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TD-LTE Uplink Power Control Research Based on Users Location

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Abstract: In order to reduce inter-cell interference, TD-LTE uplink uses slow power control in 3GPP 36.213 specification. This paper proposes an uplink power control method based on users location .firstly, the path loss of the different users should be estimated based on the value of RSRP. Secondly, these users are placed to different areas according to the size of the path loss .Lastly, a specific region uses the corresponding power control algorithm. The simulation shows that the method can effectively reduce the inter-cell interference and increase system throutthput.

Keywords: TD-LTE, path loss,power control,throughput.

1. Introduction

3GPP Long Term Evolution (LTE) [1] is the largest new technology research and development projects launched by 3GPP, which improves spectrum efficiency, peak data rates, performance of cell edge users ,cell capacity and reduces system latency. The LTE project able to satisfy the personal communications and entertainment needs and complies with the high demands of modern mobile communications, which is concerned by people and also won the favor of the communications sector in the world.

TD-LTE uplink uses SC-FDMA technology, which benefits from a lower Peak to Average Power Ratio(PAPR).The different UE uplink signals within a cell are orthogonal to each other, which avoid the intra-cell interference. It does not exist the necessity about power control because of the near-far effect like CDMA system. But in order to improve the efficiency about the spectrum utilization, TD-LTE system implements the same frequency network mode, all cells share a set of spectrum resources, therefore the inter-cell interference becomes the restricting factor about the performance of the whole system. Uplink interference mainly comes from the users of adjacent communities . The users location, number and the transmit power changes are random, so the uplink inter-cell interference is more complicated. Cell edge users are far from eNode B, signal attenuation is more serious, usually this case adopts larger transmit power, it can produce strong interference, reduce the capacity of the system. So, how to balance the communication quality about the edge of users and the performance of the whole system, is a problem which is worthy to study, and the uplink power control can balance the relationship between them [2] better. In this paper, on the basis of the uplink power control in 3GPP 36.213 protocol, we make a more detailed classification about its application, and consider the influence of adjacent cells path loss and interference information to the power control decision about the district cell users.

2. Power control algorithm which is based on different user position

Traditional power control algorithm adopts the whole region loss compensation method, it hopes all users to achieve the same goal SINR (Signal to Interference plus Noise Ratio) value, the calculation formula is as follows:

$$PSD_{Tx} = min\{SINR_{target} + I_{serving} + PL_{serving}, PSD_{Txmax}\} \quad (1)$$

Where the PSD_{Tx} means transmit power, the $SINR_{target}$ means user target SINR in the cell, the $I_{serving}$ means interference of the serving cell, the means path loss between the user and the serving eNode B, the PSD_{Txmax} means

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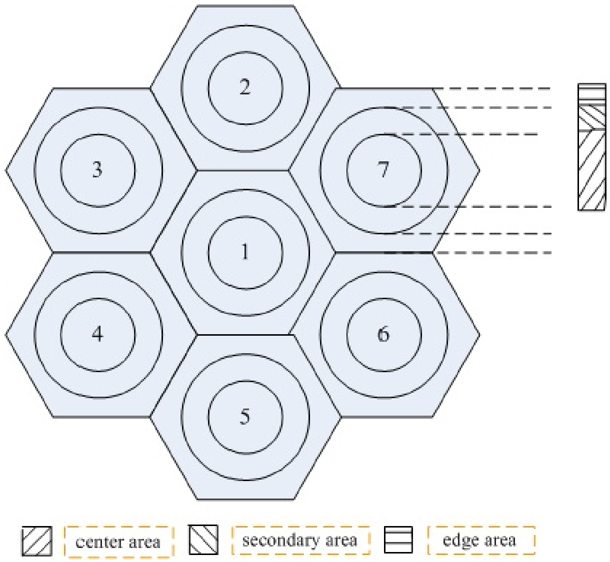

Figure 1 The corresponding relationship of the power control algorithm with different regions

