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System Level Performance of a Novel Dynamic CoMP Scheduling in 3GPP LTE-Advanced Heterogeneous Networks

[1,2]Yuan Gao, [1]Yi Li, [2]Hongyi Yu, [2]Xianfeng Wang and [2]Shihai Gao
[1]State Key Laboratory on Microwave and Digital Communications,
National Laboratory for Information Science and Technology, Tsinghua University, 100084, Beijing, China
[2]Department of Communication Engineering, Information Science and Technology Institute,
Zhengzhou, China

Abstract: With the rapid development of 3GPP specifications and standardization, more and more researchers are concentrating in the related areas. As the cell-edge user performance gradually becomes the restriction of total cell performance, Coordinated Multipoint Transmission/Reception (CoMP) is raised to solve the problem. Previous research about CoMP has proved the effectiveness in improving the cell-edge performance but related work about scheduling is still uncertain. In this paper, we raised a novel scheduling method in LTE-Advanced heterogeneous networks scenario which is an extension from normal scheduling scenario. From fairness point of view, the novel method proved to be fairness and the performance of the method under the evaluation of LTE system level simulation proved to be effective and better than that in 3GPP specification. Complexity of the novel method also proved to be acceptable according to the simulation result.

Key words: Scheduling, heterogeneous networks, system level

INTRODUCTION

Previous standardization work of IMT-Advanced has marked the importance of cooperative communication in solving the problem of cell-edge user performance. Both LTE-Advanced and 802.16 m have related work in evaluating and developing key techniques of cooperative communication.

In release 11 of 3 GPP LTE specifications, research on CoMP has brought many significant results, such as the incensement of spectrum efficiency, total cell sum-rate, etc. Research on resource allocation of system resources is still uncertain and mainly under ideal assumption. In cooperative transmission scheme, cooper-ative information is exchanged through cooperative links, such as X2 interface. In heterogeneous networks, hybrid cooperative scheme is adopted to avoid interference and increase cell throughput.

In order to make full use of cooperative resources, a proper resource scheduling method is in great need. Common scheduling method like Proportional Fairness (PF), max throughput, max SINR, etc., will work properly under traditional scenarios without cooperative. When CoMP is perfor-med, joint resource scheduling has some difference.

The cell edge area has complex channel environment that makes cooperative scheduling hard and unstable. Main problem that affect system performance at cell-edge is the interference from adjacent cells. The aim of cooperative scheduling in heterogeneous networks in LTE-Advanced is to make proper use of precious time-frequency resource, rather than copy the scheduling method in non-CoMP scenario.

So in this work, we studied and raised a novel scheduling method used in LTE-Advanced heterogeneous scenario (Gao and Yu, 2011). Both low power RRH and traditional eNodeBs are located in the area; the optimal scheduling method used in this scenario is given. From fairness point of view, a comparison with traditional PF is given. Also a comparison of throughput and BLER is given to prove the effectiveness of our novel method.

PROPORTIONAL FAIRNESS SCHEDULING SCHEME

The most common scheduling method used in 3 GPP evaluation work is the proportional fairness scheduling. From fairness point of view, it can offer the equal probability of scheduling for every given user. But from

Corresponding Author: Yuan Gao, State Key Laboratory on Microwave and Digital Communications,
National Laboratory for Information Science and Technology, Tsinghua University, 100084, Beijing, China

Table 1: Relation of bandwidth and resource

Bandwidth (MHz)	FFT No.	Resource block	Transmission mode
1.4	128	6	SISO
3	256	15	SISO/1*2
5	512	25	2*2
10	1024	50	2*2,2*4
15	1536	75	4*4
20	2048	100	4*4, 4*8
100	2048 or higher	100 or higher	8*8 with CA

efficiency point of view, a fairness scheduling is sometimes a waste of resources. For example, a user located at the edge of the cell will require more system resource to maintain transmission and also get a poor transmission capacity. If the resources are scheduled to a user with better channel condition, it may receive better throughput. The wideband transmission scheme provides higher bandwidth resource and reduces transmission power than traditional communication. In LTE-Advanced, the 100 MHz bandwidth is introduced to support maximum 1 Gbit $\sec^{-1}$.

Table 1 gives the relation of bandwidth, subcarrier number, resource blocks and transmission scheme supported by LTE and LTE-Advanced. As key technique of LTE-Advanced, OFDMA provides frequency resources for wideband transmission. It is hereby mapped to FFT number related to given bandwidth. Number of resource blocks is depending on the subcarrier spacing given by 3 GPP and the transmission mode is the maximum supported mode in the given bandwidth with high spectrum efficiency.

