Uplink Power Control in Multi-Cell in LTE

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***Abstract*–Uplink power control in LTE is one of the important radio resource management functions,and mainly affects the system capacity.As the LTE employs OFDM techniques,this paper focuses on the uplink control in multi-cell in LTE,namely scheduling to combat uplink inter-cell interference(ICI) and thus extend system capacity,elevate the users performance.Firstly I will present the specific techniques employed in LTE uplinking,and analysis the main interference of LTE system.Then ,traditional mechanisms of uplink power control will be introduced.Finally,some kinds of scenarios with the frequency reuse of 1 are displayed.**

1 INTRODUCTION

LTE(Long Term Evolution) belonging to 3G mobile system is standard in 3GPP with a wider scalable bandwidth, a higher data transmitting rate,a more flexible spectrum allocation ,and more than twice the capacity over High-Speed Packet Access (HSPA).To accomplish such requirements,OFDM(Orthogonal Frequency Division Multiplexing) was chosen.And due to its orthogonality,the ICI becomes the main interference in LTE uplinking. In traditional methods of uplink power control,the frequency reuse of the cell edge is more than 1 to reduce the ICI and thus also reduce the system capacity.To maximize the system capacity,more and more scenarios are proposed with the frequency reuse of 1.

2 OFDM AND INTERFERENCE ANALYSIS

OFDM is a method of encoding digital data on multiple carrier frequencies.All the carrier signals in one single cell are orthogonal to each other,meaning that cross-talk between the subchannels is eliminated and inter-carrier guard bands are not required. This greatly simplifies the design of both the transmitter and the receiver; unlike conventional FDM, a separate filter for each sub-channel is not required. So the interference from other channels in one cell become less important and the ICI is the dominant interference that limits the system capacity,especially the performance of cell edge users.And ICI is mainly caused by co-channel interferenceCCI).In LTE,frequency spectrum is a precious resource which is divided into non-overlapping spectrum bands which are assigned to different cells.However,after certain geographical distance, the frequency bands are re-used, i.e. the same spectrum bands are re-assigned to other distant cells. The co-channel interference arises in the cellular mobile networks owing to this phenomenon of frequency reuse.Thus, besides the intended signal from within the cell, signals at the same frequencies (co-channel signals) arrive at the receiver from the undesired transmitters located (far away) in some other cells and lead to deterioration in receiver performance.

3 TRADITIONAL MECHANISMS WITH ICI

Generally,we adopt frequency reuse techniques to mitigate the ICI in LTE, so that nearby cell-edge users belonging to neighboring cells do not share the same frequency.It is usually design the cellular system with frequency reuse 7,3 or 1,and the smaller the number,the higher frequency reuse efficiency.The followings are two mechanisms with soft frequency reuse in traditional ways.

3.1 The scenario proposed by Nokia and Huawei [1] [2]

Generally,we adopt frequency reuse techniques to mitigate the ICI in LTE, so that nearby cell-edge users belonging to neighboring cells do not share the same frequency.It is usually design the cellular system with frequency reuse 7,3 or 1,and the smaller the number,the higher frequency reuse efficiency.The followings are two mechanisms with soft frequency reuse in traditional ways.As shown in FIG.1.

FIG.1 the topology of the system

3.2 The scenario proposed by Alcatel [3]

This scenario firstly divides one cell into three sections,and every section has seven small areas,correspondingly,the frequency band is also divided into seven parts,and allocated to the seven small areas in every sections.In a word,we finally get a cellular system in which the neighboring users belonging to abutting areas are allocated the different frequency. Comparing with the The scenario proposed by Nokia and Huawei,the frequency reuse efficiency in the cell edge is promoted from 1/3 to 6/7.The picture below shows the scenario model.