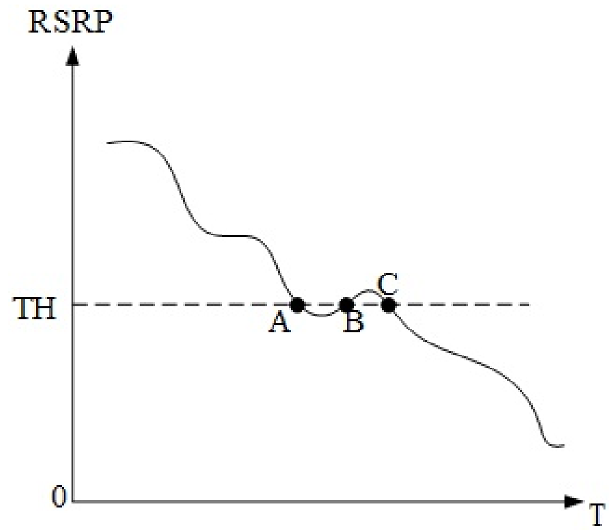

Figure 2 Table tennis effect

the maximum transmit power. Because of Eq. 1 did not consider the contribution about the different position of the user on the inter-cell interference, Therefore, in order to achieve the same SINR value with the center users of the cell, the edge users of the cell must use a high transmit power, which increases the inter-cell interference, thereby affects the performance of the system. Based on this situation, the TD-LTE uplink power control algorithm improved the traditional power control algorithm, adopts the part of the road loss compensation method [3]. In order to control the transmit power of users in different regions more accurately and reduce the interference among cells, this paper is based on the value of the downlink of RSRP (RS Received Power) , estimates the path loss of different users, then according to the size of path loss, divides user into different regions, and then uses the corresponding power control algorithm for a specific region. Each cell can be divided into three regions: central region, secondary edge region, edge region [4]. The principle shown in figure 1:

2.1. The judgment of the UE location

Usually the position of UE can be divided by using two kinds of methods: the first kind, according to the UEs actual geographical position in base station to judge; The second, according to the strength of the reference signal receiving power (RSRP) to judge. According to 3GPP 36.211 protocol specifications we can know that the RSRP is the linear average of the received power measurement band considered to carry the RS RE in a particular district, formula such as 2 as shown in:

$$RSRP_i = P \sum_j \in RS_{set} G_{i,j} \tag{2}$$

Among them, the RSRP is the value of i cell, P is the reference signal transmit power, $G_{i,j}$ is the channel gain.

When it knows the UEs RSRP value , we will compare it with the set RSRP threshold,as shown in 3

$$UE = \begin{cases} centeruser, RSRP_i > RSRP_{Th-h}; \\ seconduser, RSRP_{Th-l} < RSRP_i \\ < RSRP_{Th-h}; \\ edgeuser, RSRP_i < RSRP_{Th-l}. \end{cases} \tag{3}$$

The system continuously measure RSRP value, according to the RSRP value to divide position of the UE, this method is simpler, and will not increase the burden of signaling system. But this is a single sentence threshold, in certain which will produce table tennis effect. Suppose when $RSRP > TH$, user in the cell center and when , user in the cell edge. When UE goes to C point from A point, the system continuously renew the position of UE. To erase table tennis effect, this paper employ a kind of double threshold method to judge the UEs position. The main idea shows in figure 4.10. First setting up two judgments threshold TH_H and TH_L, if $RSRP > TH_H$, the UE is in cell center; otherwise the UE in cell edge. In the process of UEs continuously moving, as the curve 1 shown, the value of RSRP is decreasing, when the value is TH_H, even occasionally under TH_H, but never below TH_L, thus the UE is still judged as in the cell center. For the point D to point F, the analysis method is the same. By double threshold judgment, the table tennis effect can be eliminated effectively.

