Green Handover with a Hybrid Satisfaction Mechanism

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***Abstract*— Green communications have emerged as one of the most important trends in wireless communications because of its several advantages of interference reduction, battery life increase and electrical bill cut. Its application to handover mechanisms is a crucial operation for its integration in practical systems, as handover is one of the most resource-consuming operations in the system, and it has to be optimized under the objective of green communications. On the other hand, a decrease in the energy consumption should not mean lower performance for the operator and customers. Therefore, this paper will present a hybrid handover mechanism where two conflict objectives of load balancing and energy consumption are tackled, where the operator's objective is to balance the data load among its macro- and small-cells, while the user equipment objective is to decrease the consumed energy in order to guarantee a larger battery life. Interesting conclusions are obtained about the presented approach through computer simulations.**

I. Introduction

The need for low energy consumption wireless systems has emerged as a main challenge for the research and engineering communities. The operator is interested in lower energy consumption at its Base Stations (BS) to decrease the intercells interference and have a smaller electrical bill. On the other hand, the User Equipment (UE) is also concerned about energy consumption to offer a larger battery life to the customer. Therefore, green communications [1] stands out as a major research field in recent literature that has attracted a large amount of research.

Handover is one of the basic techniques in cellular systems to keep connections while the user is moving across the coverage of several BSs [2]. More sophisticated handover techniques have also been included in the system to allow the operator to balance the loads over several cells [3], so that if a cell is congested, some of its users that are also covered by adjacent cells are forced to handover, thus a higher global performance is obtained. The availability of several access technologies has enabled vertical handover [3] among them to offer better data rate, delay and price to the customer.

Green handover [4] seems as an interesting and timely proposal to be embedded in realistic systems, where the objective would be to decrease the consumed energy in the system. The Long Term Evolution (LTE) technology [5] is the newest standard for cellular systems, and it is targeted for both macro- and small-cells that will coexist in the same scenario [6]. Applying handover over the different kinds of LTE cells is encouraging, where the operator objective behind macro- and small-cells is different, so that the whole system performance is improved.

Nevertheless, handover cannot come at expenses of other benefits to the operator and the users [7]. The motivation behind any handover technique must stand on the benefits from 2 main points of views: Customer's interests and Operator's interests. Several proposals in literature deal with either one of the two approaches, where the customer benefit-based techniques may collide with the operator benefit-based strategies, and vice versa [7]. Therefore, for any handover proposal to succeed in realistic systems, a joint consideration of the interests of both parties should be tackled.

From the user part, the objective is to decrease the energy consumption as energy is currently a trap for the UEs, with an increasing consumption pattern over the last years that has not been corresponded by a larger battery life [8]. Therefore, energy efficiency at the UE is of crucial importance and one of its main targets, so that the UE is willing to undergo through a handover process if its serving cell/technology enables energy reduction. It is expected that UE will desire to handover from macro-cells to small-cells in order to achieve its objective, as the path loss in small-cells use to be lower than macro-cells, and thus the Signal-to-Noise-Ratio (SNR) is larger, which enables the application of energy reduction techniques.

On the other hand, the operator benefit from the handover procedure can be presented in terms of a load balancing among the different cells and/or access technologies, so that if some cell is saturated with users/rate, the system can redistribute some of the users to other access networks [2]. For the case of macro- and small-cells, the latter can be saturated at some instant, mainly because the small-cells use to be installed in coffee-shops and malls, where the costumers consume the system resources through applications that require large data rate, like videos sharing, social networks, etc. Therefore, the operator is interested in handover to the macro-cell to decrease the load on the small-cells. Former studies have always proposed handovers from the macro-cell to decrease its congestion, but the change on the customers' usage patterns [9] [10], has reversed the handover targets of load balancing.

This paper achieves both operator and UE objectives

ISBN 978-3-8007-3529-7

through a hybrid handover mechanism that obtains energy saving at the UE while it cares of the load balancing among macro- and small-cells. The paper presents a decision metric that fits within Self Organizing Networks (SON) to automatically decide whether to undergo a handover or not, providing the system with the ability to offer both advantages at the same time, where the metric can be even modified to account for all possible objectives.