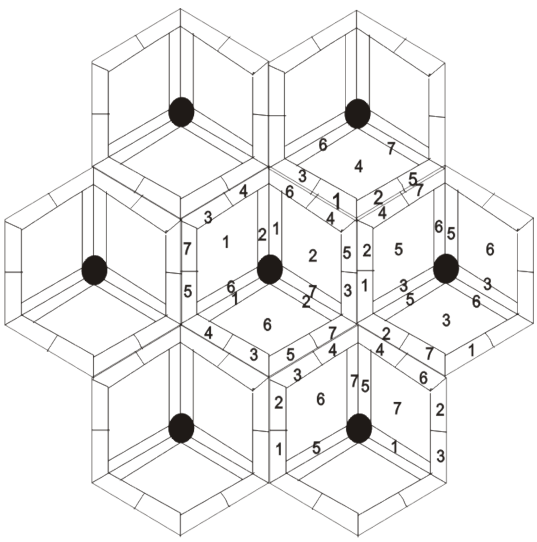

FIG.2 the topology of the system

However,as radio resource(bandwidth) nowadays becomes more and more treasures,so modern cellular networks move increasingly toward the maximal frequency reuse of 1, where all the cells share the same frequency.

4 MODERN MECHANISIMS IN LTE UPLINKING WITH FREQUENCY REUSE 1

4.1 Coordinated Scheduling based on Overload Indicator for LTE/LTE-A Uplink [4])

4.1.1 Overload Indicator and System Model

I.OI(Overload Indicator) in LTE

LTE specifications have included uplink inter-cell interference coordination(ICIC) schemes based on the OI signaling, as shown in Fig.1. The basic idea is that eNB measures the uplink IOT (Interference Over Thermal noise power ratio), if the value overcomes a pre-determined threshold, OI report is triggered, low, medium and high OI reports can be signaled via the X2 interface to the neighbor cells. There is support for frequency selective OI, so that the aforesaid measurement and the subsequent reporting is per RB (Resource Block). One potential use of OI is to dynamically adjust the uplink open loop power (e.g. Po) to maintain a certain maximum desirable uplink interference to noise ratio based on the OI exchanged between the neighbor cells.

II.System Model

We consider an OFDM based system having multiple BSs which are deployed in a hexagonal grid and each BS is positioned in the center of each cell. Let L denote the number of BSs and M the number of users connected to each BS, so the entire network has M*L users in total. The total available bandwidth is divided into N sub-bands, where each sub-band is a cluster of k consecutive OFDM sub-carriers. On the other hand, the time resource is divided into frames, and a number of consecutive frames construct a super-frame. The smallest resource unit which can transport data is a combination of one frequency resource unit (sub-band) and one time resource unit (frame).

III.OI (Overload Indicator) Based Inter-Cell Power Control

In this method,we set different OI thresholds on different RBs,and depending on the exchanged OI information among neighbor cells,schedule users to the proper RB,on which the co-channel neighbors users can endure such ICI.Therefore the high interference generating users and the high interference endurable users are scheduled together, which can mitigate the negative impact from inter-cell interference.

A.

Multiple Levels of OI Thresholds Within a cell on different resource block group, different OI trigger thresholds are used, and among neighbor cells, the OI threshold pattern is designed as complementary.

The motivation of setting multiple levels of OI thresholds is to decrease the necessary power reduction as shown in Fig.4, considering different users located at different area of the cells may endure different level of interference, in other words, the IOT level or the OI triggering thresholds for different users may be designed differently.

B.

Multi-Cell Coordinated Scheduling Methods The scheduling depends on the exchanged OI information between cells.The main procedures are described as below.

1.Set predetermined multi-level OI thresholds on different RBs with a complementary pattern between neighbor cells as shown in Fig.3.