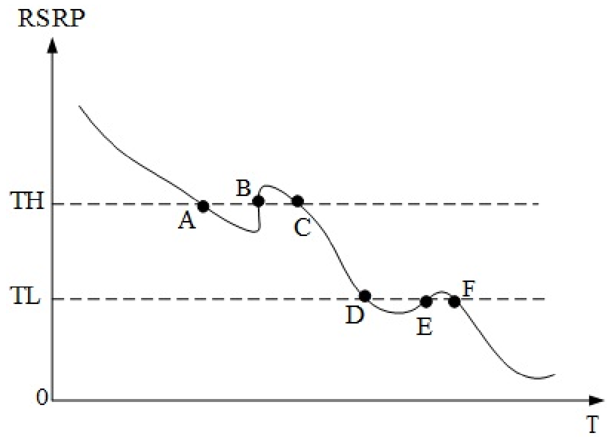

Figure 3 Double threshold judgment

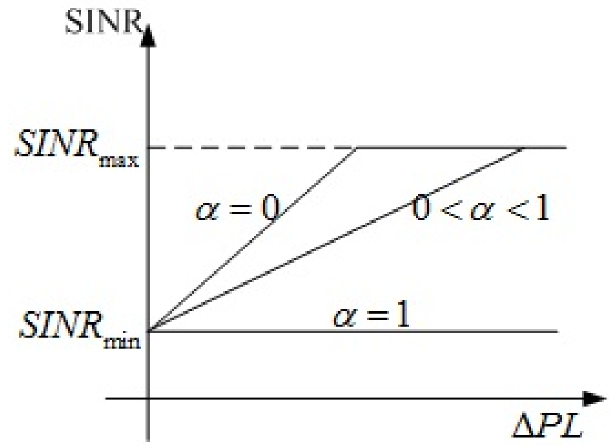

Figure 4 the relationship between center user target SINR and ΔPL

2.2. The uplink power control algorithm of the central region

The users locating in the central region are far from the serving eNode B, the channel conditions are relatively good, and they are far from the adjacent cells, the subjection to adjacent cell user interference is small, therefore we may use the power control method in 3GPP 36.213 protocol, it is the part of the path loss compensation power control algorithm, by setting a higher target SINR value, reducing power constraints, the purpose is to improve the performance of the whole system. Based on the Eq. 1, we propose the improved power control algorithm [3] which is improving the part of the path loss compensation, it is just as follows:

$$PSD_{Tx} = \min(SINR_{target} + I_{serving} + \alpha PL_{serving}, PSD_{Txmax}) \tag{4}$$

In the Eq. 4, means the path loss compensation factor, the value ranges in (0,1), it is used to adjust the extent of road loss compensation. When $\alpha = 1$, all users in a cell having the same emission power spectral density, as the traditional slow power control algorithm as.

2.3. The power control algorithm of the secondary edge region

The secondary edge region users compared with the central region users, they are distance from a serving eNode B, the channel conditions are not stability compared with the center of regional, the interference from adjacent cells users is correspondingly increased, thus the power control method of the secondary edge region users can not simply use partial path loss compensation power control method. The influence of the secondary edge region users communication quality on the performance of the whole system is very important, so we should consider not only the path loss from the mobile station to the cell eNode B, but also the path loss from the mobile station to the adjacent cell eNode B. In the case of neglecting fast decline, the user of interference for adjacent area is mainly affected by two factors: the transmit power and the path loss [5] from the user to the adjacent cell, as Eq. 5 shown below:

$$I_{serving} = \sum_{i=0}^{n} P_{(Tx)i} \times PL_{(neighbour)i} \tag{5}$$

In the Eq. 5, means interference of the servicing cell; n means the number of users which is out of the area of the community; $P_{(Tx)i}$ means transmit power about user i; $PL_{(neighbour)i}$ means path loss from user i to the adjacent cell eNode B. If the two users are having the same transmit power, and the path loss reaches the adjacent cell is not the same, by the formula 3 shows, the interference on adjacent cell is not the same. If the user has larger road loss to the adjacent cell, even if the transmit power is high, nor caused great disturbance on the adjacent cell. Based on this situation, we can consider the users in the secondary edge region, adopting the power control algorithm based on the difference of the path loss. The target SINR of the secondary edge region sets as follows:

$$SINR_{semi-target} = SINR_{target} - (1-\alpha)(PL_{serving} - PL_{neighbour}) \tag{6}$$