The rest of the paper is organized as follows: Section II presents the system model and the considered parameters followed by section III with the hybrid handover mechanism. Section IV shows the computer simulations while Section V tackles the paper conclusions and future work.

II. System Model

The LTE communication standard is tackled in this paper, where two kinds of BS are present in the scenario: Macro-cell providing coverage to the whole cell, and small-cells (femto-cells) that deliver high data rate but to a smaller geographical area, so that more than one small-cell is usually setup in each macro-cell [6]. Figure 1 shows an example of the BS locations over the scenario. We focus on the single cell scenario where N receivers, each one of them equipped with a single receiving antenna, are available in the considered area. The transmitters at the BS for macro- and small-cells are with a single transmitting antenna.

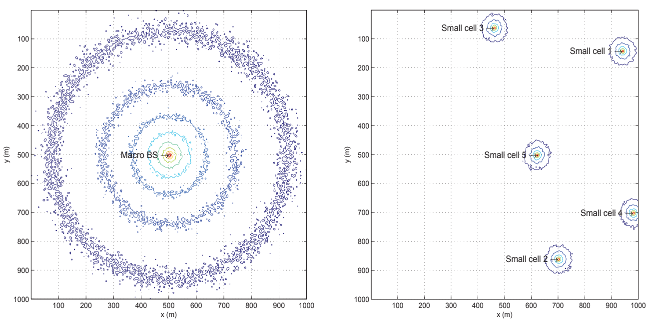

Fig. 1. Location and coverage strength of the macro- and small-cell BSs.

Even two kinds of cells are considered, but the user is only serviced through one single cell on each time. Both the macro- and small-cells channels $h(t)$ are modelled by a quasi static block fading model, which keeps constant through the coherence time, and independently changes between consecutive time intervals with independent and identically distributed (i.i.d.) complex Gaussian entries $\sim \mathcal{CN}(0,1)$. Therefore each user is assumed to keep fixed during each fading block (i.e., coherence time T_c), and allowed to move from block to block, where the duration of each fading block is assumed to be 20 ms to match with practical wireless broadband systems. Let $s_i(t)$ denotes the uncorrelated data symbol with $E\{|s_i|^2\} = 1$ to the i^{th} user, then the received signal $y_i(t)$ is given by

$$y_i(t) = h_i(t)\, s_i(t) + z_i(t) \tag{1}$$

where $z_i(t)$ is an additive i.i.d. complex noise component with zero mean and $E\{|z_i|^2\} = \sigma^2$, and for ease of notation, time index is dropped whenever possible. Path loss is considered in the system, as the users are randomly distributed over the considered area. The Free-Space path loss equation is considered as

$$PL = 32.4 + 20\log_{10} d + 20\log_{10} f \tag{2}$$

where d is the distance in Km and f the operating frequency in MHz.

The maximum transmission power at BSs and UEs is $P_m = 23$ dBm following the LTE specs [5], but in order to mitigate the intercells interference, the LTE standard enables the Maximum Power Reduction (MPR) on the basis of the employed modulation and the channel characteristics. An MPR value of (1, 2, 3) dB is enabled, where this paper considers the MPR as its energy efficiency indicator, which is a practical and standard compliant metric. The different scenario parameters are collected in Table 1 for both the macro- and small-cells.

Area	circular 1 km diameter
Macrocell Coordinates	x: 500, y: 500
Smallcell Coordinates	
Smallcell1:	x: 940, y: 140
Smallcell2:	x: 700, y: 860
Smallcell3:	x: 460, y: 60
Smallcell4:	x: 980, y: 700
Smallcell5:	x: 620, y: 500
Macrocell Frequency	2 GHz
Smallcell Frequency	2 GHz
Macrocell Bw	10 MHz
Smallcell Bw	5 MHz
Macrocell Coverage	1 km Diameter
Smallcell Coverage	50 m Diameter
Modulation Scheme	64QAM, 16QAM and QPSK
Packet Size (w/t FEC)	216 Bits
CRC Size	16 Bits
FEC Size	50 Bits
Correctable Errors	8 Errors
Subcarrier Bw	15 KHz
α	0.5
β_{th}	50% of Link Load

Table I: Environment considered parameters.