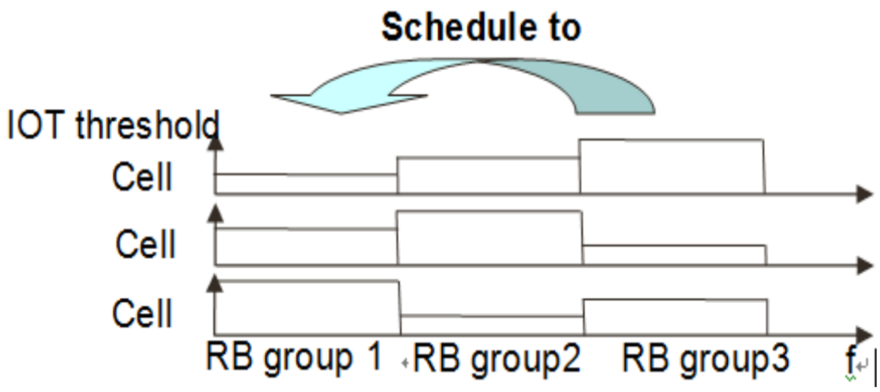

FIG.3 different OI threshold for different RBS

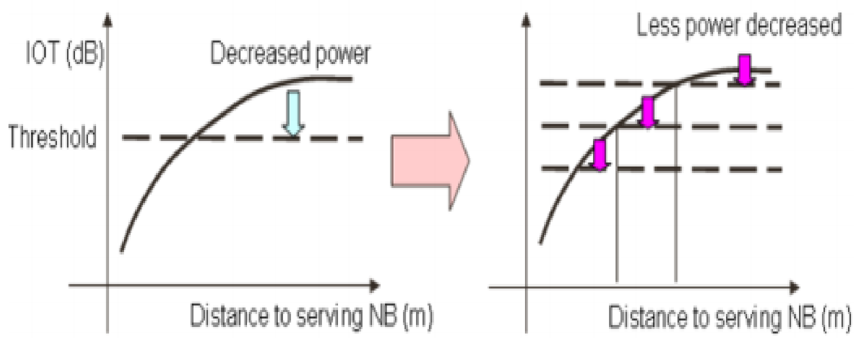

FIG.4 Comparison between single and multiple OI thresholds

2.Initial scheduling:
a) Schedule users based on their path-loss and RB assigning pattern.

3.Iterative scheduling:
a)Judge if the user is a high interference generating user according to below criterion:

i. When OI signaling is transmitted from neighbor cells to the severing cell the user located;

ii. The interference caused by the user accounts for a dominate part of the suffered interference of the OI triggered cell, as

$$\frac{P_{UE} * PL_{BS}}{P_N} > \alpha * IOT_{BS} \tag{1}$$

Where P_{UE} is users transmission power,PL_{BS} is the path-loss from the user to the OI triggered neighbor eNB, P_N is the thermal noise power,IOT_{BS} is the OI trigger threshold on the RB of the neighbor cells, $0 < a < 1$ P_{UE} and PL_{BS} can be calculated based on user power headroom and neighbor cell RSRP measurement reporting.

b)If the user is a high interference generating user based on step a), calculate if the user will cause high interference to other neighbor cells on other RBs.

i. If the interference caused by the user accounts for a dominate part of the suffered interference of other cells, as

$$\frac{P_{UE} * PL_{BS*}}{P_N} > \alpha * IOT_{BS*} \tag{2}$$

Where PL_{BS*} is the path-loss from the user to the other neighbor eNB,IOT_{BS*} is the OI trigger threshold on other RB of other neighbor cell.

c)If the user will cause high interference to other neighbor cells on all other RBs.

i. use inter-cell power control to reduce the caused interference by the user;

d)If the user will not cause high interference to other neighbor cells on other RBs.

i. Schedule the user to other RBs, which have higher OI threshold used in the OI triggered cell.

e)If the user is not a high interference generating user

i. Schedule the user to other RBs, which have lower OI threshold used in the OI triggered cell.

4.1.2 Simulation

The system bandwidth is set to 5 MHz, we employ a 3-sectored 19-hexagonal cell layout model with a sector antenna beam pattern with a 70-degree beam width. We set the inter-site distance to 500 m, and the corresponding cell radius is 289 m. The propagation model follows a distance-dependent path loss with the decay factor of 3.76, lognormal shadowing with a standard deviation of 8 dB, and instantaneous multi-path fading.

Table.1 Simulation Parameters

PARAMETERS	ASSUMPTION
Cellular layout	19cell, 3sectors/cell
Antenna horizontal pattern	70 deg ($-3dB$) with 20 dB front-to-back ratio
Site to site distance	500 m
Propagation model	128.1 + 37.6log10(R), R(km)
Slow fading variation	8 dB
Carrier frequency	2000 MHz
UE distribution	Uniform random distribution
System bandwidth	5MHz
Thermal noise	-174dBm/Hz
Fading channel model	ITU 6 ray
User speed	3 km/h
Scheduling scheme	PF
Single IOT threshold	8 dB
Multiple IOT threshold	4, 8, 12dB
Useful sub-carrier	300
Modulation	QPSK, 16QAM
Traffic model	Full buffer

Fig.5 shows the results of user throughput as the number of user per cell increases. From the results we can draw the conclusion that, the proposed method can always provide better performance than other ICIC methods, the cell average throughput gain is around 9-10 percentage.

