Analysis of Macro-Fem to Cellular Performance in LTE Under Various Transmission Power and Scheduling Schemes

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Abstract —The mobile networks use femtocells as low power nodes to improve indoor coverage and thus achieve a high network capacity. In this paper, we focus on a combination of macrocells and femtocells in Long Term Evolution (LTE) networks. To achieve a high LTE network performance, we investigate the influence of power allocated to Evolved NodeB (eNodeBs) and Home Evolved NodeB (HeNodeBs) respectively. Using the Round Robin scheduling, while decreasing the eNodeBs transmit power and increasing the HeNodeBs transmit power, improve the user's throughput significantly. We further demonstrate, by simulations, that applying other scheduling algorithms under the low eNodeBs transmit power and high eNodeBs, results in a significantly increased performance of LTE network.

Index Terms—Scheduling, transmit power, HetNet, LTE, resource block

I. Introduction

Wireless data traffic is increasing exponentially in recent years. Driven by many factors such as the new generation of devices (smart phones, netbooks, tablets, etc), highly bandwidth demanding applications, users' attitude to be always connected to social networks and other applications, the capacity demand increases much faster than spectral efficiency improvement [1]. As a result, the growth in mobile data traffic will be multiplied in next few years.

Heterogeneous mobile networks are the solution to improve system capacity as well as effectively enhance network coverage [2]-[6]. Moving from the macro-centric cellular deployment to small-cell deployment seems to be the only sensible way to generate ten or thousand percent increased capacity on the network.

It is estimated that in cellular networks 2/3 of the calls and over 90 percent of the data services occur indoors [7]. Hence, it is extremely important for cellular operators to provide good indoor coverage for not only voice, but also video and high-speed data services, which are becoming increasingly important. So, a very powerful property of heterogeneous networks is that in one side to offload the congested macro traffic, and in other side to improve the performance of majority mobile communications that are indoor generated. Improvement in performance means high data rate, high capacity, always-on, and always-connected-to-the-best-network user experience [8], [9].

Until now, some studies have been carried out by researchers concerning the problem of power control in heterogeneous networks [10], [11]. A fully distributed power control algorithm which adapts the pilot power of the femto base station in a heterogeneous network to improve the coverage is explained by authors in [12], [13]. A different approach which shows an improvement in terms of capacity for heterogeneous networks by optimizing the transmit power in uplink under the low Signal to Interference (SIR) regime has been made by authors in [14].

One of the key issues in macro-femto cell deployment are the scheduling of resources and interference mitigation. A joint uplink and downlink scheduling based on channel state information is proposed by authors in [15]. Differently from that, in [16], the authors have proposed a method which considers the fairness to solve the user's resource allocation without considering the interference mitigation problem that comes due to the difference in transmit power between macro cell and femto cell in a macro-femto cellular scenario.

Even a significant number of mobile operators around the world have already deployed the Long Term Evolution (LTE) network, they still have difficulties to mitigate interference while using the appropriate scheduling algorithm. A distributed resource allocation scheme employing scheduling algorithms in uplink OFDMA systems is made by authors in [17]. The implementation of Proportional Fair Scheduling (PFS) which reduces the feedback signaling while keeping the user's throughput is done in [18].

To offer an appropriate solution to the mobile operators, we analyzed three different scenarios of macro and femtocells in LTE network using LTE system-level simulator [19], [20]. The LTE System Level Simulator calculates the post equalization SINR per subcarrier [21], [22]. Referring to [23] it is possible to evaluate the performance of the Downlink Shared Channel of LTE Single Input Single Output (SISO) and Multiple Input Multiple Output (MIMO).

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The scope of this paper is to evaluate the network performance considering interference mitigating and scheduling the radio resources. We use the Empirical Cumulative Distribution Function (ECDF) to evaluate the network performance in terms of average user's throughput and users wideband Signal to Interference and Noise Ratio (SINR). In the first and second scenario, we use Round Robin scheduling algorithm [24] and analyze the network performance when the Macro base station (eNodeB) and Femto base station (HeNodeB) transmit power varies. In the third scenario we analyze the network performance when four scheduling algorithms are applied under the condition of minimized interference: Round Robin, Best CQI [25], Prop fair Sun [26] and Max Throughput [27]. A comparison in terms of average throughput, fairness index, and mean Resource Block (RB) occupancy is performed.

