A Dynamic MaxPRB-adjusting Scheduling Scheme based on SINR Dispersion Degree in LTE System

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Abstract—**The max C/I, Round Robin (RR) and Proportion Fair (PF) are three primary scheduling schemes adopted by LTE system to allocate shared resources among users in the time-frequency domain. However, most of the scheduling methods are static and ignore the relation between user dispersion degree of the sector and maximum PRB number (MaxPRB) allocated to one user. In this paper, we propose an improved dynamic MaxPRB-adjusting scheduling scheme (DDS) based on user SINR dispersion degree, which can win better tradeoff between throughput and user fairness in LTE downlink. Simulation results show that the proposed scheme will adjust the MaxPRB according to user SINR dispersion degree of the sector to obtain a good balance between sector throughput and user fairness.**

Key words-LTE；scheduling algorithm；dispersion degree；throughput；user fairness index

I. INTRODUCTION

LTE (Long Term Evolution) is the largest technology research and development project launched by the 3GPP (3rd Generation Partnership Project) in the recent 4 years. As a promising mobile communication technology, LTE improves air interface performance and enhances the spectrum efficiency by some key technologies, for example, OFDM (Orthogonal frequency division multiplexing), MIMO (multiple-input–multiple-output) and resource sharing [3]. So Compared with the previous technologies, LTE has some advantages, such as higher data rate and lower time latency. Furthermore, OFDM makes it possible to divide the radio-link resources in both time domain and frequency domain and this kind of distribution is more flexible to allocate and schedule resources[6][7]. In general, there are three major scheduling schemes, max C/I, Round Robin (RR) and Proportion Fair (PF), with different emphasis on throughput and user fairness. Max C/I algorithm always allocates wireless resource to the user who has the best current channel quality. In contrast, RR algorithm gives equal scheduling chance to each user in the cell. Actually, PF is a compromise method of Max C/I and RR, which tries to balance the system throughput and user fairness.

Obviously, scheduling algorithms have significant influence on user experience and throughput performance in a resource-sharing system, such as LTE, because it decides how to allocate radio resource among users with different wireless channel conditions. In [5], the authors proposed several principles to consider in the scheduling algorithm: 1). Maximize the overall system throughput; 2).Graceful compensation of large delays; 3).Fairness in resource sharing. In this paper, we mainly talk about how the scheduling algorithm can balance the throughput and user fairness. Two key factors are given in the proposed scheduling algorithm, one is user SINR dispersion degree of the sector, and the other is maximum PRB number (MaxPRB) for one user in each transmission time interval (TTI). PRB (Physical Resource Block) is the basic scheduling unit in LTE. To the best of our knowledge, these two factors have not been studied jointly. Hence, based on dynamic adjusting MaxPRB according to the SINR dispersion degree of the sector, this paper proposes a dynamic scheduling strategy to improve LTE system capacity while maintaining fairness among different users.

The article is organized as follows. In Section II, we attempt to introduce related works and compare the performance of most popular scheduling schemes. In section III, we put forward our dynamic scheduling algorithm in detail. The simulation results are shown in the figures and the analysis is presented in section IV. Finally, conclusions drawn from this article are summarized in section V.

II. RELATED WORKS

In the wireless communication system, scheduling is a core technology for radio resource management. In LTE system, we need to use scheduling to share the limited bandwidth among multiple active users. So an efficient scheduling mechanism is needed to order these users for efficient resource allocation. And the scheduling in the wireless system is different from wired system, because it faces a more complex condition: time-changing channel environment, limited radio resources and so on.

In LTE, radio resources are divided into PRBs by the application of OFDM technology, as shown in Fig.1. One PRB contains one slot (0.5 ms) in the time domain and 180 kHz in the frequency domain. So radio resource can be scheduled both in time domain and frequency domain. As the LTE bandwidth

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is 20MHz, we pay more attention to the frequency selective fading characteristics of the wireless channel. With frequency selective scheduling, we can assign the optimum frequency band to the most suitable user at each time and make the system to obtain a multi-user gain in the frequency domain.

In LTE downlink, the scheduling is mainly based on reported CQI (Channel Quality Indication), which represents the downlink SINR (Signal to Interference plus Noise Ratio). CQI is obtained by measuring the reference signal and shows the state information of different frequencies.