There are two main steps of the traditional proportional fairness scheduling: Prediction of transmission performance and calculate coefficient of scheduling.

Prediction of transmission performance is to ensure the fairness of scheduling. Key technique of the prediction is the effective SNR mapping. Both SRS in TDD systems and channel estimation in FDD systems can obtain the outdated channel response. Using the Mutual-Information based effective SNR mapping method; predicted SINR and throughput are obtained using the outdated channel information. Detailed information about effective SNR mapping can be found in, we also have previous work on this method given by Wan *et al.* (2005), so we do not give deep description here. The second step of the PF scheduling is the generation of coefficient. The coefficient is defined in the following equation:

$$M_i(t) = \frac{T_{current}(t)}{T^{\alpha}_{average}(t)} \tag{1}$$

In Eq. 1, the scheduling coefficient of the i-th user is defined as $M_i(t)$, $T_{current}(t)$ is the predicted throughput at current time sample using effective SNR method and $T^{\alpha}_{average}(t)$ is the average throughput in the given duration, where, α is the fairness factor with common value of 1. Influence of this value can be found in 3GPP specification.

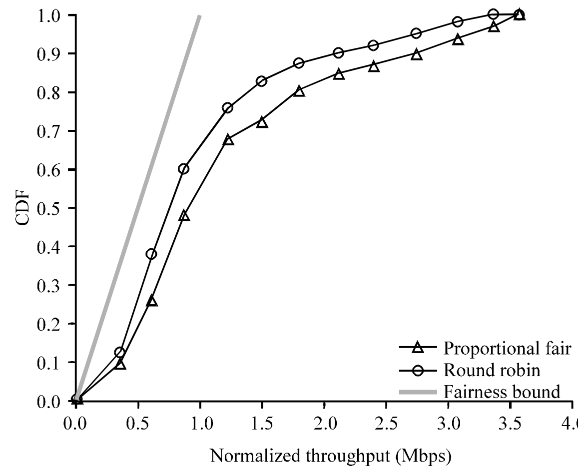

Fig. 1: Comparison of fairness between two common method. The grey solid line is the fairness curve, scheduling method that has the CDF at the right side is a fairness one

Method of calculating the average throughput is given in Eq. 2:

$$T^{\alpha}_{average}(t) = \frac{1}{N} \times T_{current}(t) + (1 - \frac{1}{N}) \times T^{\alpha}_{average}(t-1) \tag{2}$$

where, N is the time window representing the delay tolerance of given user, the minimum N is and the urgent that target user is. Typical value of packet service is 100.

In Fig. 1, the comparison between proportional fairness and round robin method is given. From the Fig. 1, it is clear that they both are fairness method that can equally treat every active user.

The 3GPP has established the fairness bound as shown in the Fig. 1. Any algorithm that needs a fairness evaluation will need to compare with the fairness bound.

SCHEDULING FOR LTE-ADVANCED HETEROGENEOUS NETWORKS

Different from traditional scenarios, the heterogeneous networks contain low power RRHs or wireless/wired relays in the network which will shorten the access distance between users and service nodes.

The remote RRH is a low power transmission node with basic processing ability, connected to the home eNodeB through optical fiber. With transmission distance continues to grow, pathloss will increase in exponent way, so at the edge of the cell, received signal power is low and

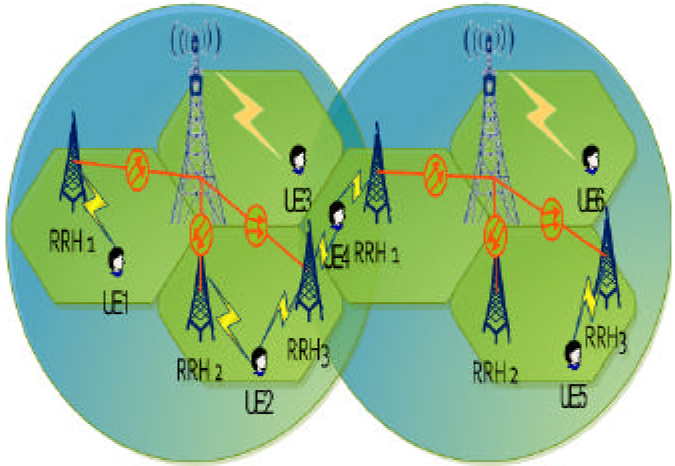

Fig. 2: Scenario of LTE-Advanced heterogeneous networks. The remote RRHs located at the edge of the cell will provide the coverage in a low transmission power which will lower the path loss and interference to adjacent cells

