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# A Power Control Algorithm and Software Tool for Femtocells in LTE-A Network

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## ABSTRACT

The heterogeneous networks (HetNets) emerge as one of the most auspicious improvements toward realizing the objective specifications of Long Term Evolution-Advanced (LTE-A) networks. Though similar to all other wireless networks, HetNet also yields from the interference problems, i.e., the co-tier and cross-tier interferences. Regarding functionality and efficiency of the HetNets, the avoidance and management of these interferences are very crucial. In this study, a power control algorithm (PCA) is suggested to decrease the interferences disadvantages in the HetNets. To calculate the signal power, the SINR (Signal to Interference and Noise Ratio) and RSRP (Reference Signal Received Power) are used for downlink and uplink, respectively. The selection decision is taken by signal strength information. The UE (User Equipment) is switched accordingly. A simulation tool is developed and used to investigate and find out the nearest cell to UE in a HetNet.

**Keywords:** LTE-A, HetNets, HeNB, user equipment, RSRP, SINR

## 1. INTRODUCTION

Due to the sheer growth of mobile broadband subscription, the demand for high data rate increased. According to Ericsson mobility report [1], until 2021 the number of mobile broadband subscriptions will reach to 9 billion, where 7.7 billion will use the mobile data. Furthermore, the growth of smartphone data and video traffics will be multiplied 20 and 25 times respectively. The Cisco calculated that the mobile data is reached up to 11.2 Exabyte per month by 2017 and 49 Exabyte per month is expected till 2021 [2].

3GPP (3rd Generation Partnership Project) proposed LTE-A (Long Term Evolution-Advanced) in 2010 to achieve the demanded high data rates. LTE-A is a promising technology which provides 300 Mbps downloading and 150 Mbps uploading data speeds with spectral efficiency [3]. The present LTE-A system is based on homogeneous network, where every single evolved Node B (eNB) cover the whole cell and use same transmission power levels, modulation techniques, access schemes, antenna patterns to offer QoS to the UEs (User Equipment) across the cell [4, 5]. On the contrary, such deployment reduces the coverage and capacity of the cell-edge users. The primary approach to solving the problem mentioned above is to shrink the cells, which will satisfy the increasing demand for high data rates in cellular systems and recover the signal to interference and noise ratio (SINR), but this approach is not economical and needs massive investments [6]. Therefore, the deployment of a heterogeneous network (HetNet) is more scalable

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and useful for both operators as well as users. It is expected, that this approach will improve the system broadband and rise the coverage and capacity of the cell cost-effectively [3]. The 3GPP LTE-A macrocells also known as eNBs are expensive and challenging to deploy everywhere. While on the other hand, 90% data services and 2/3 calls are expected to be inside of the building, and the indoor users complain of poor coverage because of the walls and others obstacles weak the strength of signals. Thus, the short-range femtocells are being deployed to extend the coverage for indoor, i.e., offices, shopping malls, and homes, etc. subscribers [7], [8]. The femtocell is also known as HeNBs (Home Evolved Node B), and the typical radius of a femtocell coverage area is around 30 m and the transmit power of a femtocell is usually less than 0.1 W (≤ 20dBm) [9]. These femtocells are connected to Evolved Packet Core (EPC) with Asynchronous Digital Subscribers Line (ADSL) link. This type of architecture is usually called the HetNet [10, 11]. The HeNBs are connected with the HeNB Gateway, and then HeNB Gateway is linked with EPC of the core system [12]. The eNBs are directly connected with each other through x2 links. S1 is a link between eNB and Mobility Management Entity and Serving Gateways (MME/S-GW). In HetNet the eNBs and HeNBs generally use the same frequency band to obtain the required cell splitting gain [12]. As a result, the HetNet provides better coverage and high throughput. However, to successfully install the femtocell architecture, different challenges are required to be considered. Among other problems, the main difficulty is to control the interference management, because femtocells and macrocells operated the same frequency which produces a cross-tier interference.

Additionally, the co-tier interferences are generated by nearby femtocells [13]. In this paper, a novel approach is proposed to reduce the interferences created by neighbor eNBs and HeNBs. Different equations are used to calculate and measure the received power of the reference signal and SINR values.