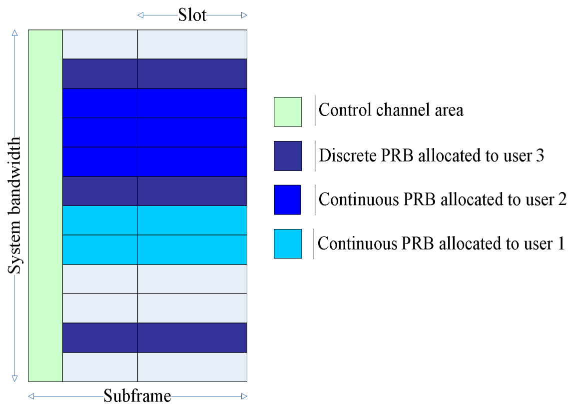

Figure 1. Sketch map of OFDM resource allocation

There are several indicators to determine the performance of the scheduling, such as the average throughput, fairness, etc. The average user throughput is the mean value of throughput that a user receives in a determined time window. The following equation is given to describe the average user throughput:

$$\overline{R(t)} = \frac{\int_{t-\Delta t}^{t} R(x)dx}{\Delta t} \quad (1)$$

Where Δt means a very short time and R(x) stands for instant data rate.

Fairness index is quite indispensable to judge the resource allocation for each user. Since the fairness index is an abstract quantity, we use the following formula defined in [9] to evaluate it. If a system allocates resources to ***n*** users, such that the user ***i*** receives an allocation x_i, then we propose the following index for the system:

$$f(x) = \frac{[\sum_{i=1}^{n} x_i]^2}{\sum_{i=1}^{n} x^2} x_i \geq 0 \quad (2)$$

This index measures the "equality" of user allocation ***x***. If all users get the same amount, i.e. x_is are all equal, then the fairness index is 1, and the system is 100% fair. As the disparity increases, fairness decreases and a scheme which favors only a selected few users has a fairness index near 0.

The max C/I, Round Robin (RR) and Proportion Fair (PF) are three major scheduling schemes used by LTE system to allocate shared resources. Now let's have a brief discussion about them.

Max C/I algorithm takes the instant radio-link condition into account and offers the best usage of the radio link resources. At each time interval, it selects the user with the best channel condition. This method can achieve nearly the peak data rate of the system. Mathematically, Max C/I scheduling method can be expressed as follows, for the scheduling user ***k***:

$$k = \arg\max_i R_i \quad (3)$$

Where R_i is the instantaneous data rate for user ***i*** [8].

Although Max C/I can be used to achieve almost the best system capacity, this method will not be fair in all situations, especially for edge users, whose radio link condition is very poor. If all users possess the same priority, fairness will be naturally guaranteed. And this is the basic principle of Round Robin (RR) method. RR aims at ensuring the fairness on user experiences. It can be seen as a fair scheduling algorithm that the same amount of radio resources is given to each user equally. However, RR cannot ensure the same quality of service to all the users, and system capacity is much lower than its peak rate. Thus, we need to seek out a scheduling scheme which is able to improve the overall sector throughput while still considers the fairness. Proportion Fair (PF) algorithm tunes the system throughput and fairness between max C/I and Round Robin (RR). That is to say, it tries to achieve the throughput rate as high as possible while avoid user fairness becoming too worse. In any allocated period, user ***k*** is selected for transmission when it has the highest priority:

$$k = \arg\max_i \frac{R_i}{\overline{R_i}} \quad (4)$$

Where R_i is the instantaneous data rate for user ***i*** and $\overline{R}$ is the average data rate for user ***i***. The average rate is calculated over a certain averaging period T_{PF}[8].

III. The Proposed Scheduling Algorithm

In [1], the authors investigate the rate and power consumption performance on the downlink of a 3GPP LTE-OFDMA system in combination with a number of proposed dynamic resource scheduling and allocation algorithms. In [15], new adaptive scheduling and resource allocation algorithms for frequency-selective time-varying downlink channels are proposed. This two articles concern on different emphasis about downlink scheduling of LTE system. However, none of them have ever taken SINR dispersion degree of the sector and MaxPRB into account. When user distribution is changed, the MaxPRB should be set to suitable values. The definition of dispersion degree and MaxPRB will be given firstly in this section, and then the description of our proposed scheduling algorithm (DDS) is presented.

A. SINR Dispersion Degree of the Sector

In general wireless system, SINR (Signal to Interference plus Noise Ratio) is an important indicator to measure the quality of radio link. It is usually defined as the ratio of received signal power to received interference plus noise power. Because SINR represents the current channel condition, it's a key factor to decide how many RBs（Radio Bearer） can be allocated to the specific user. When users are distributed in different position in the sector, they would experience different level of SINR due to their path loss, shadow fading and penetration loss.