In the Eq. 6, means path loss from the target cell to the strongest adjacent cell [6,7]. Figure 4 can be seen, when $0 < \alpha < 1$,as the value of ΔPL increases, the target SINR value approanches the system SINR and target SINR value of the upgrade will make the system uing high code modulation, and thus enhance the system performance. Putting Eq. 4into the Eq. 2 , we get it:

$$PSD_{Tx} = min(SINR_{target} + (1-\alpha)PL_{neighbour} + I_{serving} + \alpha PL_{serving}, PSD_{Txmax}) \tag{7}$$

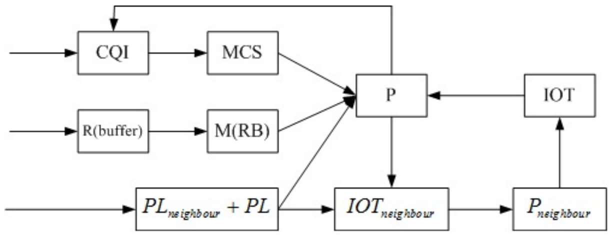

Figure 5 the interference of adjacent cells power control

Comparing Eq. 4 and Eq. 7, we can see that the transmit power of the Eq. 7 is larger then the Eq. 4 does, which is consistent with the condition of the actual network.

2.4. The power control algorithm of the edge region

Edge region users are most far away from the eNode B, channel conditions are poor, interference been affected by adjacent cell is maximum, so in order to guarantee the basic communication quality, it needs a larger transmit power, which in turns leads to higher interference. In order to overcome the interference, the mobile station needs higher transmit power, transmit power and interference rising alternating, eventually causes the transmit power of the users in the edge area first reaches the maximum value, at the same time, the interference is the most serious. In order to avoid interference with the transmitting power rising alternating, we will limit the IOT (thermal noise rising) values, and keep it at one point. IOT values can characterize interference degree of the system, it is calculated by the following formula: $IOT = \frac{I+N}{N}$, where I means interference power, N means noise power. The size of the edge regions transmit power will largely determine the size of the interference of the system, so the edge region users transmit power based on difference path loss in power control method should taken IOT information into account.

The stability of the system IOT is an important reference to judge the performance of a cellular network, so the core of power control is to make sure that the system IOT can't change greatly. But the traditional power control method is each cell alone for power control, but IOT is the result of the interaction of multi-cells, that will lead to instability of system, with two cells as an example to explain, as shown in figure 5: Transmitted power P of the users depends on the CQI, distribution of the number of RBs M and path loss value and other cells interference IOT to native cell. Once the transmit power P is determined, it will produce same frequency interference to users in the neighbor cells which use the same RB. At the same time, the adjacent cells also according to similar information to determine the transmit power $P_{neighbour}$, and the power will be effect by $IOT_{neighbour}$. Then $P_{neighbour}$ will produce interference IOT for native cell, and IOT influence the native power P. This kind of influence is mutual, circulation, can form a positive feedback. In order to break this positive feedback, the most effective way is introduced into the control of interference between cells. And the transmission power of the edge users, will largely determine the system interference, so the edge users transmission power need to take the system IOT information into account, this kind of power control method called power control method based on interference information.