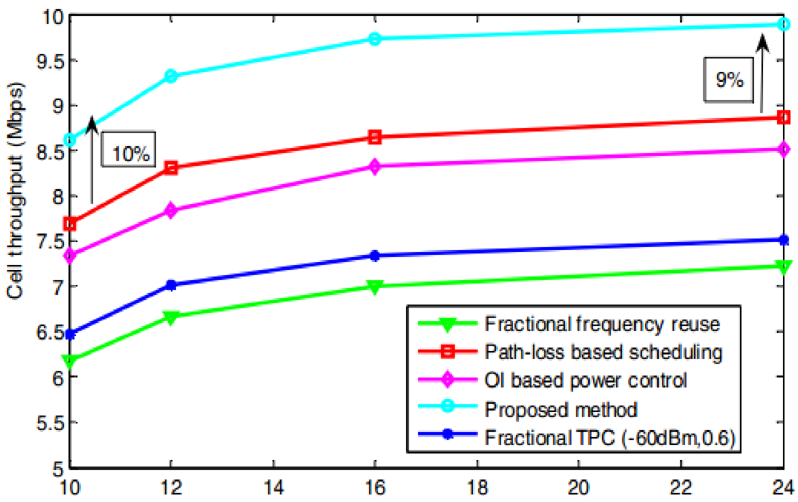

FIG.5 User throughput as UE number per cell increases

Fig.6 shows the comparison results in terms of user throughput distribution. From the results we can see, our proposed method can provide about 10 percentage cell average throughput gain than other ICIC methods, and about 10.5percentage cell edge throughput gain than other ICIC method except for FFR, the cell edge throughput is nearly the same as FFR method.

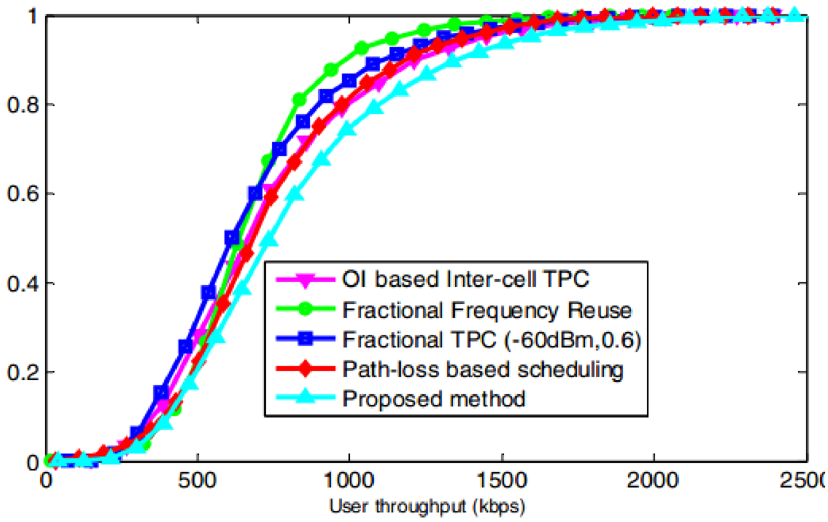

FIG.6 CDF of user throughput.

The merits of the proposal include that, first we resort to scheduling but not power reduction which improves the power efficiency; second, high interference generating users in the serving cell and high interference endurable users in the neighbor cell are paired as accurate as possible; finally, we suppress inter-cell interference fluctuation, that improves the efficiency of AMC and channel dependent scheduling.

