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Energy Control in 4G Networks

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Abstract

Objective: The design of wireless networks mainly focuses on resource allocation and energy efficient schemes to meet the increasing demands. **Methods/Analysis:** In this paper, we proposed an algorithm for Resource block (RB) allocation and Transmit power control in Long term evolution (LTE) downlink heterogeneous networks. **Findings:** Energy efficiency is increased by increasing the number of smaller cells. To satisfy the required user throughput energy efficiency is minimized and suitable resource block allocation is maximized. **Novelty/Improvement:** In the proposed power control algorithm, user is allowed to select minimum powers to reduce power of Evolved NodeB (eNB).

Keywords: Energy efficiency (EE), LTE, Macro (MeNB), Resource Block (RB), Small eNodeB (SeNB).

1. Introduction

Mobile data traffic is increased three times in 2016 when comparedto2016anditisexpectedtoincreaseexponentially in coming years. Reducing energy consumption is the main challenge in recent wireless systems mainly that adopts 4G/5G technologies. According to information and Communication Technologies (ICT), 9% of total carbon emission is because of mobile communication and specifically radio access part consumes 70% of its total power[1]. Next generation mobile networks are ready to provide high speed internet access. European Member State (EMS) signed to reduce greenhouse gas emission by 20% by 2020. Vodafone group agreed to reduce CO_2 emission by 50%. Because of increasing of energy costs and environmental issues energy efficiency (EE) demands increased recently[2]. Further, EE become very important in radio access networks to design future wireless networks. Energy efficiency is defined as the ratio of data rate and total power consumptions. Here, we deployed small cells jointly coordinate with macro cells. This proposed scenario is called as heterogeneous network[3]. By implementing this heterogeneous network increases the Energy Efficiency and throughput of the network. Deployment of small cells in such a green manner that improves global network energy efficient. Smaller cells can be classified into femto cells, Pico cells and micro cells. Femto cells and micro cells cover less area and consume less power. Pico cells covers more coverage compare to micro cells and femto cells and less power consumption compare to macro cells and consumes more power than micro cells and femto cells[4,5]. Pico cells are used as outdoor coverage or large number indoor user's area like shopping malls, airports, etc. Femto cells are mainly deployed for indoor coverage. Now a days, buildings are built with thick walls and glasses to control room temperature. So, base station requires more power to penetrate through the walls. In LTE network main goals are faster, flexible, improved energy efficiency, spectral efficiency and decreasing per bit cost, increases bit rate of cell edge, simple network architecture and provide mobility management[6]. Recently mobile traffic rate increased due to wide spread use of mobile phones and smart phone devices. More power is consumed by base station because of power amplifiers, feeders, cooling devices, signal processing devices[7]. For Pico cells, micro cells and femto cells do not require cooling devises so in heterogeneous networks we can save-much power[8,9]. The main challenges in LTE is bit allocation and power allocation is to be performed in efficient manner. Water

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filling is one of the method for optimal power allocation to minimize required power and to maximize data rate[10,11]. Although heterogeneous networks are very effective in reducing in energy and power consumption. According to recent reviews small cells shipments are expected to be more than 70 million by in[12-14]. In that small cells half are femto cells, in that each femto cell requires 12W (105 KWh/annum), the total power consumption of femto cells are more than 3×10^9 KWh/annum. In future more energy efficient algorithms are to be developed for more amount of energy saving. The purpose of energy efficient algorithms is to save more power with maintaining quality of service and increase throughput[15]. In LTE power adjustment also plays key role. Sub carriers shared transmit powers of eNodeB. So transmitted power of sub carrier power is depends upon system bandwidth[16]. Heterogeneous networks will improves energy efficiency of cellular network[17] because number of using small cells. In cellular networks if mobile is far away from eNodeB that user requires very strongest signal, so transmit power should be increased. Here, we allocate resource block to each user maximizes the minimal energy efficiency[18]. Resource blocks are allocated to user iteratively with maximum channel gain. Initial transmit power is adjusted on water filling algorithm to satisfy minimum throughput requirement of each user with minimum power. In LTE, each sub carrier spacing is 15 kHz and total 18 MHz bandwidth of LTE include guard band so total 1200 number of subcarriers and 180 kHz of each resource block bandwidth with total 100 resource blocks. LTE downlink is mainly works on OFDMA, here data is carried by parallel with orthogonal frequencies. For modulation, 64-QAM is used in the analysis. When modulation rate is increased, the probability of bit error rate also increased. Every symbol is combined in phase and amplitude, and adjacent symbols are wider so Bit Error Rate (BER) are also less in LTE. In OFDM, sinusoidal symbols are spaced orthogonally without any interference. So, spectral and energy efficiency is improved.