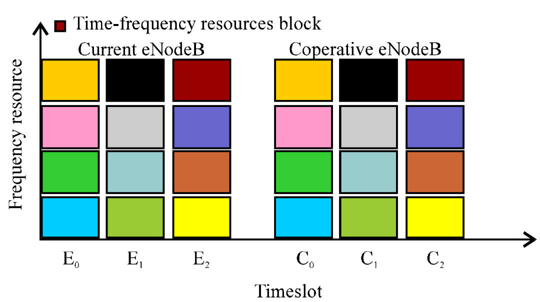

Fig. 3: Principles of time-frequency resources in LTE-Advanced heterogeneous networks

interferences at the same power level from adjacent cells will greatly affect system performance.

RRHs have shortened the access distance and lower the interference to adjacent cells, so the performance of cell-edge user will greatly increase as a cost of establishing RRHs or relays. In Fig. 2, the scenario of LTE-Advanced heterogeneous networks is given (Gao *et al*., 2011a).

In this scenario, scheduling is no longer the behavior of one eNodeB, it is conjunct with RRHs from own eNodeB and other type of nodes from adjacent eNodeB.

How to make full use of system resources is the main problem in the heterogeneous networks.

Time-frequency resource: In order to increase system spectrum efficiency, reuse factor of LTE and beyond systems is set to 1. That means, same frequency band is used in adjacent cells. Joint scheduling is the method that allocates time-frequency resources jointly.

Figure 3 present the principle of time-frequency resource blocks. The x label indicates the timeline and the y label is the usable bandwidth, each block is consisting of subcarriers with both localized or distributed.

At the same time, resources from adjacent nodes are scheduled to match the transmission environment and make full use to resources (Fig. 3).

Novel scheduling technique: Resources from other cells will be scheduled jointly, so the time-frequency resources can be used in a total point of view.

In our previous work of Gao *et al.* (2011b), performance evaluation in HetNet CoMP is done. Here we only need the result of calculating the predicted SINR in heterogeneous networks.

Suppose k is the index of OFDM in resource blocks and l is the index of OFDM symbols. Consider there are M transmit antennas and N receive antennas, H is the N×M channel matrix, U is the M×1 precoding matrix and n is the N×1 Additive White Gaussian Noise. The receiving of the i-th user vector can be described in Eq. 3:

$$\begin{aligned} r(k,l) = {} & (H_{i,0}(k,l) \quad H_{i,1}(k,l)) \times \binom{U_{0,0}}{U_{0,1}} \times s_0(k,l) + \\ & (H_{i,0}(k,l) \quad H_{i,1}(k,l)) \times \binom{U_{1,0}}{U_{1,1}} \times s_1(k,l) + n(k,l) \end{aligned} \tag{3}$$

After the MMSE detector, the predicted signal is calculated. $W_{i,0,1}(k,l)$ indicates the MMSE detector. It is commonly used in many signal processing references. Equation 6 gives the result directly:

Table 2: Simulation parameter and assumptions

Name	Parameter
Cell layout	19 Cell/57 Sector
Radius of cell	500m
BS T×power	40w
RRH T×power	10w
Number of RRHs	6
RRH delay	ideal
Re-transmission time	4
Pathloss	L = 128.1+37.6log10(R)
Shadowing Std	4dB
HARQ scheme	Chase Combine
Channel model	SCME-Urban Macro
Noise power	-107 dBm
Service type	Full Buffer
Simulation TTIs	1000
User No.	570, 30 per Cell
CQI measurement	Ideal
AMC	3GPP, 15 basic MCS
Target BLER	0.1

$$\begin{aligned}\hat{r}_i(k,l) = {} & W_{i,0,1}(k,l)\times \\ & [(H_{i,0}(k,l)\quad H_{i,1}(k,l))\times\begin{pmatrix}U_{0,0}\\U_{0,1}\end{pmatrix}\times s_0(k,l)+ \\ & (H_{i,0}(k,l)\quad H_{i,1}(k,l))\times\begin{pmatrix}U_{1,0}\\U_{1,1}\end{pmatrix}\times s_1(k,l)+n(k,l)]\end{aligned} \tag{4}$$

