Research on Sliding Window Uplink Frequency Domain Scheduling Scheme in LTE-A

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Abstract. In order to advance the transmission data rate and meet the traffic needs of users, the higher requirements for wireless communication system radio resource management was put forward by mobile operators. Meanwhile, considering lower rate radio resource utilization resulted from unreasonable particle size of resource allocation in existed researches on LTE-A uplink frequency domain scheduling, a dynamic resource allocation scheme based on sliding window is proposed to improve the performance. The program determines the user's resource allocation size dynamically relay on the required one. And the sliding window mechanism is used to search the optimal channel quality resources for the user in the whole system resource. Simulation results show that compared to the fixed resource granularity of traditional programs, the dynamic resource allocation scheme based on sliding window gains more significant improvement in the system throughput and RB utilization and effectively improves the system spectral efficiency.

Introduction

With the wide application of intelligent terminals, a reasonable and effective scheduling policy should be designed in the wireless communication system with limited resources to improve customer service satisfaction, multi-user diversity gain, system throughput and make full use of spectrum resources.

Single-carrier Frequency Division Multiple Access (SC-FDMA) technology is applied as the physical layer transmission scheme by 3GPP organizations in LTE-A uplink. Compared to OFDM scheme in downlink, SC-FDMA scheme not only can resist the co-channel interference and channel fading more effectively, but also can reduce the Peak to Average Power Ratio (PAPR) better and meet up lower power requirements. However, the radio resources assigned to the user must be continuous for SC-FDMA, further limiting the flexibility of scheduling uplink resources and increasing higher challenge of uplink scheduler resource allocation.

In LTE-A protocols, one resource block (RB) act as resource scheduling element, including 12 adjacent sub-carriers (15kHz) in frequency domain and 7 OFDM symbols in time domain (conventional CP)[1], and time domain size of resource scheduling is one TTI (1ms). One RB can only be occupied by one UE which may be required a plurality of RB based on data buffer volume, and the continuous frequency domain[2] is limited. The target of uplink resource scheduling is based on the frequency-selective channel, allocating resources of the optimal channel quality for user to improve the throughput of the system.

Four uplink resource scheduling algorithms have been studied in [3], analyzing the defects and disadvantages in extreme situations. A RB Grouping algorithm has been proposed in the fourth algorithm to avoid the impact of small-scale fading by the frequency domain correlation among adjacent resource. Furthermore, the RBG acted as the smallest unit of resource allocation, system bandwidth and the number of scheduling users were used to determine the size of RBG and the maximum scheduling metric RBG was assigned to the user in the algorithms. In [4], a frequency-selective scheduling scheme was developed with the priority sorting of system resources based on the reported of UE channel quality indication and the best resources of channel quality with the scheduling priority. The particle size of resource allocation is based on the sub-band of PRB reported by CQI to look for the basic unit of PRB resources and the scheduler retrieves the best sub-band of CQI in the entire band. To ensure the QoS, one scheduling policy was proposed by introducing the weighting factor of dynamic QoS by using RC resource allocation scheme in frequency-domain scheduling, which meant using the RC as the granularity of resource scheduling, establishing UE-RC(RC = 3PRB) pairs, and finding the necessary resources for users via the "search tree" algorithm[5][6]. The minimum unit allocated by frequency domain scheduling resource with the relatively fixed size had no direct relationship between the size of resource required by the user. In this case, the smaller particle size of resource would cause discontinuous allocation resources. Otherwise, it may lead to the waste of resources and lower resource utilization. Therefore, a dynamic sliding window resource allocation scheme is proposed in this paper, which can significantly improve system throughput and resource utilization.

Model of Resource Scheduling

Assuming that the system bandwidth of the serving cell is 20MHz in LTE-A, i.e., divided into 100 PRB (M = 100). Meanwhile, the number of scheduled users is N in the cell and in the scheduling cycle users always have data to send, which means that the user has been needing to be scheduled.