III. Macro-Small Handover Hybrid Proposal

The huge increase in the customers' data rate demands together with their on-the-move requirement has pushed a wide spread of wireless access technologies, where LTE outstands as one of the most sophisticated and with highest capabilities to accommodate the customers' demands. Standardization bodies have studied the customers' usage profiles and they have noted their tendency to run data rate hungry applications while being on low mobility, as coffee shops, stadiums and shopping malls among others. Such a usage pattern motivated the standardization of small-cells within the LTE specs [6], that offer a tremendous data rate but for a small coverage area, while the traditional macro-cell offering good data rates with a wide coverage.

ISBN 978-3-8007-3529-7

The customers run resource demanding applications (e.g., video streaming, social networking, online games, etc) that congest the small-cells and make the whole system to decrease its performance. Carrier aggregation [11] is one of the proposals to deal with such situation by increasing the allocated bandwidth to the small-cells, but its application requires the availability of extra bandwidth that may not be possible. Another proposal is through the operator-initiated handover to move some customers from the small-cells to the macro-cell.

The operator-initiated handovers where proposed as a way to decongest the macro-cell by forwarding some users to another un-congested macro-cells in the system. Vertical handovers [3] are also proposed to decongest the macro-cell by moving users to other access technologies like WiFi [7]. But the usage pattern of data rate hungry applications at low mobility has reversed the need for operator-initiated handovers, as now the congested cells are the small-cells, and the operator is interested in redistributing their load over the macro-cells. The recent large investments in small-cells are motivated by the considerable income the operators are grasping from this relatively "recent" BS setup [10].

Such a switch from small-cell to macro-cell and viceversa has to be smooth and without any disruption on the provided service. Therefore, a customer running any application does not have to stop the application when moving from an access network to another; but it has to be seamless. An important concept that enabled the seamless handover is the LTE system being built on the Internet Protocol (IP) standard, where each user is assigned an IP address that is fixed whenever it moves within the LTE cells.

On the other hand, moving from the small-cell to the macro-cell is expected to increase the energy consumption at the user terminals, as the macro-cell coverage is larger and therefore, more path loss is presented. Energy efficiency is a key parameter in current wireless systems in general and in LTE in particular. The energy restrictions are tougher for the data rate hungry applications that consume more energy [8].

Therefore, a tradeoff appears as two conflicting objectives are tackled. First, the operator is interested in moving some costumers to the macro-cell in order to balance the system, while the user is interested in being at the small-cell to increase its battery life. A hybrid approach is required to meet both objectives and decide on the best strategy. We now propose a joint metric Th for such scenario where the hybrid handover decision will be based on it

$$Th = \alpha S_c + (1-\alpha) S_{op} \tag{3}$$

where S_c indicates the customer satisfaction indicator, while S_{op} refers to the operator satisfaction metric. The α parameter $\alpha \in (0,1)$ is to identify the weight of each satisfaction indicator, so that if the operator is only interested about the load balancing because the system is starving at the small-cells, then α can be close to zero, while if the system is balanced then the operator can give priority to the customer satisfaction and push α to a value of 1. Practical values for α are within the two extreme cases and dependant on the load per cell and system congestion, among others.