4.2 Scheduling and Power Control in Multi-Cell Coordinated Clusters [5]

This scenario envisions an advanced wireless cellular network in which base-stations cooperate with each other in the joint scheduling of users and in the joint optimization of transmit power spectra over the frequencies for all users across the cells

4.2.1 System consideration

We consider a cellular system in which multiple cells are assigned a common central node that is responsible for the coordination of the radio resource allocation in each of the connected cells. The set of cells that are under the coordination of the same central entity is called a coordination cluster.As shown in the following picture.

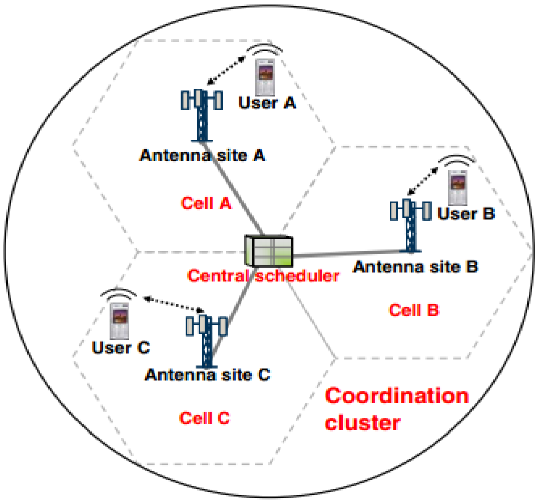

FIG.7 Coordination cluster example

The signal-to-interference and noise ratio (SINR) is calculated for each transmission and it is used to determine the quality of the reception:

$$SINR_{m,f} = p_{m,f}(\frac{g_{m,l(m),f,1}}{I_1} + \frac{g_{m,l(m),f,2}}{I_2}) \tag{3}$$

where

$$I_a = \sum_{l \neq l(m)} \sum_{i \in M_l} y_{i,f} \cdot p_{i,f} \cdot g_{i,l(m),f,a} + \sigma^2_{RB} \tag{4}$$

and $g_{m,l,f,a}$ contains the long and short term channel gain of UE m towards cell l on RB f and on receiver antenna port $\alpha \in \{1, 2\}$ Let $p_{m,f}$ denote the transmission power employed by UE m on RB f and let the indicator variable $y_{m,f}$ take the value of 1 whenever RB f is assigned to UE m and zero otherwise. The cell that serves UE m is denoted by l(m),where $l(m) = argmax_l\{g^{avg}_{m,l}\}$,in which $g^{avg}_{m,l}$ is the channel gain without multipath fading between UE_m and cell l.M_l denotes the set of users served by cell l . The constant noise power on a RB is denoted by σ^2_{RB}.

4.2.2 Central Scheduling

The main idea behind the central scheduler is to control the interference caused and suffered by UEs scheduled on the same resource in different cells by properly selecting the UEs that can be scheduled concurrently. Utilizing the channel information available in the central node for all UEs and antenna site pairs, the scheduler can estimate the interference that would be caused to neighbor sites if a given UE were scheduled. Then, it is possible to recalculate the optimal transmit power setting corresponding to the new source of interference and obtain the achievable SINR, after which the link adaptation (LA) can choose a corresponding modulation and coding scheme (MCS), which gives the number of bits that can be transferred on the given connection.

We propose a RB weight measure that expresses the loss in terms of carried number of bits suffered by already scheduled UEs when the UE in question. The UE that causes the minimum loss of bits to other UEs should be selected for scheduling. We call this measure the relative link rate loss and define it according to the following expression when UE k is about to be scheduled in cell l on RB f :

$$\Delta r = \frac{\sum_{j \in C_f} r_j - \sum_{j \in C_f} \hat{r}_j}{\sum_{j \in C_f} r_j} \quad (5)$$

where C_f denotes the set of UEs that are already scheduled on RB f in other cells r_j is the number of information bits of UE $j \in C_f$ when UE k is not scheduled on RB f , and $\hat{r}_j$ denotes the number of information bits of UE j ,when UE k is also scheduled on RB f. The term Δr expresses the normalized link rate lossof UEs in C_f when UE k would be scheduled on RB f .

The steps of the scheduling algorithm executed by the central processing entity, are as follows :

1) Take the next cell l and start the allocation of RBs in that cell (cells can be chosen in arbitrary order).

2) Calculate the QoS weight for all UEs Ml and the RB weight for all $UEs \in M_l$ and for all RBs in cell l .