Key challenges of small cells from operator's perspective are mentioned.

Radio access: Optimization of smaller cells and self-configuration is the main requirement for residential small. For urban areas more number of smaller cells are to be deployed.

Deployment: Small cells deployment depends on area of demand, and also depends on physical and geographical design.

Services: small cells should provide all value added services, like SMS, calls, video calls, and data.

Security: Security is very important in deployment of small cells. Small cells should provide high security protocols. Due to number of base stations operators wants to decreases number of base stations, to reduce cost and to save much power. This is main aim of green wireless communication

In section 2, we discuss about proposed system model and energy efficiency allocation problem. In section 3, energy efficient allocation algorithm process is given. Section 4 discusses the simulation results followed by conclusion.

2. System Model

Let the system as single cell downlink heterogeneous LTE network with one Macro eNodeB (MeNB) and N Small cells eNB (SeNB). This system considers with M number of users and K number of resource blocks. One resource block is allocated to each user to avoid intra cell interference between users. Achievable data rate of user is given as in equation (1);

$$R_m = B \sum_{k \in K_m} \log_2 \left(\sum_{n=0}^{N} \frac{\delta_{n,m,k} P_{n,m,k} |h_{n,m,k}|^2}{N_0 B} \right) \tag{1}$$

Where B is bandwidth of resource block, h is channel coefficient between eNodeB and user, P is transmitted power of eNodeB to user on resource block. The resource block indicator is denoted as,

$$\delta_{n,m,k} \in \{1,0\} \tag{2}$$

If δ = 1, connection is established and zero shows no connection between base station and user and N is noise variance. The resource Block allocation indication matrix denotes as,

$$\varphi = \left[\delta_{n,m,k}\right]_{(N+1)*M*K} \tag{3}$$

Transmitted power matrix denoted as

$$\rho_t = \left[\rho_{n,m,k}\right]_{(N+1)*M*K} \tag{4}$$

Power consumption is different for different modes of operation such as sleep mode, transmit mode, idle mode, and receive mode. In active mode signal processing unit, analog to digital convertor, digital to analog convertor, mixers cooling devices and synthesizer consumes more power. Hence, there is a need to optimize power consumptions in the network. In downlink more power is consumed by the radio frequency amplifiers to transmit high frequency signals. Circuit power consumption is mainly divided into two parts, dynamic part and static part. These are proportional to throughput, which is given as in equation (5);

$$P_c = P_s + \varepsilon R \tag{5}$$

Where P_c is power consumption of circuit, P_s is static term, ε is dynamic power consumption and R is total throughput denoted as

$$R = \sum_{m=1}^{M} R_m \tag{6}$$

The total power consumption is given by,

$$P = \zeta P_t + P_s + \varepsilon R \tag{7}$$

The total transmitted power P_t is denoted as

$$P_t = \sum_{n=0}^{N}\sum_{m=1}^{M}\sum_{k=1}^{K} \delta_{n,m,k} P_{n,m,k} \tag{8}$$

Where, ζ is the drain efficiency of power amplifier equal to 0.38 and ε is dynamic power consumption

Therefore, the Energy efficiency of the network is given as,

$$\eta_{EE} = \frac{R}{\zeta P_t + P_s + \varepsilon R} \tag{9}$$

To get maximum efficiency and better quality of service the following condition is to be satisfied,

$$max_{\varphi,\rho_t} \eta_{EE} \tag{10}$$

Every resource block is allocated to at most one user. In some cases, equation (10) is not possible and in that case, we have to decreases some user throughput based on priority. Energy efficiency is decreases with increases of Dynamic power consumption ε and static term P_s. In Figure 1, we consider one macro station and many smaller cells, when number of small cell eNBs are increases, energy efficiency (EE) also monotonically increases.