The power control algorithm which is based on the interference information must make full use of IOT and power margin information, and finds the maximum available SINR value which is meeting the conditions, in order to enhance the user's performance without making the whole systems disturbance become too high. Firstly, according to the IOT margin, estimating the size of interference which is can be increased, then according to the power consumption, we get the SINR value can be enhanced which is calculated by Eq. 6, as:

$$\Delta SINR = \frac{P_{max} - P_{actual}}{(IOT_{target} - IOT_{actual}) * N} \tag{8}$$

So, power algorithm of the edge region users is as shown as Eq. 9:

$$\begin{aligned} PSD_{Tx} = min(SINR_{target} + \Delta SINR + (1-\alpha) \\ PL_{neighbour} + I_{serving} + \alpha PL_{serving}, PSD_{Txmax}) \end{aligned} \tag{9}$$

According to the Eq. 8 and Eq.9, when [8] value is larger then IOT_{target} value, $\Delta SINR < 0$, then the target SINR value of the edge region is been reduced, thereby reducing the transmit power in order to reduce the inter-cell interference; Conversely, then increasing the transmit power to improve the edge users' performance.

3. System simulation process and result analysis

The simulation in this paper mainly analyzes how to control the uplink power with the changing of the IOT system value among the users of three different regions, as well as the impact on system throughput [8]. In the simulation, the SINR value of the three different regions is identified which is based on link level simulation of BER in 1% cases, the target SINR value for central region is 20dB. The detailed parameters of simulation are shown in table 3.

In this paper, the static simulation method can be used. Each snapshot of the static simulation system is in a balanced state. The result of statistics assess the performance of the system, while the balance of the system in this paper is to reflect the system IOT value. The power control iterative process uses the distributed power control mode.The iteration process is over when the system is in equilibrium. The algorithm process is as follows: Step1: Power control strategy based on the different types of users to set up the

Table 1 Simulation parameters

parameters	Numerical value
Bandwidth	10MHz
Carrier frequency	2GHz
BS and BS distance	0.5Km
Channel model	ITU 6 diameter slowly fading channels
Path loss model	128.1+37.6lg(R)
Area layout	Hexagon, 7 District, 3 sectors / area
The number of users per sector	10
Dispatching mode	Proportional fairness
Penetration loss	20dB
UE maximum transmit power	23dBm
Antenna waveform	70 degree-3dBThe front-to-back ratio 2
Business model	Full buffer
Channel estimation	Ideal channel estimation

user's target SINR.Because of different path loss values due to the different types of users to the serving cell and strongest neighbor cell, so the value of the target SINR is also variable

Step2: The initial transmit power of M_i is set to any positive number $P_T(0)$, according to the formula (1) to calculate the base station measured the actual SINR value. Eq. 10 as follows:

$$SINR_i(0) = \frac{P_{Ti}(0)G_{ii}}{\sum_{j=1,j\neq i}^{Q} P_{Tj}(0)G_{ij} + N} \tag{10}$$

Step3updated the transmit power according to the formula 11. Formula 11 as follows

$$P_Ti(n+1) = P_{Ti}(n) \times \frac{SINR_{target}}{SINR_i(n)} \tag{11}$$

Step4Set the number of iterations n, return to Step3 repeat iteration until the end. Algorithm flow shown in Figure 6

The results and analysis of the simulation are as follows. One of the important effects of uplink power control is that during controlling the users transmit power. it can not only compensate the path loss and the shadow fading between the user and the eNode B, but also reduce system interference level and prolong the using time of the mobile phone battery on the other hand. Figure 7 is the cumulative distribution curve of the user transmitting power on the basis of soft frequency reuse, the system uses different power control scheme, in which the users maximum transmit power is 200mW, about 23dBm.