Defining a variable $x_i^c(t)$ as whether subframe resource RBc in TTI = t assigned to the user, $x_i^c(t) \in (0,1)$. Channel quality conditions mainly dependent on the frequency-domain resources, the users, the user's location and time slot. Therefore, resource blocks depend on the users and time-varying channel conditions. $\gamma_i^c(t)$ represents the instantaneous data rate the user i obtained with subframe resource RBc in TTI = t. It is indicated that the amount of data transmission on the RBc for user i evaluated as $x_i^c(t) \cdot \gamma_i^c(t)$ [1].

Since the proportional fair scheduling algorithm can be a good balance between throughput and fairness of the user, so the algorithm is widely used in the actual mobile communication system. In this paper one based on dynamic sliding window resource allocation scheme based on proportional fairness metric in the frequency domain is adopted to allocate frequency domain resource for scheduling users.

The objective function [6] of frequency domain proportional fairness (PF) algorithm could shown as:

$$\max \sum_{i}^{N} \log R_{avg,i}(t), i \in (1,2,...,N) \tag{1}$$

In order to meet the objective function PF, $\sum_{i}^{N} \frac{r_{inst,i}(t,n_i)}{R_{avg,i}(t)}$ should be maximized. Where $r_{inst,i}(t,n_i)$ is the average transmission rate in the last t sub-frame for user i. The instantaneous transmission rate obtained in resource block RB ^{n_i} for user i in the sub-frame of TTI=t, donated as $r_{inst,i}(t,n_i)$, and $r_{inst,i}(t,n_i) = \sum_{c}^{c+n_i-1} x_i^c(t) \cdot \gamma_i^c(t)$. Therefore the specific objective function PF can be evaluated by:

$$\max \sum_{i}^{N} \frac{r_{inst,i}(t,n_i)}{R_{avg,i}(t)} = \max \sum_{i}^{N} \frac{\sum_{c}^{c+n_i-1} x_i^c(t) \cdot \gamma_i^c(t)}{R_{avg,i}(t)} \tag{2}$$

Where $\lambda_i^c(t)=\dfrac{\gamma_i^c(t)}{R_{avg,i}(t)}$, Eq.(2) can further convert to Eq.(3) which shown as:

$$\max\sum_i^N\frac{r_{inst,i}(t,n_i)}{R_{avg,i}(t)}=\max\sum_i^N\sum_c^{c+n_i-1}x_i^c(t)\cdot\lambda_i^c(t) \tag{3}$$

$$\begin{cases}\sum_i^N x_i^c(t)\le 1,\forall c\in(1,2,...,M)\\ \sum_i^N\sum_c x_i^c(t)\le M\end{cases} \tag{4}$$

By Eq.(3), $\lambda_i^c(t)$ is the frequency domain proportional fair PF metric for user i in TTI=t, which indicating the channel quality weigh of resource RBc and as a measure of channel quality metric allocated by the frequency-domain resources. Uplink scheduler allocates optimal continuous resource for users based on the value of $\lambda_i^c(t)$ over the entire system bandwidth. Eq.(4) is a resource constraint, indicating that one RB maximum used by one user and all of the resources should not exceed the system bandwidth.

Dynamic Sliding Window Scheme

For the problem irrationally allocating particle size of resources of existing research, dynamically adjusting the resource size scheme, according to reach scheduling period per user, acting as the size of sliding window to successively slidably search the resource needed by user on the overall system bandwidth, is adopted in this paper. Methods for determining the particle size of the dynamic resource is mainly based on its own data buffer volume of users, the transmit power of users, and the requirements of uplink single carrier in protocol.