We need for practical satisfaction indicators that can match with the standard specs and/or follow the operator implementation objectives. For the customer satisfaction, we use the MPR indicator that emerges from the LTE specs [5], showing very good intuition about the amount of saved energy that the user can obtain by changing among the different cells. On the other hand, we define a minimum threshold for the operator satisfaction, so that if the load is balanced among its cells, the operator is pleased. We can formulate a metric to account for its obtained load β_{ob} and its comparison to the threshold desired level β_{th} as

$$S_{op} = \begin{cases} 1 + \frac{\beta_{th} - \beta_{ob}}{\beta_{th}} & \text{if} \quad \beta_{\text{th}} \geq \beta_{\text{ob}} \\ 1 - \frac{\beta_{ob} - \beta_{th}}{\beta_{ob}} & \text{if} \quad \beta_{\text{th}} < \beta_{\text{ob}} \end{cases} \tag{4}$$

that shows a value below 1 if the operator is not satisfied (i.e., the load is larger than the threshold), and a value larger than 1 is the load is below the threshold load value. Along the paper, the operator satisfaction indicator is the system load, so that the objective of the operator is to make load balancing in its system.

IV. Simulations

In order to check the behavior of the proposed hybrid handover mechanism, Monte Carlo computer simulations are carried out, and following the LTE system parameters [5]. A wireless scenario covered by one macro-cell and 5 small-cells is considered, where the user moves through the cell in a random direction. The user moves each coherence time (assumed to be 20 ms) without exiting the cell macro-cell coverage. While moving through the considered area, the received SNR from the different cells is varying and highly affected by the path loss. All the transmitting BSs are equipped with a single antenna and all UE are also single antenna. To obtain an average performance over several users, 10 users are considered in the system and all of them are assumed to have the same average channel characteristics, and showing

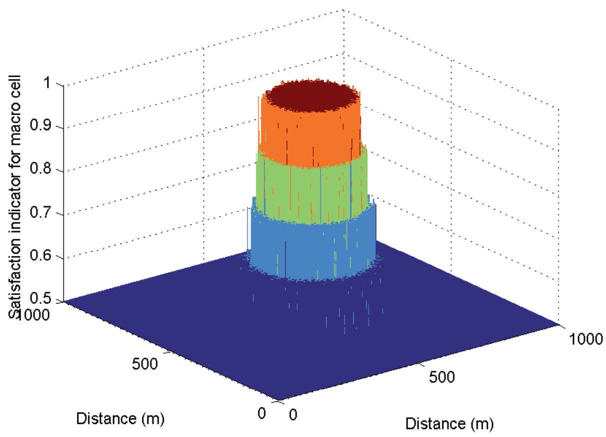

Fig. 2. Satisfaction indicator when only macro-cell is considered in the scenario.

ISBN 978-3-8007-3529-7

the same SNR distribution. While the location of the macro-cell is fixed at the center of the covered area, the locations of the small-cells is variable. An example of their positions is shown in Table I.

We start the simulations by plotting the satisfaction Th when only the macro-cell is available in the system in order to present traditional systems behaviour. Fig. 2 shows how the satisfaction is at its maximum while the user is close to the cell center, as maximum energy saving is achieved. Obviously, no balancing is considered in this scenario, as only one cell is tackled, so that the value of α is fixed to 1.

Now by introducing the small-cells in our consideration and fixing the value $\alpha = 0.5$, Fig. 3 plots the satisfaction over the whole area, where it is clearly increased when the user comes close to the location of any BS (either macro- or small-cell), as the energy saving is larger and its impact on the satisfaction indicator in Eqn.(3) is larger.

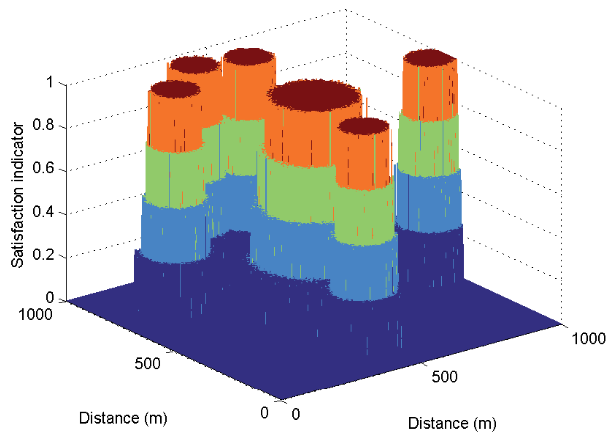

Fig. 3. Satisfaction indicator when one macro-cell and 5 small-cells are considered in the scenario.