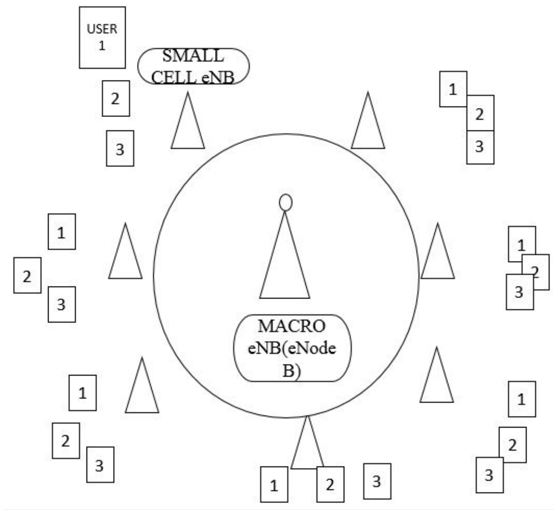

Figure 1. Proposed system network model.

3. Energy Efficient Resource Allocation Algorithm

The energy efficient resource allocation algorithm procedure as follows:

Step 1: Initialize all transmit powers as zero.

$$P_{n,m,k} \leftarrow 0 \tag{11}$$

STEP 2: For each user calculate transmit powers and minimum throughput.

$$P_{n,m,k} = \left(\frac{1}{N\lambda \ln 2} - \frac{|h_{n,m,k}|}{N_0}\right) \tag{12}$$

Allocate power by using

$$P_{n,m,k} = \begin{cases} L - q^{-1}_{n.m.k} & , \quad L \geq q^{-1}_{n.m.k} \\ 0 & , \quad L < q^{-1}_{n.m.k} \end{cases} \tag{13}$$

Where $L = \frac{1}{N\lambda \ln 2}$ and

$$q^{-1}_{n.m.k} = \frac{N_0}{|h_{n,m,k}|} \tag{14}$$

STEP 3: Initiate RB allocation indicator. If the value is one indicates connection is established, otherwise no connection.

$$\delta_{n,m,k} \in \{1,0\} \tag{15}$$

STEP 4: Calculate m^{th} user data rate.

$$R_m = B \sum_{k \in K_m} \log_2 \left(1 + \sum_{n=0}^{N} \frac{\delta_{n,m,k} P_{n,m,k} \left| \boldsymbol{h}_{n,m,k} \right|^2}{N_0 B} \right) \tag{16}$$

$\boldsymbol{h}_{n,m,k}$ is the channel coefficient between eNB n, user m on RB k.

STEP 5: Calculate total transmit power

$$P_t = \sum_{n=0}^{N} \sum_{m=1}^{M} \sum_{k=1}^{K} \delta_{n,m,k} P_{n,m,k} \tag{17}$$

STEP 6: The Energy Efficiency (EE) is given by

$$\eta_{EE} = \frac{R}{\zeta P_t + P_s + \varepsilon R} \tag{18}$$

Flow diagram of energy efficient algorithm is shown in Figure 2.