II. System Model

In this Section we present a macro-femto cellular system model. It consists of a cluster containing 7 macrocells with homogenous distribution of femtocells within macrocells. We use sectorized macrocells where in each sector there are 4 femtocells located.

The network model is shown in Fig. 1, where all considered users are pedestrian, moving at 5 km/h speed. The femto users are considered as Closed Space Group (CSG) [28] so that the interference between macro and femto users is avoided.

For SISO case, the SINR for a mobile user is given as in [23]

$$\boldsymbol{SINR} = \frac{\boldsymbol{P_{tx}}}{\frac{\boldsymbol{1}}{|\boldsymbol{h_0}|^2}\boldsymbol{\sigma^2} + \sum_{l=1}^{N_{int}} \frac{|\boldsymbol{h_l}|^2}{|\boldsymbol{h_0}|^2}\boldsymbol{P_{tx,l}}} \quad (1)$$

where the $\frac{1}{|h_0|^2}$ and $\frac{|h_l|^2}{|h_0|^2}$ are the noise and interference parameters. In Equation (1), the macroscopic pathloss between eNodeB and User Equipment (UE), and HeNodeB and UE is modeled by two components: propagation loss due to distance and the antenna gain.

We use the pathloss model for urban areas [29] as expressed by the following equation

$$\boldsymbol{L = 40(1 - 4 \times 10^{-3} \times Dhb) \times \log_{10}(R) - 18 \times \log_{10}(Dhb) + 21 \times \log_{10}(f) + 80dB} \quad (2)$$

where, R is the distance between base station and the UE in kilometers, f is the carrier frequency in MHz, and Dhb is the base station antenna height in meters, measured from the average rooftop level.

Considering a carrier frequency of 2014 MHz and a base station antenna height of 15 meters above average rooftop level, in Equation (2) we have the following formula for propagation model given by

$$\boldsymbol{L = 127.68 + 37.6 \log_{10}(R)} \quad (3)$$

After propagation model (L) is calculated in Equation (3), log-normal distributed shadowing (LogF) with standard deviation of 10 dB is added to it. The shadowing correlation factor of 0.5 for the shadowing between sites (regardless aggressing or victim system) and a factor of 1 between sectors of the same site is used.

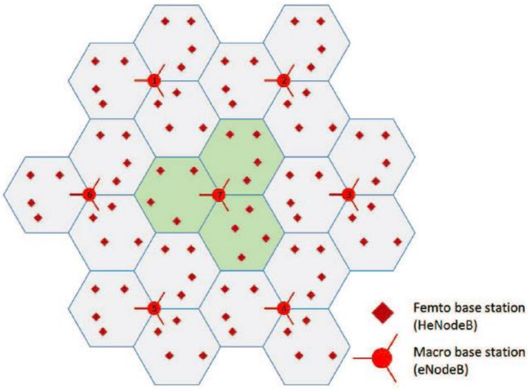

Fig. 1. Distribution of eNodeBs and UEs in LTE macro-femto deployment.

The pathloss is given by the following equation

$$\boldsymbol{Pathloss_{macro} = L + LogF} \quad (4)$$

The standard 2D radiation pattern G in Equation (4), for each sector in 3-sector cell site, dependent on the azimuth angle θ is given by following expression

$$\boldsymbol{G(\theta) = -min\left[12\left(\frac{\theta}{\theta_{3dB}}, A_m\right)\right]} \quad (5)$$

where θ_{3dB} is the 3 dB beam width that corresponds to 65◦, and Am = 20 dB is the maximum attenuation. The antenna gain is 15 dBi

III. Simulation Results

TABLE I: Simulation Parameters

Parameter	Value
Carrier frequency	2.14GHz
Transmission bandwidth	20MHz
Number of Transmit antennas (nTx)	1
Number of Recieve antennas (nRx)	1
Transmit mode	CLSM
Macroscopic pathloss Urban,	TS 36.942
Channel Model	Winner+
Shadow fading	Claussen
Number of eNodeB rings	1
Number of femtocells per cell	4
Number of users per eNodeB	15
Number of users per HeNodeB	3
User speed	5km/h
Antenna type	Kathrein antenna with 15 dBi gain

In this Section we evaluate the possible deployment scenario of LTE heterogeneous network using the Vienna LTE System Level simulator. In such network, we evaluate different transmit power and scheduling schemes.