$$\begin{aligned}W_1(k,l) = {} & \begin{pmatrix}U_{i,0}\\U_{i,1}\end{pmatrix}^H (H_{i,0}(k,l)\quad H_{i,1}(k,l))^H \times \\ & \left\{\begin{matrix}(H_{i,0}(k,l)\quad H_{i,1}(k,l))\begin{pmatrix}U_{0,0}\\U_{0,1}\end{pmatrix}\begin{pmatrix}U_{0,0}\\U_{0,1}\end{pmatrix}^H(H_{i,0}(k,l)\quad H_{i,1}(k,l))^H + \\ (H_{i,0}(k,l)\quad H_{i,1}(k,l))\begin{pmatrix}U_{1,0}\\U_{1,1}\end{pmatrix}\begin{pmatrix}U_{1,0}\\U_{1,1}\end{pmatrix}^H(H_{i,0}(k,l)\quad H_{i,1}(k,l))^H + \dfrac{R_n}{\sigma^2}\end{matrix}\right\}^{-1}\end{aligned} \tag{5}$$

$$SINR_i(k,l) = \frac{\sigma^2 \,|\, W_{i,0,1}(k,l)H_{i,0,1}(k,l)\begin{pmatrix}U_{i,0}\\U_{i,1}\end{pmatrix}|^2}{\sigma^2 \,|\, W_{i,0,1}(k,l)H_{i,0,1}(k,l)\begin{pmatrix}U_{1-i,0}\\U_{1-i,1}\end{pmatrix}|^2 + W_{i,0,1}(k,l)R_n W_{i,0,1}{}^H(k,l)} \tag{6}$$

Our novel scheduling method is given below:

```
1   Dynamic choose cooperative set χ
2     For every cooperative set
3       Predict transmission SINR
4         Calculate scheduling parameter for every user
5         Renew calculation parameter for every user
6     End
7   Perform transmission
```

In step 1, decision of cooperative set is the optional process. It is also done in our previous work.

Our novel method of calculating scheduling parameter is given below, where β is the weight factor that will reflect the importance of resource from adjacent cells. In real transmission scheme, this value is changed by channel condition. When channel condition is good, this value may increase with the value 0.5 at the most and when channel condition is poor, this value can be set to 0 and the scheduling is degenerated:

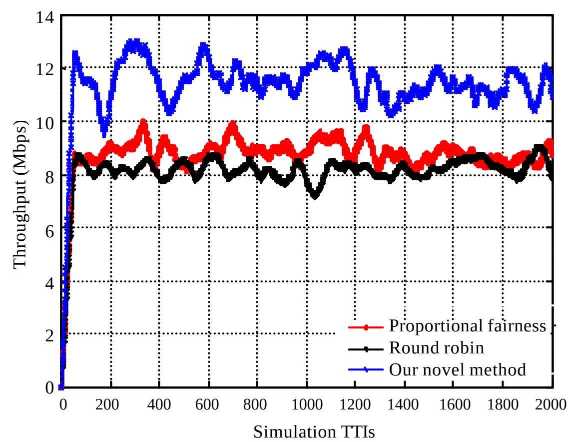

Fig. 4: Comparison of target user throughput. Our novel method, 3 GPP proportional fairness, round robin are given

$$M_i(t) = \frac{T^i{}_{current}(t) + \alpha T^{k\neq i}{}_{current}(t)}{\beta T^i{}_{average}(t) + (1-\beta)T^{k\neq i}{}_{average}(t)} \tag{7}$$

Simulation result and analysis: In this part, we made a system level simulation to evaluate the effectiveness of our scheduling method.

Simulation parameters and assumptions: Simulation parameters are shown in Table 2.

Result and analysis: In Fig. 4, performance comparison is given among our method and other two typical methods. As the utilization of adjacent resources, our method performs better those other two methods. There is about 3 Mbps increase when adopting our novel method.

It is from another point of view proved that: The LTE-Advanced heterogeneous networks provide more complex network environment, traditional method no longer meet the need of the performance.

CONCLUSION

In this study, we make a full analysis of scheduling used in 3GPP LTE-Advanced systems and raise a novel scheduling method according to the complexity of the heterogeneous networks.

Considering different level of resources, full use of time-frequency resources is proved can help increase the user throughput according to the simulation result.

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