Therefore according to various environment aspects, we define α to represent the maximum value of sector SINR dispersion degree, thus the dispersion ranges from one to α. From the empirical CDF curve of SINR shown in Fig.2, it can be concluded that user's SINR distributes almost in a linear way. According to this evidence, we introduce the definition of SINR dispersion degree. Firstly, the whole SINR region will be divided into α sections equally. Secondly, calculate every user's SINR in the given sector. $D(C_i)$ is a logic value (shown in the following) which is used to indicate whether users' SINR locate into this section ***i***. C_i represents the section i that $D(C_i)$ belongs to. If a user's SINR locates in section C_i , then $D(C_i)$ will be marked to be one. Otherwise, $D(C_i)$ is set to zero. Thirdly, in this given sector ***j***, the SINR dispersion degree D_j can be calculated by the sum of $D(C_i)$:

$$D(C_i) = \{x | x = 0 \ or \ 1\}$$
$$D_j = \sum_{i=1}^{\alpha} D(C_i) \qquad (5)$$

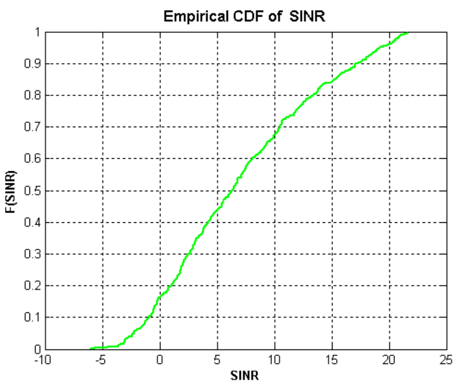

Figure 2. The empirical CDF curve of user's SINR

B. Maximum PRB Number for one user in one TTI (MaxPRB)

In LTE system there are different types of resource allocation methods. The allocation scheme of PRB directly affects the gain and fairness of the users. Besides SINR, there is another important factor in the scheduling algorithm, i.e. MaxPRB. MaxPRB stands for the maximum number of PRB that can be allocated to a user in a scheduling period (TTI). In our proposed method, we try to get more insight into the effect of changing MaxPRB on scheduling method.

C. New Proposed Dynamic Scheduling Algorithm Based on SINR Dispersion Degree（DDS）

The main challenge in scheduling algorithm is to endeavor to achieve the best spectrum efficiency, as well as to maintain certain reasonable degree of user fairness. Under different system environment, it's quite important to tune the scheduling parameters properly to adapt the changes. For that purpose, it's necessary for us to seek out the optimum MaxPRB to fit the different dispersion degree of the sector.

Generally speaking, when dispersion degree is low, that means users' SINR are relatively centralized. In this scenario, fairness is a minor factor to be considered because each user has high probability to get a chance to send its packets in a short time interval. If we increase the MaxPRB, the users with better channel condition will get more resources. Thus the whole system capacity can be improved to a large extent at a little cost of fairness sacrifice. When dispersion degree is high, it indicates that different users experience very distinct SINR levels. Some users may locate in good channel environment while others may be in very poor radio condition. In this circumstance, we need to decrease the MaxPRB to guarantee user fairness. It limits the maximum allocation PRB number for one user to avoid too much resource to be distributed to only a few users. Fig.3 shows the steps used to express our method.

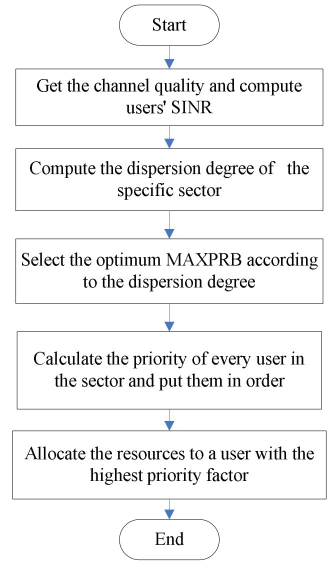

Figure 3. The empirical CDF curve of user's SINR

To sum up, sector dispersion degree and MaxPRB can jointly affect the system throughput and fairness, and it is always neglected by other scheduling algorithms. Based on the analysis above, we put forward a new formula which contains both MaxPRB and dispersion degree:

$$M = \mu D + \lambda \qquad (6)$$

Where D stands for dispersion degree, M represents MaxPRB. μ and λ are two flexible constant parameters which can be adjusted according to different scenes. Here, μ is always set as negative number. That means the bigger the dispersion degree is, the smaller MaxPRB will be.

Due to different dispersion degree of the sector, each sector selects its best suitable MaxPRB to gain high system capacity. Meanwhile, it can prevent fairness among all the users from falling down drastically. Therefore, our dynamic algorithm can achieve remarkable tradeoff between throughput and fairness under almost all practically relevant conditions.