Some of the simulation parameters are defined as in the following. The maximum transmit power recommended by [30], for 10 – 20 MHz carrier is 46/49 dBm, while we consider range of power level for femtocell between 50 mW to 200 mW. For macrocell base stations we consider the range of power level between 10W to 40W using a 20 MHz carrier.

The other network simulation parameters are shown in Table I.

A. Effect of HeNodeB Transmit Power Inmacro-Femto Deployment Using Round Robin Scheduling

In this Subsection, we evaluate the impact of the femtocell transmit power in LTE network using Round Robin scheduling algorithm. We analyze the network performance of macro-femtocell topology, using constant eNodeBs transmit power and variational HeNodeBs transmit power.

We use the simulation parameters given in Table I and the LTE System Level Simulator to provide the simulation results based on ECDF calculation. The ECDF of average user's throughput is shown in Fig. 2.

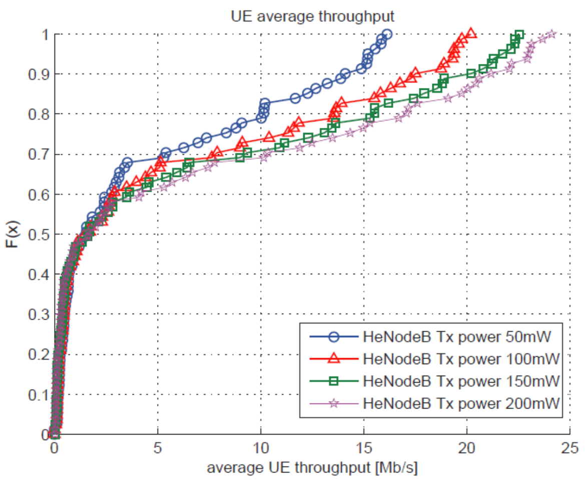

Fig. 2. ECDF of average UE throughput for variable HeNodeB Tx power.

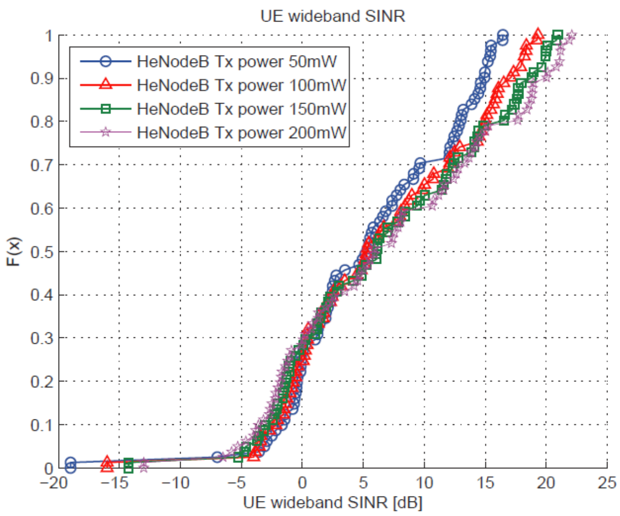

Fig. 3. ECDF of wideband SINR for variable HeNodeB Tx power.

The simulation results shown in Fig. 2, indicate that the increase in HeNodeB transmit power has no impact on user's throughput until the value of 3 Mbps. In this case the eNodeB transmit power is set to a constant value of 46 dBm. One can see that higher throughput is achieved for higher transmit power of HeNodeBs, in this case for 200 milliwatt. The increase of user's throughput shown in Fig. 2, even the HeNodeBs transmit power is increased comes as result of low power operation of HeNodeBs compared to eNodeBs, which results in low interference. The ECDF of users versus wideband SINR is shown in Fig. 3.