If the system does not use power control technology, in order to get a better communication quality, each user will use the maximum transmit power, but in order to reduce system interference level, we using the power control to reduce users transmit power. From figure 7, it can be seen that when the system using the traditional power control scheme, 70% of the users transmit power lower than 50mW, more than 90% users transmit power lower

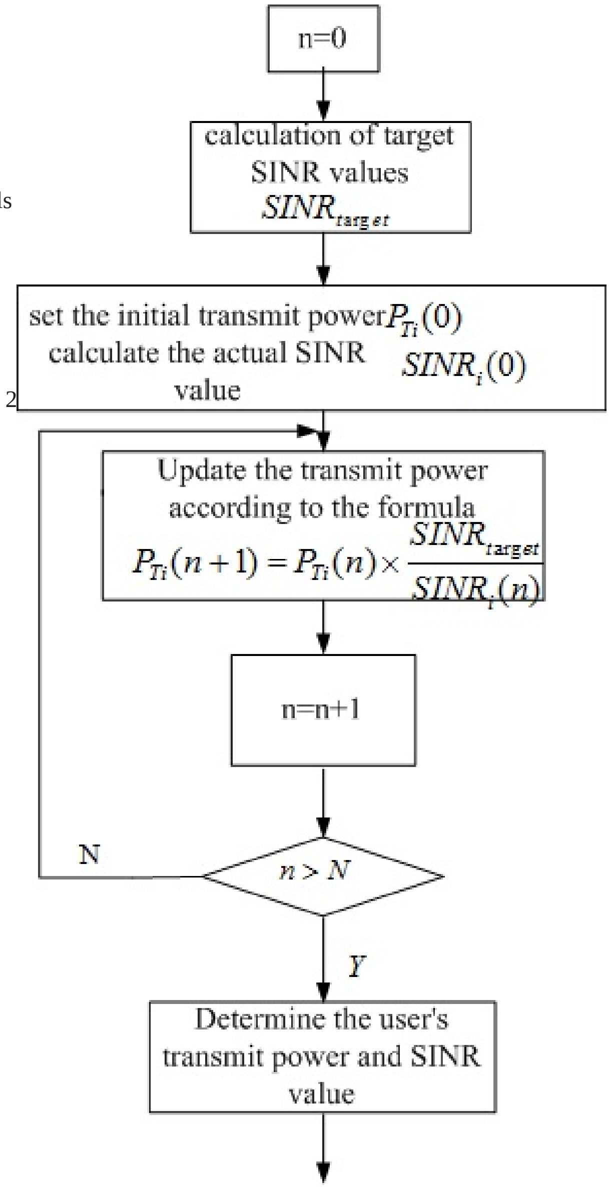

Figure 6 Power control iteration flowchart

than 100mW. In order to take care of the communication quality of the edge, LTE protocol using parts road loss power control scheme that the user transmit power is reduced but not too obvious compared to the original power control scheme. After using the improved power control scheme which is based on the users position, 95% of the users transmit power is lower than 50mW, all users transmit power is not more than 100mW, this is more favorable for controlling the system interference and prolonging the standby time of the mobile phone.

From figure 7, we can seen that users transmit power have been limited to a range after we use the improved power control scheme based on user position. It can reduce

