An Enhanced Cost Efficient Resource Scheduling Algorithm for Dense Heterogenous Networks

Fudong Yang, Xiaodong Ji and Lei Li

Abstract In this paper, a frequency division and resource block allocation strategy are proposed based on the cost of the system and the different rates of user equipments. Small cell enhancement has been adopted by 3GPP LTE-advanced to improve system performance. However, since the number of small cells in one cluster increased, the interference between thee small cells and the cost of system will increase significantly. A new resource allocation scheme combing both the full frequency reuse and orthogonal strategy is proposed to address this problem. The proposed resource block allocation consider both the cost of the system and the different rates of user equipments. Simulation result are presented to verify the effectiveness of the proposed algorithm.

Keywords Small cell · Heterogenous network · Cost efficiency

1 Introduction

Work on standardizing long-term evolution (LTE) was completed at the end of 2010. As a major enhancement of LTE, the third generation partnership project (3GPP) LTE advanced (LTE-A) was standardized with the aim to fulfill the anticipated higher requirements of the fourth generation (4G) communication systems. The major goals in LTE-A is to support higher downlink throughput and high energy efficiency. Many of the corresponding techniques have been developed to support these requirements and the small cell enhancement (SCE) is one of the promising techniques to significantly improve downlink throughput [1].

Due to the low capital expenditure (CAPEX) and operating expense (OPEX) of the traditional cellular networks, dense small cells will be deployed to improve the network capacity in hotspots such as stadiums and shopping malls [2]. The small cell

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layer accommodates most of the data traffic load in a network [3]. To support the high traffic load in these areas, a number of small cells can be deployed in a cluster. 3GPP has defined several scenarios as indicated in the Release-12 SCE study item [1]. In these scenarios, the macrocells and the small cells use the same frequencies. In scenario 1, small cells are deployed as the outdoor cells in the coverage area of a macrocell. In scenario 2b, small cells are deployed as the indoor cells in the coverage area of a macrocell, while small cells are deployed as the indoor cells outside of the coverage area of a macrocell in scenario 3.

As the number of small cells in one cluster increases, the interference, power consumption, and the system cost increases significantly [4]. There are many interference cancelation methods. In the time domain, enhanced intercell interference cancelation can reduce the interference by configuring almost blank subframes [5, 6]. However, more channel state information is needed for feedback in this case. In the frequency domain, fractional frequency reuse can reduce interference using different bandwidths for the cell edge user equipments (UEs) [7, 8]. However, problems arise in that the spectrum efficiency is low and centralized control is necessary, resulting in the system cost increased significantly. And the cost contains the deployment cost and transmission cost. The transmission cost is used to service the UEs and backhaul cost, while the resource block (RB) allocation problem should be considered as well [9]. In order to address these problems, a new RB allocation scheme has been proposed that provides a new frequency by combing the advantage full reuse and orthogonal strategies. In the RB allocation scheme, not only the different rates of UEs have been considered, but also the system cost has been considered. Moreover, the simulation results have demonstrated the effectiveness of the proposed algorithm. The rest of this paper is organized as follows. Section 2 introduces the system model and cost efficiency. In Sect. 3, the frequency divided is analytically derived, and RB allocation algorithm is then presented. System simulation results are shown in Sect. 4 to help us look into the effectiveness of the algorithm. Finally, conclusions are drawn in Sect. 5.

2 System Model

2.1 Topology

In this paper, the small cell in scenario 1 is considered in which the macrocell and the small cells use the same frequencies. For the macrolayer, the macrocell sites are deployed within a hexagonal grid and each cell site is divided into three sectors. For the small cell layer, a small cell cluster is dropped uniformly and randomly within the macro geographical area. There are ten small cells in cluster. Small cells are uniformly and randomly dropped within the cluster area. Among all small cells, 40 % small cells have ideal backhaul and the others have nonideal backhaul (wireless backhaul). There are 40 UEs in each sector. 2/3 UEs are uniformly distributed within the small cell cluster, and the others are uniformly distributed within the sectors. Each UE is dropped without mobility during the entire simulation. Each UE will access the BS with the Min pathloss.