3) Take the next UE which has the highest aggregated weight (i.e., the sum of the QoS and the RB weight) on the RB adjacent to the last allocated RB.

4) Apply the multi-cell power control algorithm to recalculate transmission powers and execute the link adaptation to recalculate transport formats for all scheduled UEs in all the cells .

5) Select the next cell and go to Step 2.

4.2.3 Multi-cell Power Control and Link Adaptation

The goal of the power control algorithm is to set the transmit power levels of all UEs in the coordination cluster such that a desired target SINR is achieved at the receiving site for all transmissions.

Let S_f denote the set of UEs scheduled on RB f in the entire coordination cluster. The proposed algorithm executes the following power allocation for each RB f .

1) Initially assume only the thermal noise(σ^2_{RM}) and no interference on RB f and assume that UEj $\in S_f$ has a target SINR of $\rho(j)$.

2) The power allocation vector in iteration stepi is denoted by $P^i = [P^i_k, P^i_l \dots P^i_m]$,where P^i_j is the transmission power of UEj$\in S_f$ in iteration step i and $|P^i| = |S_f|$.

3) The transmission power of UE j in iteration step i is calculated according to the following function (note that P^{i-1}_k is available for each UEj$\in S_f$):

$$P^i_j = \frac{\rho(j) \cdot I^{i-1}_1 \cdot I^{i-1}_2}{g_{j,l(j),f,1} \cdot I^{i-1}_2 + g_{u,l(j),f,2} \cdot I^{i-1}_1} \quad (6)$$

where

$$I^{i-1}_a = \sum_{l \neq l(m)} \sum_{u \in M_l} y_{u,f} \cdot p^{i-1}_u \cdot g_{u,l(j),f,a} + \sigma^2_{RB} \quad (7)$$

4) Increase the iteration counter by one and apply Step 2 until the power converges(i.e., the

difference between the power vector obtained at step i and i+1 is below some threshold) or the maximum power is reached for one or more UEs.

4.2.4 Simulation Results

Multi-cell coordinated RRM functions can provide considerable performance benefits without imposing strong requirements on the backhaul infrastructure. The combined multi-cell power control, link adaptation and scheduling algorithms, proposed above requires only the exchange of channel state information as additional signaling data on the backhaul links, while user plane data needs to be transferred only from one site at a time, meaning that parallel data transfer with more significant transport network implications can be avoided. Moreover coordinated fast RRM schemes have demonstrated low sensitivity to backhaul delays during the simulations. multi-cell coordinated fast RRM not only increases the received SINR but it also provides a more accurate matching between the expected and the received SINR in link adaptation, which altogether result in significantly higher cell edge and cell throughput values as compared to single cell RRM. High accuracy link adaptation and power control can be expected to provide additional benefits also for signal processing based multi-cell coordination schemes when they are used in combination.

4.3 Joint Scheduling and Dynamic Power Spectrum Optimization for Wireless Multicell Networks [6]

This scenario envisions an advanced wireless cellular network in which base-stations cooperate with each other in the joint scheduling of users and in the joint optimization of transmit power spectra over the frequencies for all users across the cells for interference mitigation. Base-station coordination can be realized by the exchange of messages among the base-stations. The main contribution of this secnario is a set of numerical power spectrum optimization methods based on a specific type of interference pricing messages. These messages reveal the effect of interference among neighboring cells. They also help maintain fairness among all users across the cells, and allow frequency allocation and power spectrum adaptation to be done in a distributed fashion.

A lot more about this method available than i have room to describe here, so i just summarize the whole scenario in a few words.Like the scenarios proposed above,this method also present a better performance including a faster coordination , a fair rate allocation across all the cells and a greater throughput.

5 CONCLUSION

In this project,we have studied the uplink power control in LTE including intra-cell , intercell interference and .My task is mainly to investigate the uplink power control in multi-cell environment.In this report,I have introduced the basic problem about the power control and then displayed some traditional methods with frequency reuse bigger than 1 which were under the use.Also, some scenarios are proposed with frequency reuse 1 and their algorithm are presented, revealing the trend of the uplink power in LTE.

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