(1) Assume that The current amount of data buffer is $B_i(t)$ for user i. The modulation and coding scheme through the link adaptation for the user is given by mcs and the encoding efficiency is efficiency. So the amount of data bore by a resource block is $b_{i,RB}(t)$, which denoted by Eq.(5). It can be seen that the resource size needed by users could be calculated by Eq.(6).

$$b_{i,RB}(t)=efficiency\times mcs\times 144 \tag{5}$$

$$n_0=ceil(B_i(t)/b_{i,RB}(t)) \tag{6}$$

(2) According to the PUSCH power control in protocol, the reported power headroom PH informs the base station to adjust the transmit power of user, where PH is expressed by Eq.(7). The maximum size of the resource expected by user can be further restricted according to the PH , evaluated by Eq.(8).

$$PH(t)=P_{CMAX}-P_{PUSCH}(t)=P_{CMAX}-\{10\log M_{PUSCH}(t)+P_{pre\_RB}(t)\} \tag{7}$$

$$P_{CMAX}-P_{pre\_RB}=PH(t)+10\log M_{PUSCH}(t) \tag{8}$$

$$n_1=\max\left\{1,\ floor(10^{\frac{PH+10\log(M_{PUSCH})}{10}})\right\} \tag{9}$$

Where P_{CMAX} represents the maximum transmission power configurated by the system for user, M_{PUSCH} is the number of scheduling resource blocks obtained with UE reporting and the transmit power allocated by user in every RB is defined as $P_{per\_RB}(t)$.

The maximum number of RB, desired by the current user, can be got by the two constraints above, derived as :

$$n_i=\min\{n_0,n_1\},i\in(1,2,...,N) \tag{10}$$

(3) The number of RB, predetermined to user ,used for PUSCH transmission , can only be the product of 2, 3 and 5 according to LTE-A system protocol, i.e., the number of resource blocks

$M_{PUSCH} = 2^{\alpha_2} \cdot 3^{\alpha_3} \cdot 5^{\alpha_5}$, where α_2, α_3, α_5 are a set of non-negative integer values[7]. The number of RB n_i assigned by the user must meet the above requirements. Otherwise, RB size n_i desired by user should be selected the value, the nearest and less than or equal to $M_{i,PUSCH}$, satisfied the number of the single carrier.

Resource allocation granularity of per user in each scheduling cycle, represented as the size of sliding window to search for the resources with a optima channel quality metric on the entire bandwidth, decided by the above three factors. Assuming that the RB for user i can be derived as $n_i = 4$ and resource sliding searching begins from system band in Fig.1.

The size of the sliding window is consistent with the user's expecting number of RB($\mathrm{n_i}$), and all PF measurements of the RB within a window should be made a statistics every time when the window slide backwards,which is remarked as a priority coefficient of the frequency domain scheduling P_{j}, as defined in the Eq.(11). Search the whole band and find out the maximum P_{j} as the result of the resource allocation of user, and it will continue until all resources have been searched for once or all users have been allocated resource.

$$P_{\mathrm{i}} = \max_j P_j = \max_j \sum_{c=j}^{j+n_i-1} \lambda^c(t) \tag{11}$$

Where j stands for the beginning serial number of the window, n_i stands for the user's expecting maximum number of the RBs, which means the size of the sliding window. After the sliding window's sliding over the whole bandwidth, the maximum P_{j} should be found out as the priority P_i of the user i, the window of which should be chosen for the resource allocation result of the user. Detailed dynamic sliding window resource allocation process is shown in Fig.2.

Complexity analysis:

The number of user’ s expecting RBs is n_i, and by sliding window's searching user's required resources over the whole bandwidth,the worst occasion needs to search for $M - n_i + 1$ times, which asks for exchanges for $M - n_i$ times to find out the maximum value of the window. Therefore, it will cost $\sum_{i}^{N}(2M - 2n_i + 1)$ times for N users using sliding window in resource allocation scheme to find and exchange in a cell, that is to say the complexity of the scheme is $O(M \cdot N)$.

Simulation Analysis

With regard to the dynamic sliding window resource allocation scheme proposed in this paper, the performance simulation and the verification of the validity of the scheme will be done in the LTE-A system level simulation platform. And the configuration of the simulation parameters in the system simulation platform goes as Table 1.

Simulation scenario Settings:

In accordance with 3GPP standards and LTE / LTE-A protocol stack, the system-level platform simulation is built, on which the performance simulation and comparative analysis of the algorithm before and after improvement have been done, simulation scenarios are set as follows:

Scenario 1: The users are randomly spread in a cell, and under the circumstance that the number of requesting scheduling users is different, the influence of the first maximum expansion(FME) algorithm, the recursive maximum expansion(RME) algorithm and the improved sliding window based resource allocation scheme on the system throughput has been simulated, as shown in Fig.3.