2.2 Cost Efficiency

According to the min requirement R_{min}, the UE was is divided into the high-speed UE and the low-speed UE. In this paper, the R_{min} of high-speed UE is 1.5 M, and the R_{min} of the low-speed UE is 150 K. While if the rate is large or equal the R_{min}, the UE cannot get any RB, as it is the same with the case that the UE data rate small or equal R_{min}. According to EARTH power model [1], the overall energy consumption of the base station (BS) can be simplified into a linear model, which can be written as

$$P_{in} = P_0 + \lambda P_{out}, 0 < P_{out} < P_{max}, \tag{1}$$

where P_{in} and P_{out} denote the overall energy consumption and radio frequency (RF) output power of the BS, P_0 is fixed power related to circuit processing, air-conditioning, etc. P_{max} is the maximum RF output power. λ is the utilization rate of RB. Pico BS and macro-BS have different parameters according to EARTH in Table 1.

Energy efficiency of the network can be calculated as

$$EE_{network} = \frac{\sum_i R_i}{\sum_j P_j}, \tag{2}$$

where $\sum_i R_i$ denotes the total data rate of all the UEs connecting to the network, and $\sum_j P_j$ is the summation of energy consumed by the BSs including the sets of macro-BSs and picos.

As the power model, the cost of BS is defined into a linear model, which is given by

$$\cos t = \cos t_0 + \sum_{i \in \{RB\}} \cos t_i, \tag{3}$$

Table 1 Power parameters

	P_{max} (dBm)	Fixed power (W)
Macro	46	130
Pico	23	6.8

where $\cos t_0$ is static cost related to construction of the base station, air-conditioning, etc. $\sum_{i\in\{RB\}} \cos t_i$ is the dynamic cost related to BS type, utilization rate of RB, backhaul type, etc. Pico BS and macro-BS have different parameters.

By considering the energy efficiency and the cost, the cost efficiency of the network can be defined as

$$CE_{network} = \frac{EE_{network}}{\sum_{i\in\{RB\}} \cos t_i}. \quad (4)$$

3 The Proposed Resource Allocation Scheme

In this section, the sequential MMSE channel estimation algorithm is developed along with the optimal training design for $\mathbf{H}_{r1}$ and $\mathbf{H}_{r2}$. The individual channel estimation of ACLs and WFLs is derived relying on the Kalman filter and EVD. According to the estimation MSE minimization criteria, the optimal training of the proposed estimators is obtained as well.

3.1 Training Design for $\mathbf{H}_{r2}$

3.2 Frequency Divide

As shown in Fig. 1, the frequency was divided into five parts: HPN Dedicated, HPN& LPN Shared, LPN Dedicated, inband backhaul, and outband backhaul. The size of these resource block is changed with the system load. The regularity of the change is shown as follows:

(1) *Light Load*
When the system is in the light load, the size of resource blocks shared by HPN and LPN is minimum, and the size of other resource blocks is the maximum. In this case,

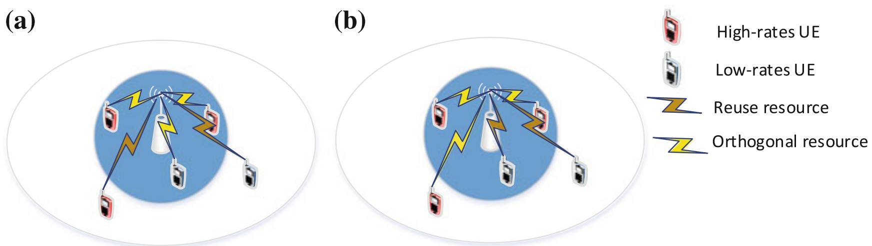

Fig. 1 System model

the wireless backhaul used the inband backhaul first. The outband backhaul is then used when inband backhaul resource has already been used.

(2) *Moderate Load*
When the system load increased, the size of each resource block is changed. The size of resource blocks shared by HPN and LPN is bigger than the light load. The size of other resource blocks is the smaller than the light load. Then, the wireless backhaul used the inband backhaul first, and the outband backhaul is used when inband backhaul resource has already been used.

(3) *High Load*
When the system load is in the high load, the size of each resource block is changed. The size of the resource blocks shared by HPN and LPN is maximum. The size of other resource blocks is the minimum. At this load, the wireless backhaul used the inband backhaul first or there is no inband backhaul. The outband backhaul is used when inband backhaul resource has already been used or there is no inband backhaul.