The paper is organized as follows. In Section II, we formulate the mathematical model and analysis. Section III presents the design of the proposed system. Simulation setup is explained in Section IV. Section V described the simulation results and Section VI is the conclusion section.

## 2. SYSTEM MODEL AND ANALYSIS

### 2.1. OFDMA and SC-FDMA

The entire LTE-A network is IP-based, and the Internet Protocol (IP) is capable of transferring voice, video and data traffic reliably and securely. The core principle behind using IP is, it dynamically assign the address when mobile is switch on and release when it is switched off. Moreover, the LTE-A uses Orthogonal Frequency Division Multiple Access (OFDMA) as an access method and Orthogonal Frequency-Division Multiplexing (OFDM) as a digital modulation scheme. To achieve high data rates, the subcarriers are shared by many users in OFDMA [14], but because of the complex processing, OFDMA needs more power to calculate. That is why Single Carrier- Frequency Division Multiple Access (SC-FDMA) is used on the UE side because of less complexity [15]. The SC-FDMA uses single subcarrier used for each UE.

### 2.2. Measurement Scales

The analysis of Radio Frequency (RF) value is essential in wireless broadcasting and communications system because these values indicate the condition and performance of the systems. There are some ranges of RF values, which have to be considered while measuring the performance of the system. Table I depicts a useful classification of RF status vs. LTE key performance indicators (KPIs). The EUTRAN vendor compiled the data in this chart during RF turning process and distributed among all the major LTE-A operators [16]. There might be several other tables exist, but the results are almost similar in large extent. All LTE-A significant vendors use the following quantities for RF signal measurements.

- SINR (Signal to Interference and Noise Ratio)
- RSRP (Reference Signal Received Power)
- RSRQ (Reference Signal Received Quality)

Table 1. Classification of RF status vs. LTE KPIs

| | Condition | SINR (dB) | RSRQ (dB) | RSPR (dBm) |
|---|---|---|---|---|
| RF Condition | Excellent | >= 20 | >= -10 | >= -80 |
| | Good | 13 to 20 | -10 to -15 | 80 to 90 |
| | Mid Cell | 0 to 13 | -15 to -20 | -90 to 80 |
| | Cell Edge | <=10 | <-20 | <= -100 |

### 2.3. Measurement in LTE-A

The management of interference in LTE-A femtocells is more critical than the conventional macro cellular networks because femtocells use the same channel frequency bands. Moreover, in the 3GPP specifications, the Radio Access Network (RAN) considered the RSRP and RSRQ in the uplink value. In the presence of the mentioned problem, the SINR to RSRQ conversion is described as below;

$$SINR = \frac{S}{I + N} \tag{1}$$

where $S$ is the power of the signal, $I$ is the interference level, and $N$ is the background noise. These measurements are obtained when the same frequency band used.

According to 3GPP, the *RSRQ* is defined as;

$$RSRQ = N_{prb} \frac{RSRP}{RSSI} \tag{2}$$

where, *RSSI* (Received Signal Strength Indicator) used by UEs, and $N_{prb}$ is the number of Resource Blocks (RBs). In the OFDM system, the own interference of a cell is often avoided and therefore, the other interferences are weighed as $I$.

$$RSSI = S_{tot} + I_{tot} + N_{tot} \tag{3}$$

where $S_{tot}$ is total signal power strength of 12 subcarriers, $I_{tot}$ is the total Interferences received from nearby cells, and $N_{tot}$ is the overall background noise. The absolute power received from 12 subcarriers depends on the OFDM symbols.

$$S_{tot} = \rho .12. N_{prb}. RSRP \tag{4}$$

where $\rho = \mathrm{RE/RB}$.