IV. SIMULATION AND COMPARISONS

The evaluation is based on a TD-LTE simulation platform. The total system bandwidth can be divided into physical resource blocks (PRBs) and allocated to different users. There are 100 PRBs in the 20MHz bandwidth system, each consisting of 12 adjacent sub-carriers. Every user computes the average SINR across all the sub-carriers in each PRB and reports to eNB using CQI (channel quality indicator) information. Thus eNB receive CQI reports from all users. So the achievable data rate of one user on each PRB will be estimated by the eNB based on the reported CQIs. At last, the eNB allocates PRBs to the specified user according to the resource allocation scheme. The main parameters of the simulated LTE system are given in Table I.

We adopt a 19 hexagonal cell layout model while each cell consists of 3 sectors. The inter-site distance is 500m. The carrier frequency is 2GHz and the system bandwidth is assumed to be 20MHz. There are 570 UEs (user equipment) uniformly distributed. The simulator uses the SU-MIMO as the MIMO scheme and SCM as the channel model. The HARQ can have 10 processes with up to 3 retransmissions.

TABLE I. . SIMULATION PARAMETERS FOR LTE OFDMA DOWNLINK

Cellular layout	Hexagonal grid, 19 cell,3 sectors per cell
Carrier frequency	2GHz
System bandwidth	20MHz
total number of PRB	100
TTI length	0.001 second
Channel model	SCM channel
Inter-site distance	500m
Propagation model	128.1+37.6log10(X),X(km)
Thermal noise density	-174 dBm/Hz
Penetration loss	20dB
FFT size	1024
Total number of UEs in the system	570
HARQ	10 processes with up to 3 retransmissions
MIMO scheme	SU-MIMO
Scheduling scheme	DDS,RR,MAX C/I,PF
Traffic model	Full buffer

As analyzed in the previous chapter, different MaxPRB values applied in a specific dispersion degree conditions can achieve quite different results. In the simulation, we divide our dispersion degree into 10 different sections. In formula (6), we set μ as -10 and λ as 110.

The normalized sector throughput and user fairness with different dispersion degrees are shown in Fig.4 and Fig.5 respectively. And for a specific dispersion degree, the figure goes through the MaxPRB at a step length of 10 PRB. Here, we take dispersion degree which equals to 1, 5 and 8 for example. As we can see, when dispersion degree equals to one, the throughput reaches its peak when MaxPRB equals to 100. In this case, the fairness remains in a medium level. Furthermore, when dispersion degree equals to eight, the throughput gets its maximum value when MaxPRB equals to thirty. By now, the fairness stays in a high level. When dispersion degree equals to five, the throughput and fairness both keep in a better level. So the three cases can appropriately verify our dynamic scheduling algorithm. When the sectors have other dispersion degrees, the situations are similar as well.

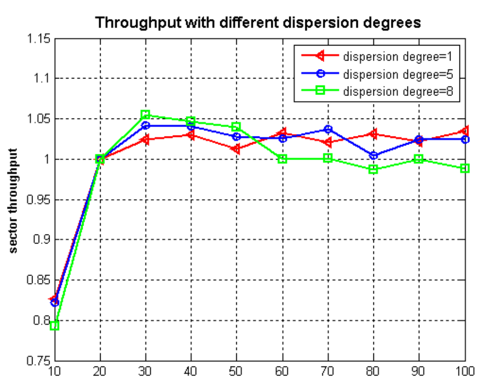

Figure 4. Sector throughput with different dispersion degree

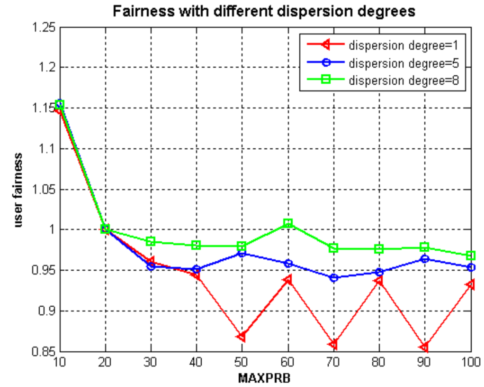

Figure 5. User fairness with different dispersion degree

In the system level simulation, we create two scenarios for comparison and discussion. In scenario I, each sector has exactly ten users in it. This scenario can be used as a baseline. Meanwhile in scenario II, 570 users are distributed randomly in the 57 sectors, and the maximum user number in each sector is less than 30. From the settings, we will regard scenario I as an ideal condition and scenario II as a more practical one.