Advantage:

- Compared to the frequency reused strategy, where all the frequencies are shared by the HPN and the LPN, the proposed frequency divide strategy can avoid interference on some frequency.
- Compared to the frequency orthogonal strategy, where the frequency resource is divided into two parts and the BSs on different layers use completely orthogonal parts, the proposed frequency divide strategy can avoid interference on some frequency and provide more resource to the BSs at the same time.
- Compared to the traditional backhaul strategy (inband or outband), the proposed strategy uses the inband backhaul resource or outband backhaul resource according to the cost efficiency of the BS.

3.3 RB Allocation

The traditional SFR (Soft Frequency Reuse) is an efficient intercell and inter-tier interference coordination technique. The SFR partitions the service area into spatial regions, and each subregion is assigned with different frequency subbands as shown in Fig. 2a. Therefore, the cell-edge-zone UEs do not interfere with the cell-center-zone UEs. With an efficient channel allocation method, the cell-edge-zone UEs may not interfere with neighboring cell-edge-zone UEs. At the future network, the HPN is mainly used to deliver the control information and guarantee the seamless service. The LPN is mainly used to deliver the big traffic and bursty traffic. The HPN will service these UEs far away from the pico base station or having high move speed. The LPN will service these UEs moving very slowly and have big data traffic or is very closed to the LPN. The cell-edge-zone/cell-center-zone UEs can be the high-rate UEs and may also be the low-rate UEs. The location of UES cannot represent the needs of users. While the deployment of the small cell will be densified,

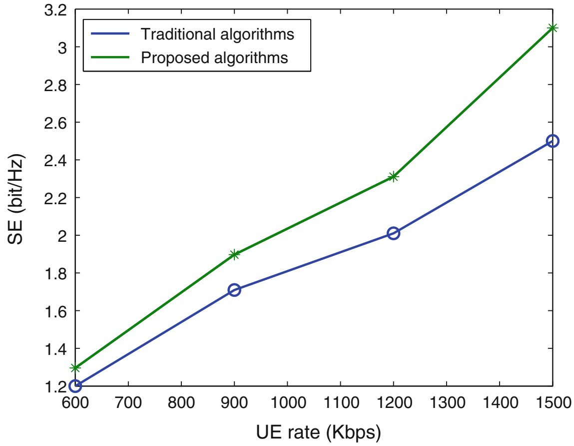

Fig. 2 SE versus UE rate with different algorithms

and the distance between the UE to the BS will be shorter. Then the needs of the cell-center-zone UEs may be bigger than the cell-edge-zone UES. Consequently, an enhanced RB allocation scheme is proposed to suppress the inter-tier interference between HPN and RRHs in Fig. 2b. In the proposed RB allocation scheme, the HPN/LPN dedicated resource block is used to service the high-rate UEs first. Then the resource shared by HPN/LPN is used after the dedicated resource block, and it is solely used by the low-rate users.

The traditional backhaul resource allocation is inband or outband, and the system cost is not considered. Therefore, a backhaul resource allocation scheme is proposed by taking the system cost and CQI (Channel Quality Indicator) into consideration. Backhaul resources will be allocated according to the following rule

$$LPN_{scheduled} = \arg\max_i \{ \frac{C_i}{\bar{R} \cos t} \}, \tag{5}$$

where C_i is the CQI, and $\bar{R}$ is the average transmission rate, $\cos t$ is the cost of the LPN to service wireless LPN.

Advantage:

- If the traditional S-FFR is utilized in the future network, the cell-center-zone UEs access to the LPN may be the high-rates UE, and will share the same radio resources with UEs access to the HPN, which decreases the spectral efficiency (SE) performance significantly.
- How to determine UEs located in the cell-edge or cell-center zone is a challenging work for the traditional SFR. However, it can be avoided in the proposed RB allocation scheme, where only the needs of rates for UEs access to the LPN should be distinguished.
- The dedicated resource is used to service the high-rates UEs, and the shared resource is used to service the low-rates UEs. This method can make a full use

of the resource. The usage of resource block and the service time is reduced in this scheme as well as the power consumption and the system cost.

- The channel quality and system cost are considered in the backhaul resource allocation.