Here the $\rho$=1 because all the subcarriers are transmitted for OFDM symbol. On the other hand, Interference and Noise are represented as

$$I_{tot} + N_{tot} = \frac{I_{tot} + N_{tot}}{12. N_{prb}} \tag{5}$$

Now we can put the values of Eq. 4 and Eq. 5 in the Eq. 1.

$$SINR = \frac{\rho .12. N_{prb}. RSRP}{(I_{tot} + N_{tot})/12. N_{prb}} \tag{6}$$

After putting the values in Eq. 6. The SINR is shown in Eq. 7.

$$SINR = \frac{12N_{prb}. RSRP}{I_{tot} + N_{tot}} \tag{7}$$

Here, we can put the values of Eq. 3.

$$SINR = \frac{12N_{prb}. RSRP}{RSSI - S_{tot}} \tag{8}$$

After modification of Eq. 2, we can get the value of *RSSI* and put in the Eq.8. Also, inserting the values of Eq. 4.

$$SINR = \frac{12. N_{prb}. RSRP}{N_{prb}\frac{RSRP}{RSRQ} - x.12N_{prb}. RSRP} \tag{9}$$

Finally, we can get the value of *SINR* from the above equations.

$$SINR = \frac{1}{\frac{1}{12. RSRQ} - \rho} \tag{10}$$

## 3. SYSTEM DESIGN

### 3.1. Topology

The 3GPP LTE-A specify the Macrocell [17] a Macrocell entity known as eNB and femtocells are known as Home eNB, which is capable of transmission and reception of signals in one or more cells. In Figure 1, the general 3GPP system specification of HetNet and EPC illustrated. The HeNBs are connected with the HeNB Gateway, and then HeNB Gateway is linked with EPC of the core system [12]. However, Figure 2 describes the overall scenario that we are focused on our paper. For instance, we used a Macrocell, two Femtocells, four Femtocell UEs and two Macrocell UEs.

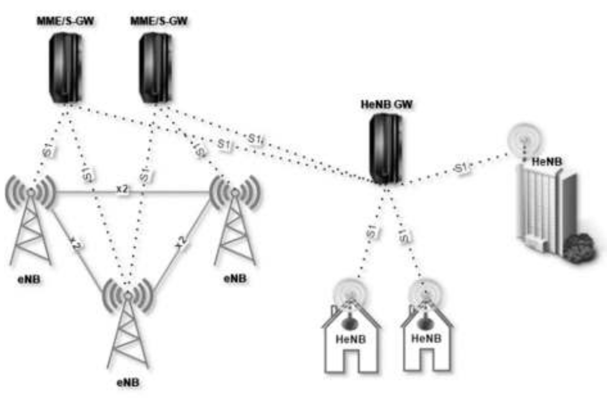


Figure 1. 3GPP heterogeneous network and EPC

### 3.2. System Flowchart

In this section, we implemented a Femtocell and Macrocell simulator, which is freely available at [18]. This simulator is used to perform the power control algorithm and to find out the maximum power level in the existing HetNets. Primarily, the proposed PCA algorithm is reasonably separated two layers. One layer is working on the back-end and calculate the values of RSRP and SINR, while the front-end layer displays the overall performance of the system. Figure 3 depicts the flowchart diagram, which is carried out during the calculation. The different modules are shown, which are to be calculated during the simulation.