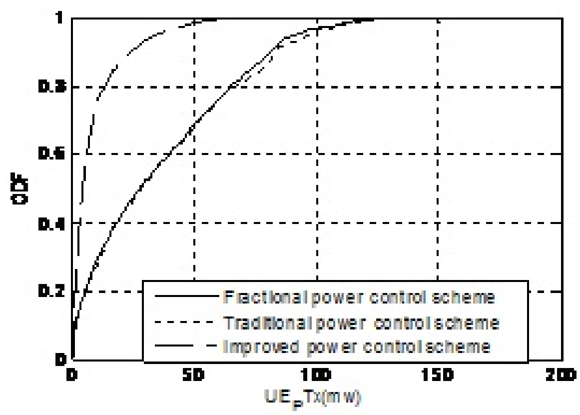

Figure 7 Cumulative distribution curve of the user transmitting power

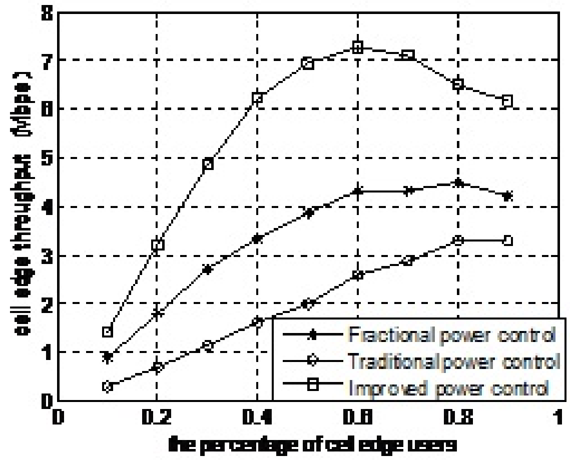

Figure 9 cell edge users throughoutput

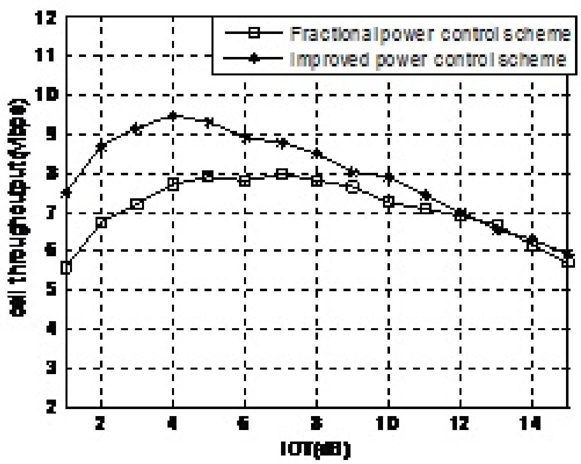

Figure 8 Cell throughputs under different IOT levels

the interference of the community user for adjacent area user, thereby also reduce system interference level. From figure 7, even though the user transmit power is relatively low, but it does not reduce the overall throughput of the area.

Figure 8 is the simulation which is mainly aimed at the two different power control schemes on the effects of the cells throughput, and comparing the throughput of cell at different points of IOT based on the two kind of scheme. It also verifies that the improvement scheme which is putting forward in this paper is feasible. The figure 8 shows that cell throughput of the two kinds of power control scheme are slowly increased with the increasing of the IOT value, and gradually reduce after reaching the peak. This is because that the power control scheme which is based on the path loss values regulates its target SINR value according to the distance of the user to the service base station, near the user its SINR value is higher while lower SINR value which is far away from the eNode B. it improves the average user throughput at the expense of the performance of the edge user. But as the system interference increases gradually, this sacrifice was insufficient to compensate the capacity decreasing caused by the interference, thus gradually throughput decreasing. But the improved scheme which contains interference information is dividing users into different groups. within the user according to the interference characteristics using different power control schemes, it make a more detailed adjustment on power according to the neighboring interference, so its performance is better than the scheme which is based on the path loss power control. The horizontal axis is the percentage of cell edge users, the vertical axis is the cell edge user throughput . From the chart we can see that the cell edge user throughput is increased gradually with the gradual increase in the proportion of edge users.When the edge of the percentage of users reaches a certain value, the traditional power control scheme and fractional power control scheme of cell throughput reached a steady state, and the decline in the power control scheme based on the location of the user throughput. SINR values are equal for all users in the traditional power control scheme, even if the edge users have a higher SINR value, the inter-cell interference with the number of edge users increasing is more serious, affecting the user's average throughput. Fractional power control scheme sacrificed the center users performance to rise the throughput. Power control scheme based on the location of the user makes more accurate adjustments according to the adjacent cell interference, its performance would be enhanced further. Figure 10 reflects the CDF of system IOT with part of power control scheme and power control based on the position of users. It shows that when the system use part of power control scheme, the IOT

