization, lower transmission efficiency and higher user drop ratio.

For PLR, when $PLR_i(t)$ exceeds $PLR^i_{\max}$, the effect of the drop ratio on the priority function is decided by $PLR^i_{\max}$; while for QG, if $PLR_i(t)$ exceeds $PLR^i_{\max}$, the priority of user i is decreased since it experiences bad channel condition and will waste the limited radio resource. So QG improves the system throughput on condition that some user's packet drop ratio is increased. Summarily, PLR has a better user drop ratio than QG, but has a worse system throughput than QG.

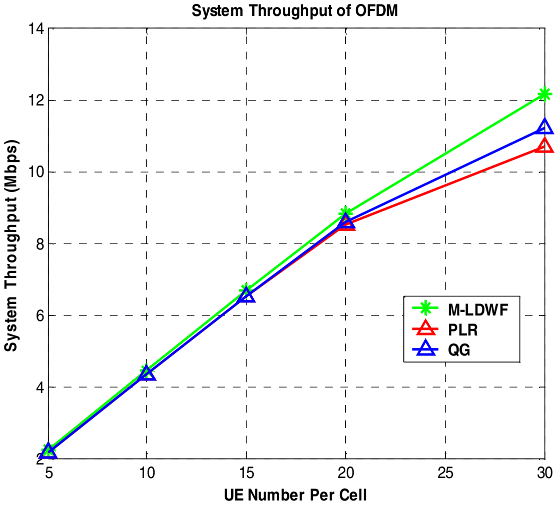

Figure 3 system throughput vs. user number

V. CONCLUSION

In this paper, the multiuser subcarrier allocation is investigated for real time service. By exploiting the channel status information, the multiuser diversity gain in frequency domain is expected to be achieved. By exploiting the queue status information, the delay sensitive service can be served well. Based one these, the channel and queue aware scheduling is proposed for real time service in multiuser OFDMA system, and modified M-LWDF, QG scheduling algorithms are proposed and compared to PLR scheduling algorithm. Three algorithms almost have the same performance when system load is low and the radio resource is enough to offer service for video service; however when the system load increases, the performance difference becomes larger. The modified M-LWDF has the best performance, while QG has a better system throughput than PLR, but a worse user drop ratio than PLR.

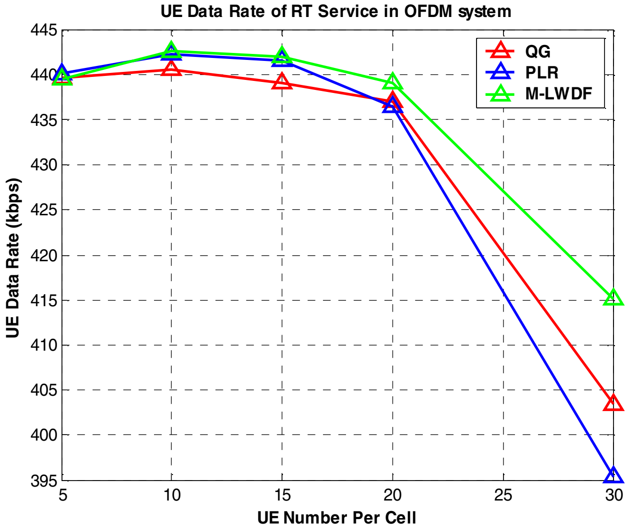

Figure 4 average user data rate vs. user number

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