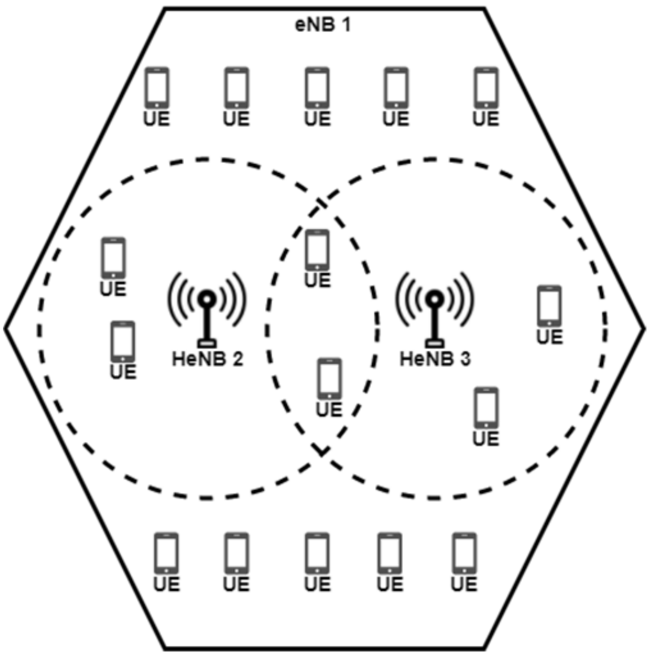


Figure 2. HetNet topology

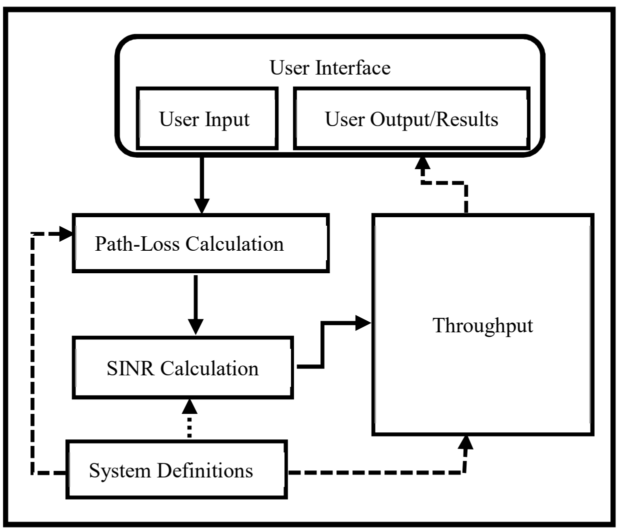


Figure 3. Flowchart of the proposed algorithm

## 4. SIMULATION SETUP

Based on the previous discussions and formulations, we set up the simulator mentioned in [18]. This simulator is very easy to use and has a user-friendly display. The researchers can modify the code according to the requirements. To obtain useful results we set the positions and values of the cells used in this work.

### 4.1. Main Layout

The main layout of the simulator provides the visual display facility for placing and organize the femtocells inside the central Macrocell. Figure 4 shows the initial window, where the user can set the number of Femtocells and the number of UEs connected with Femtocells or Macrocell. Here the user can also set the parameters to obtain the results accordingly.

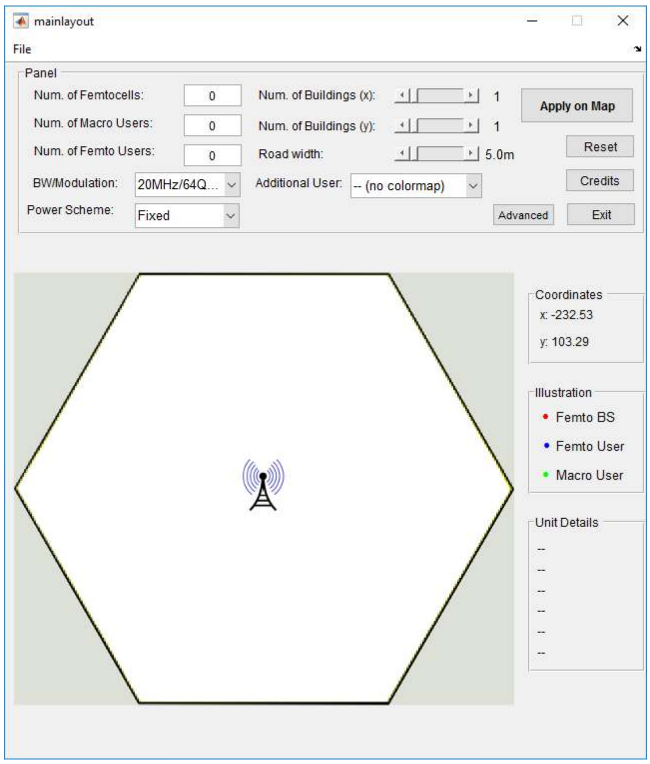


Figure 4. Main layout of the simulator

### 4.2. Parameters

As stated above, there are many altered options available to set up the values according to the requirements.