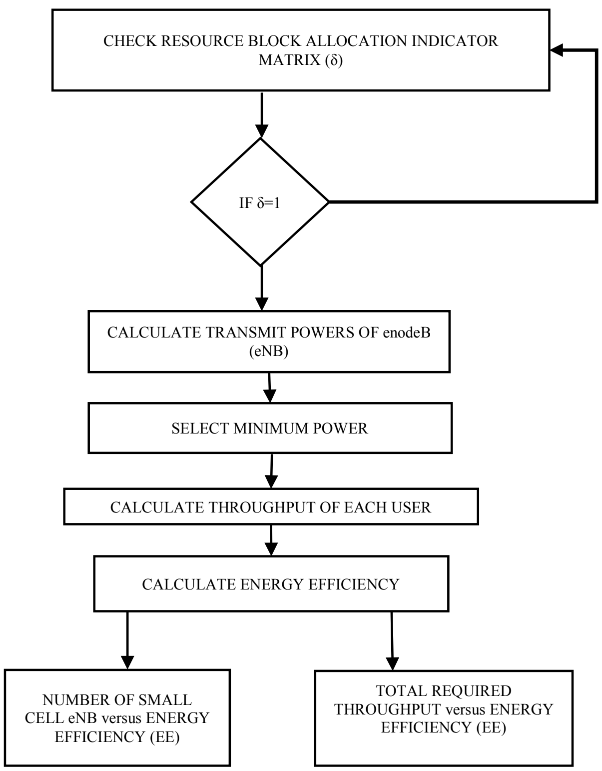

Figure 2. Flow diagram of Energy Efficient Algorithm.

4. Simulation Results

The performance of resource allocation of the proposed system simulation is based on LTE standard. We have considered drain efficiency of power amplifier is 0.38. The energy efficiency of heterogeneous network are shown. Figure 3 shows the energy efficiency performance of the existing algorithm and modified algorithm with number of small eNB. It is observed that existing algorithm requires 0.68 Mbps/w energy efficiency whereas in the modified algorithm requires 0.6 Mbps/w energy efficiency for 35 number of eNB. It shows that, existing algorithm provides 12% improvement in energy efficiency when compared to modified algorithm for 35 number of eNB. If the number of cells increases the existing algorithm provides better performance than modified algorithm. Figure 4 shows that static term is varied 10 to 20W and dynamic power consumption from 1 to 2W/Mbps. It is observed that energy efficiency is decreasing when dynamic power consumption and static term increases. Therefore, selection of optimal static term is very important in energy efficiency scheme.

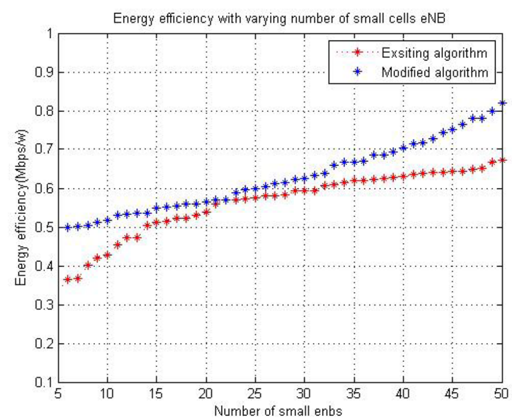

Figure 3. Energy efficiency with varying number of small cells eNB.

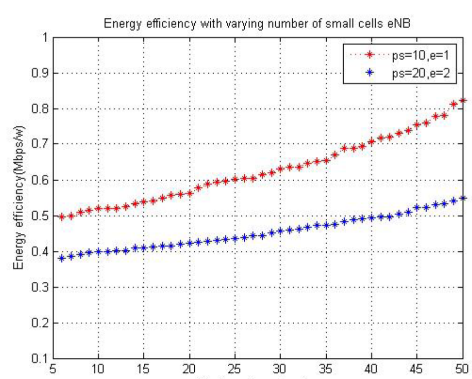

Figure 4. Energy efficiency with different static term and power consumption value.

5. Conclusion

This resource allocation method is evaluated and simulated based on LTE standard. Energy efficiency is first increases and later decreases with required throughput because of transmit power increases with increasing required total throughput. But in practical systems energy efficiency is monotonically increased and decreased with transmit power. When number of smaller cells energy efficiency increases and path loss decreases due to less distance between transmitter and receiver. So, the transmitter losses are reduced and more power is saved.

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