Scenario 2: Under different channel conditions, respectively, the improvement of the system throughout shown in Fig.4 has been simulated by setting the UEs location near point, midpoint,far point or random spread after using the sliding window based resource allocation scheme.

Scenario 3: It has been simulated the impact to the system spectrum efficiency and he utilization of the resource blocks within the system bandwidth using different resource allocation algorithms ,where the users are evenly distributed, as shown in Fig.5 and Fig.6 respectively.

Table 1. System simulation parameters configuration table

parameters	Configurable value
cell radius	289/1000m
carrier frequency/system bandwidth	2GHz,5/10/15/20MHz
path loss	L=34.5+35log10（d）,m is the unit of d
shadow fading	lognormal
standard deviation of shadow fading	8dB
antenna configuration	omnidirectional,downlink 2T/2R
	uplink 1T/2R
channel model	SCME channel model
UE position	randomly distributed/near/middle/far point
UE speed	0,3,30,120km/h
transmission power of base station	43dBm(20W)on every antenna
the maximum transmit power of UE	23dBm
power control	α=0.8,Po=-76dB
distance between UE and base station	>=35m
the average SINR model of the subcarriers	EESM
modulation	adaptively select
service type	InfiniteBuffer/GBR

Simulation results analysis:

(1) The system throughput simulation results show that with the increasing number of the mobile users in the cell, the throughput is gradually rising, this is caused by the multi-user gain. And with the increase of the number of users, the improved scheme makes it more rational as with resources allocation. In scenario 2, with users distributed at different locations in the cell, the throughput increment simulations in near, middle and far locations have been respectively accomplished under different channel conditions.

(2) As is known, the RB utilization rate is a statistics of a proportion of the number of the RBs that can be assigned to the users in the system resources among the RBs in the entire system.The simulation results show that the RB utilization can be well improved by the improved scheme, with the advantage of reducing RB debris. Meanwhile, the spectral efficiency of the system can be well improved, which has particularly described in Fig.5 and Fig.6.