Table 2. Simulation Conditions

| Parameter | Value |
|---|---|
| Macrocell Coverage Area | 250 m |
| Femtocell Coverage Area | 20 m |
| Carrier Frequency | 2 GHz |
| Macrocell TX Power | 46 dBm |
| Femtocell TX Power | 20 dBm |
| Outdoor Walls Loss | 20 dB |
| Indoor Walls Loss | 5 dB |
| Bandwidth | 10 MHz |
| Modulation | QPSK |
| Subcarrier Spacing | 15 KHz |

Table II shows the parameters which are used in the simulation work. The values are set before running the simulation. The 3GPP LTE-A can operate on many different frequency bands. First of all, the radius of both Macrocell and Femtocells are selected. Following are the general values, used in our simulations.

## 5. RESULTS

In an initial step, the location of Femtocells and UEs are randomly located. The specific values for generating the scenarios of rearranging the particular position of Femtocell and UEs are entered, and the action of the "Apply The Map" is applied. Figure 5 illustrated the detail graphical overview of the network with particular positions of Femtocells and UEs. Furthermore, the coordinate's points (x,y), power schemes, modulation techniques and other detail are also mentioned.

In next step, the "Run Simulation" is selected for generating the result. In Figure 6, we can analyze the power level of the signal from lowest to the highest value. The maximum power value of the selected unit indicates the position and throughput received at the UE. If the UE is near to femtocell, it will receive the high power of the signal, and when it moves far away from the femtocell, the signal power level will decrease to the minimum level. When the UE receives another signal from nearby femtocell or Macrocell, then the two received signals power would be compared according to the equation discussed in Section II.

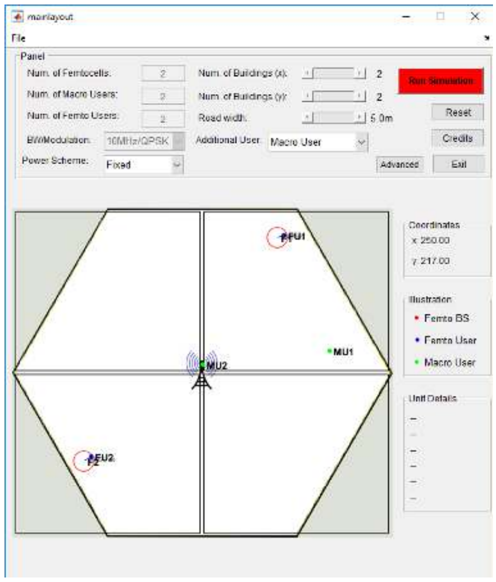

Figure 5. Topology configuration display

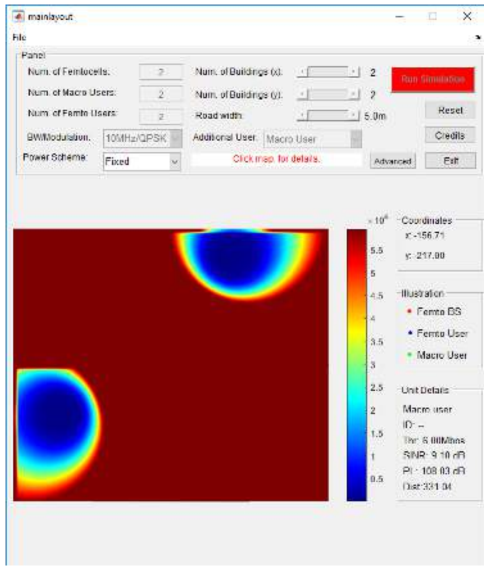

Figure 6. User output display/results

## 6. CONCLUSION & FUTURE WORKS

In this paper, the power control algorithm is presented for the radio resource management (RRM) in LTE-A femtocells network. A simulator tool is done to analyze the SINR and RSRP of the signal. The LTE-A macrocell and femtocell position are rearranged according to the defined topology for generating the required results. Based on these outcomes and system information, the throughput at UE is calculated to control the connectivity. Furthermore, it is analyzed that PCA method, has the capability to reduce the interferences issue occur by the unorganized deployment of HetNets. Additionally, the smooth handover is probable during mobility from one cell to another. In the future work model of the system will be extended to investigate the new strategies for RRM in LTE-A femtocells networks. Some of the approaches include fractional frequency reuse and self-organizing methods in femtocells overlay.

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