Applying the proposed hybrid handover mechanism is beneficial to both the operator and the customers, specially when $\alpha = 0.5$ is set, as a compromise between the operator load balancing benefits and the customer energy saving benefits is obtained. Obviously, the operator is who controls such behaviour, whom is also interested in the satisfaction of its customers. Notice that the UE energy saving requirements are mainly crucial to the smart phones with multimedia and internet capabilities, so that keeping the customers pleased with their phones guarantees that they continue using the operator resources for browsing and files exchange, with the consequent economical benefit to the operator. Therefore, both objectives of load balancing and UE energy efficiency are beneficial to the operator on a large time scale. Fig. 4 plots the amount of saved energy by running the proposed handover mechanism over the whole considered area. Remind that the energy saving is restricted to the 3 MPR levels (1, 2, 3) dB as enabled in the LTE specs [5], so that the figure shows the 3 different levels of energy saving.

The last issue that will be presented in the simulations section is the impact of the α value on the amount of energy

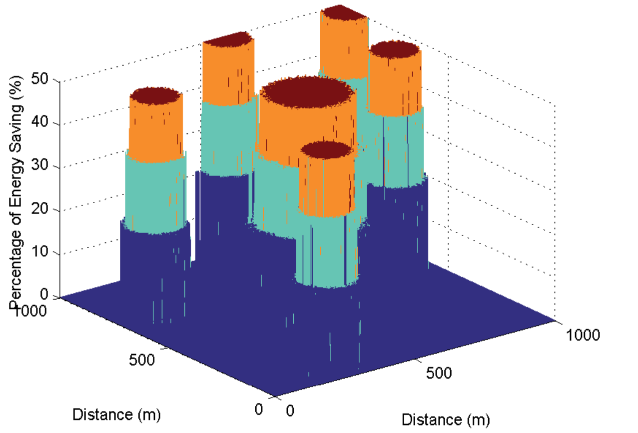

Fig. 4. Percentage of achievable energy saving over the scenario by running the proposed handover mechanism.

saving. Fig. 5 plots the system behaviour for a variable α value where it is clearly seen how we obtain a larger energy saving as the UE satisfaction is given more importance than the operator satisfaction (i.e., increasing the α value).

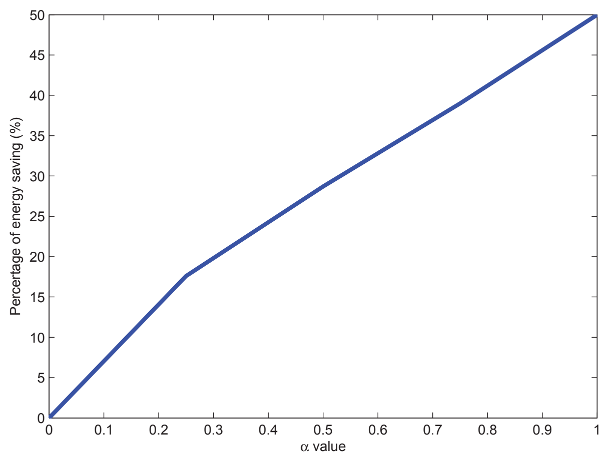

Fig. 5. Percentage of achievable energy saving over the scenario for a variable α value.

V. Conclusions

The paper proposed a hybrid handover mechanism between macro- and small-cells where two conflicting objectives are tackled. The operator satisfaction that is identified by a load balancing among its cells, and the customer benefit through energy saving at its terminal. A joint satisfaction indicator is presented and analyzed through simulations where interesting results are obtained. The optimization of α value for the hybrid handover mechanism is not tackled in this paper and proposed as a future work.

Acknowledgement

This work was made possible by NPRP grant 09-406-2-153 from the Qatar National Research Fund (a member of The Qatar Foundation). The statements made herein are solely the responsibility of the authors.

ISBN 978-3-8007-3529-7

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ISBN 978-3-8007-3529-7