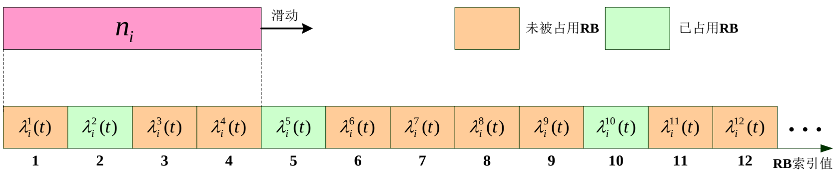

Fig.1. Schematic diagram of the sliding window searching mechanism

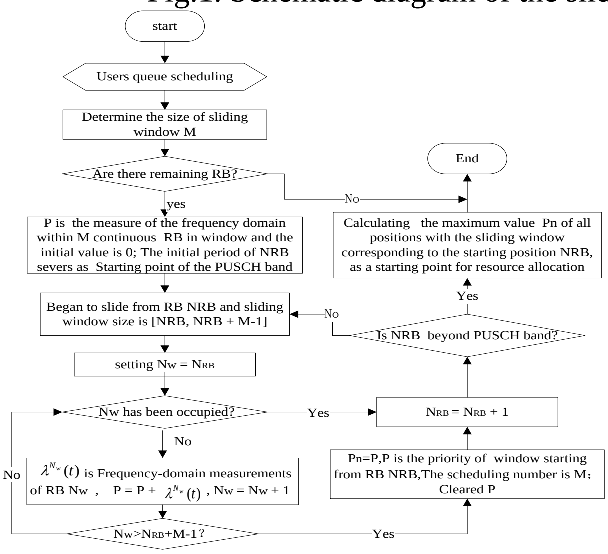

Fig.2. The flowchart of searching by dynamic sliding window

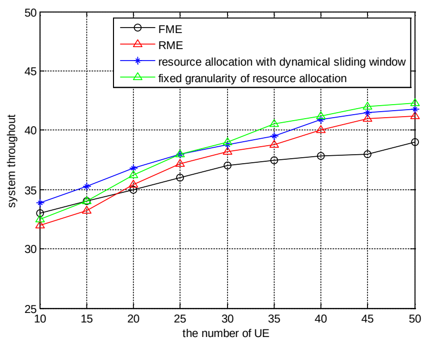

Fig.3. System throughput related to the number of users

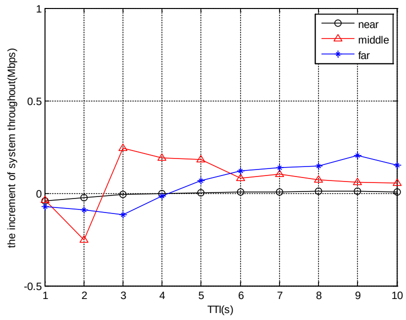

Fig.4. The increment of system throughout in different channel conditions

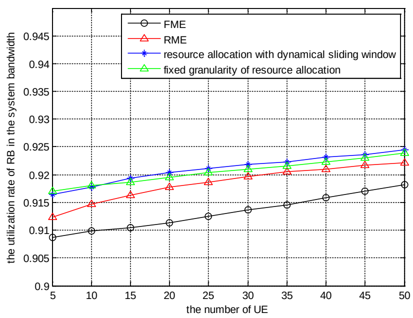

Fig.5. The utilization of system resource RB

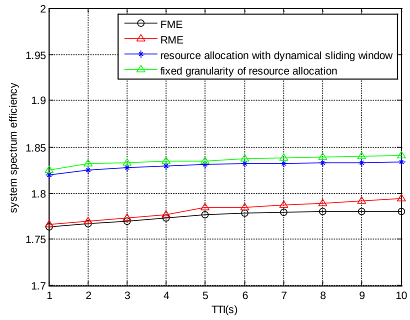

Fig.6. System spectral efficiency

Conclusion

Due to the relatively fixed existing uplink resource allocation granularity, which results in irrational allocation of resources and low resource utilization efficiency, the proportional fairness uplink resource scheduling algorithm in the LTE / LTE-A system has been studied in this paper. Under the premise of ensuring the continuity of resources a dynamic sliding window based resource allocation scheme is proposed in this paper. In each scheduling period, the resources allocation granularity is dynamically adjusted in accordance with the resources required for each user, and it is designed as the size of the sliding window in the whole frequency band to allocate the optimal resources required for the user. The simulation results show that the improved scheme can reduce the RB debris effectively, resulting in improving resource utilization, as well as increase system throughput and spectrum efficiency.

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References

[1] 3GPP TS 36.211: "Evolved Universal Terrestrial Radio Access (E-UTRA); Physical channels and modulation". (Release 9). Universal: 3GPP, 2009.

[2] Xiong Zhongyuan. LTE system wireless resource allocation research. Huazhong University of Science and Technology, 2011.

[3] Lee S B, Pefkianakis I, Meyerson A, et al. Proportional fair frequency-domain packet scheduling for 3GPP LTE uplink. pp.2611-2615,2009.

[4] Zhang Xiangpeng, Xu Jianguo and Zou Lihong. A frequency-selective scheduling scheme in the LTE system. Journal of television Technology, 36(9), pp.62-64,2012.

[5] Marwat S N K, Zaki Y, Goerg C, et al. Design and performance analysis of bandwidth and QoS aware LTE uplink scheduler in heterogeneous traffic environment. Wireless Communications and Mobile Computing Conference (IWCMC), pp.499-504,2012.

[6] Marwat S N K, Weerawardane T, Zaki Y, et al. Performance evaluation of bandwidth and qoS aware LTE uplink scheduler.Wired/Wireless Internet Communication. Springer Berlin Heidelberg, pp.298-306,2012.

[7] 3GPP TS 36.321: "Evolved Universal Terrestrial Radio Access (E-UTRA); Medium Access Control (MAC)protocol specification". (Release 9). Universal:3GPP, 2009.