Similarly, to the results shown in Fig. 2, the simulation results shown in Fig. 3, achieve higher values of users wideband SINR for higher HeNodeBs transmit power.

B. LTE user Throughput Under Different Scheduling Algorithms

In Subsection B, by simulations we have shown the positive impact of HeNodeB, to user's throughput in a maco-femto cellular scenario that use the round robin scheduling algorithm.

To compare the influence of different scheduling algorithms to LTE user's throughput, we use the simulation parameters in Table I in LTE system Level Simulation. The transmit power for HeNodeB is set to 20 dBm and for eNodeB is set to 46 dBm. In this scenario we compare four scheduling algorithms: Round Robin, Best CQI, Proportional Fair, and Maximum Throughput scheduler. The performance evaluation of the mentioned scheduling algorithms in terms of user's average throughput, fairness index and mean RB occupancy are given in Table II.

TABLE II: RESULTS FOR DIFFERENT SCHEDULERS

Scheduler	Results		
	Avg. Throughput	Fairness index	Mean RB occupancy
Round Robin	5.61 Mbps	0.398	90.93%
Best CQI	9.74 Mbps	0.372	98.76%
Prop Fair	7.88 Mbps	0.435	93.88%
Max Throughput	9.72 Mbps	0.366	97.98%

For average throughput comparison, the best performance schedulers are Best CQI and Max Throughput, which offer the highest throughput rate. Round Robin offers the lowest throughput because this algorithm doesn't consider channel conditions. Between Best CQI and Max Throughput is not depicted any big difference, these two algorithms are quite similar in throughput, fairness index and mean RB occupancy. In terms of fairness index the Proportional fair Sun algorithm has the highest fairness index of 0.435 meaning that 43.55 percent of the users are served with a fair sharing resources, while for the rest of users the sharing of resources is unfair.

In Fig. 4 is shown the ECDF of average user throughput.

From simulations results shown in Fig. 4, one concludes that with Best CQI and Max Throughput higher UE average throughput can be achieved compared to Round Robin and Proportional fair Sun.

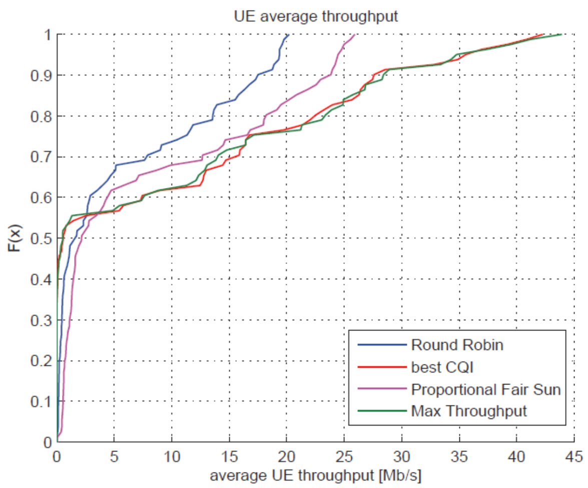

Fig. 4. ECDF of average UE throughput for different schedulers.

IV. Conclusions

In this paper, we evaluated the performance of LTE network in a macro femtocell scenario using the LTE system level simulation. From the simulation results we noticed that when the eNodeB transmit power is reduced the system performance is improved in terms of average user's throughput and wideband SINR. Differently to that, if the HeNodeB transmission power is increased, the system performance is improved for the same scenario. Furthermore, we investigated the impact of scheduling algorithms and we found that the decision of the mobile operator to use the scheduling algorithm in (LTE, LTE-Advanced) network is a tradeoff between average throughput and fairness index of resource sharing. If the radio resources are not scarce, then the best schedulers are Max Throughput and Best CQI, which offers the highest throughput. If the radio resources are to be shared in a fair manner to users, then the best scheduler is Proportional Fair Sun scheduler, but the average throughput will not be as high as for best CQI scheduler.

As future work we plan to compare the simulation results with real data from LTE operator.

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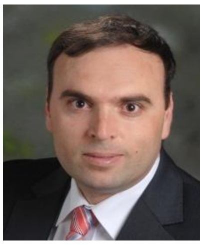

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