In scenario I, Fig.6 and Fig.7 illustrate the performance of three traditional scheduling algorithms, i.e. MAX C/I, RR, PF and our algorithm DDS. In terms of sector throughput, MAX C/I algorithm achieves the highest throughput while RR has the lowest one, because MAX C/I only considers the instantaneous channel strength. However, in terms of user fairness, MAX C/I algorithm is much worse than RR, indicating that many users actually cannot enjoy service at all. So MAX C/I and RR cannot satisfy the demand of most users or effectively promote the capacity of whole system. Compared with PF, DDS improves the sector throughput by almost 7%. At the same time, user fairness of DDS only declines slightly by about 4%. From the discussion above, we can see our algorithm DDS obtains significant improvement of system capacity while keeps user fairness in a favorable degree.

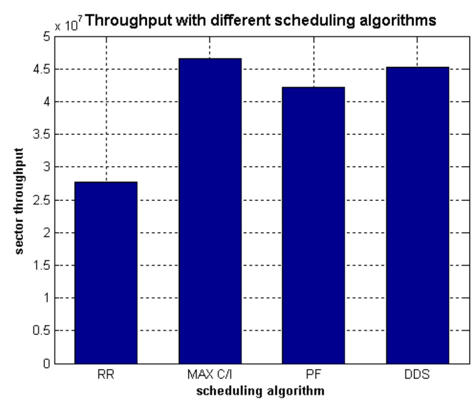

Figure 6. Throughput with different scheduling algorithm in scenario I

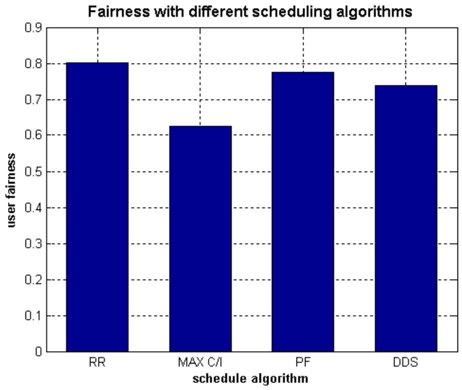

Figure 7. User fairness with different scheduling algorithm in scenario I

In scenario II, as depicted in Fig.8 and Fig.9, MAX C/I and RR algorithms have nearly the same performance as in scenario I respectively. Nevertheless, DDS has superior performance than the PF algorithm in both sector throughput and user fairness. As scenario II is more likely close to the practical scene, DDS is an optimized scheduling scheme compared with others.

In brief, our proposed method DDS owns several obvious advantages over the traditional algorithms. Note that, it gives considerations to both system throughput gain and user fairness index. In addition, it can also be applied to different user distribution situations.

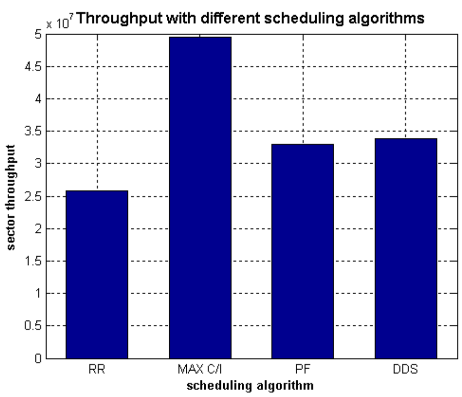

Figure 8. Throughput with different scheduling algorithm in scenario II

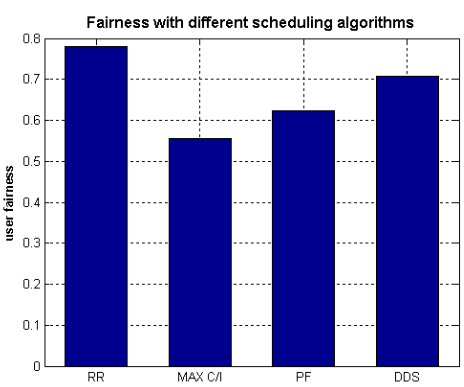

Figure 9. User fairness with different scheduling algorithm in scenario II

V. CONCLUSION

In order to derive the feasible optimized scheduling of the LTE downlink, a novel scheduling algorithm based on PF has been put forward. It's a dynamic scheduling strategy which adjusts the MaxPRB according to the SIN dispersion degree of the sector to achieve the suitable tradeoff between throughput and user fairness. We compare the simulation results of the system throughput and the user fairness among the most commonly used algorithms. From the simulation results, we can see this proposed algorithm DDS has a significant improvement of the system throughput. Meanwhile it can balance fairness well both in ideal and practical user distribution situations.

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