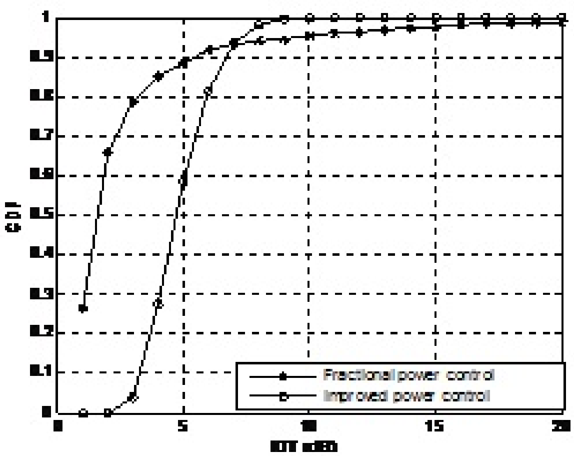

Figure 10 The CDF of system IOT under different power control scheme

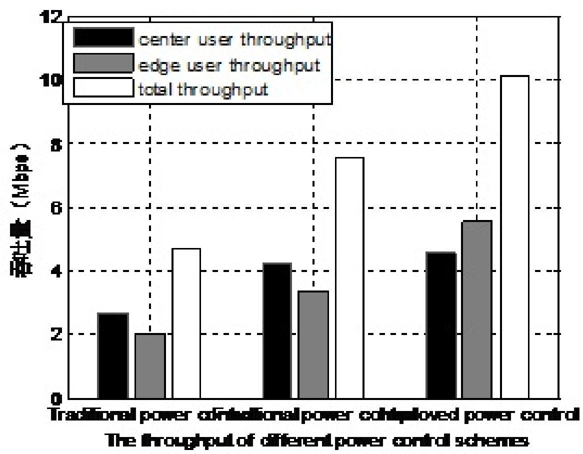

Figure 11 Comparison diagram of the center and edge of cell and the total throughput under different power control scheme

range from 1 to 20, the cumulative probability of IOT¡5dB is 89% and IOT¡10dB is about 95%, IOT¡15dB is about 98%. So it shows that the system IOT maybe too high. If the IOT too high, it will effect the performance of the system. When the system adopt the improved power control scheme, the change of scope of IOT is little, the IOT of the system is below 10dB, the cumulative probability of IOT¡5dB is 60% and IOT¡7dB is about 92%, IOT¡10dB is about 100%. So we can see that the improved scheme is better on IOT of the system. This is because the improved scheme draws up different power control strategy based on the users different interference character, especially take consider in the interference of the neighbor cells. So the native cells users will take some reserve when they change their transmit power, not just sacrifice the gain of the whole system for improve their selfs performance. Figure.11 is the comparison of traditional power control scheme, part of the power control scheme and improve power control scheme under the center throughput, edge throughput and total throughput. As can be seen from the graph, part of power control scheme of the center of the user throughput is 57% higher than traditional power control scheme throughput, the throughput of the improved power control scheme and the part of power control scheme of the center of the user throughput remained; under the three kinds of power control scheme the throughput of the edge users in turn up, the improved scheme throughput of the edge users is the largest, grow by 50% than part of power control scheme. Traditional power control scheme requires that all users with the same SINR value, so that led to the edge users of the cell of high transmission power, moderate high power can improve the throughput of system in a certain degree, but if the transmit power too high it will produce higher interference, which affect system throughput. Part of power control scheme with part of the road damage compensation, namely according to the distance between the users and the base adjust SINR value; this is fit for the actual situation, so in performance is superior to the traditional work control scheme. But part of the power control scheme only think about the intra cell, and no consideration to the effects of the interference between cells, aiming at this issue, this paper put forward the adaptive power control scheme based on the users, through the simulation we can see, this scheme improved the throughput of the edge users and keep the throughput of the center users, its performance has certain improvement.

4. Conclusions

This paper proposes TD-LTE uplink power control method which is based on the location of the users, we can divide the regions into different areas based on the actual business environment, and for the different regions using the different power control algorithms, which can make full use of limited power to improve the throughput of the system as much as possible, it is having the reference value for the current large-scale network.

Acknowledgement

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