4 Performance Analysis

The performance evaluation parameters are given in Table 2, and the cost parameters are shown in Table 3. The throughput performance, energy efficiency and cost efficiency of the network is considered in the simulation. In order to drop the small cell cluster, macrocell sites are deployed first. Nineteen macrocell sites are deployed within a hexagonal grid and each cell site is divided into three sectors. In each sector there is only one small cell cluster of 10 small cells. A cluster is dropped uniformly and randomly within the macro-geographical area. Small cells are uniformly and randomly dropped within the cluster area with a radius of 70 m. There are 40 UEs in each sector. Among all the UEs, 2/3 UEs are uniformly distributed within the small cell cluster, and the others are uniformly distributed within the sectors. The traffic mode is FullBuffer traffic model, but each UE has a rate limit. In this paper, the high rate is 600 K, 900 K, 1.2 M, and 1.5 M, while the low rate is 150 K. In the simulation, the system load is high load. The contrast scheme is the traditional SFR technology as described above.

Figures 2, 3, and 4 show the spectral efficiency (SE), energy efficiency (EE), and cost efficiency (CE) at different algorithms for different UE rates, respectively. The SE, EE, and CE of the proposed algorithm are significantly improved compared with the traditional algorithm in Figs. 2, 3, and 4, respectively.

These figures shows the proposed algorithm achieve a significant gain to the SE, EE and CE. From Figs. 2, 3, and 4, the higher the load is, the more obvious the gain can be. When the UE rate is as high as 1.5 M, the gain of SE is 20 %, the gain of the EE is 25 %, and the gain of the CE is 27 %, respectively.

Table 2 Simulation parameters

	Macrocell	Small cell
System bandwidth (MHz)	5	5
Carrier frequency (GHz)	2.0	2.0
Pathloss	ITU Uma with 3D distance	ITU Umi with 3D distance
Clusters and cells	1 cluster with 10 small cells	
Traffic model	Fullbuffer with rate-limited	
UE receiver	MMSE-IRC as baseline	
UE speed	3 km/h	
Backhual model	2/5 is ideal and 3/5 is wireless	

Table 3 Cost parameters

	Static cost ($1e^4$¥)	Unit cost ($1e^4$¥)
Macro	21	0.05
Ideal backhaul pico	1	0.05
Wireless backhaul pico	1	0.02

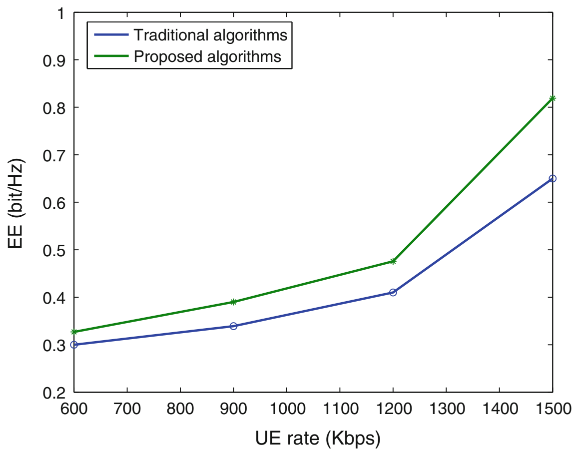

Fig. 3 EE versus UE rate with different algorithms

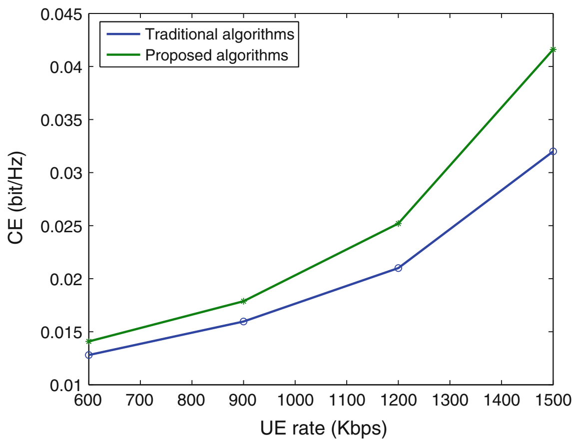

Fig. 4 CE versus UE rate with different algorithms

5 Conclusion

In this paper, a new frequency divide and RB allocation scheme has been proposed to reduce the interference and the system cost in the small cell networks. In order to mitigate the interference, the proposed scheme was divided the frequency into five parts by combining the advantages of the full reuse and orthogonal strategies. The different rates of UEs and the system cost have been taken into consideration in the RB allocation scheme. Finally, the simulation results have shown the effectiveness of the proposed scheme.

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