

Energy Efficient Handover Algorithm For Green Radio Networks

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Abstract—The coverage area and the capacity of existing cellular network systems are not sufficient to meet the growing demand of high data rate for wireless communications. Heterogeneous Networks (HetNets) based on Long Term Evolution (LTE) can be a possible solution to enhance indoor coverage, deliver high bandwidths and off-load traffic from the macro base stations. However, this technology is still under development and several open issues have to be still investigated, such as interference coordination, power consumption, resources management and handover techniques. The aim of this work is to guarantee the reduction of power consumption using a new handover algorithm based on green policy. In addition, the proposed scheme guarantees the minimization of unnecessary handovers. The simulation campaigns have been conducted through the open-source Network Simulator 3 (NS-3). The preliminary results demonstrate that an efficient use of green approach improves the HetNETs performance in terms of power saving, energy efficiency and allow to reduce the number of unnecessary handovers

Index Terms—HetNet; 4G mobile communication; Green Handover; Power Saving; Green Networks; Networking and QoS; Performance evaluation.

I. INTRODUCTION

THE fast diffusion of advanced user terminals and multimedia applications such as mobile web-browsing, video downloading, on-line gaming, and social networking, leads to the growing demand of high data rate for wireless communications. In addition, the lack of radio spectrum due to the more and more request of bandwidth by the end users in order to achieve high transmission rates and high levels of Quality of Service (QoS) represents still an open issue.

Since the existing cellular networks are not able to solve this problem, a new paradigm called Long Term Evolution (LTE) has been proposed as the basis for the fourth generation mobile cellular networks (4G) [1]. The aims of the LTE standard are higher user bit rates, lower delays, increased spectrum efficiency, reduced cost, and operational simplicity. However, the presence of coverage holes and weak signal areas due to the cell edge and high level of inter-cell interference, leads the scientific community to consider new paradigms and approaches [2], [3]. A possible enhancement of the LTE systems is to overlap different low power base stations (BSs) within an existing macro cellular coverage. Such a system is called Heterogeneous Network (HetNet) [4].

LTE HetNet can be a possible solution to enhance indoor coverage, delivers high bandwidths and off-loads traffic from

the macro base stations. The high power BSs (i.e. macrocells) are integrated with low power BSs (i.e.: pico, femtocell, and relay nodes) that are dynamically arranged and turned on/off directly by the end users. Although the usage of small BSs enhances the coverage of the system and the network performance, the inter-cell interference increases linearly and has to be taken into account. In addition, the use of a high number of small cells causes a high power consumption and increases the inter-cell interference. Power consumption, power saving, and energy efficiency are the main topics of the Green Networks [5] [6] [7]. The aim of these networks is to design power control schemes and Radio Resource Management (RRM) algorithms in order to guarantee the power saving and the energy reduction of the networks without decrease the users and system performance. These goals can be achieved by minimizing the base station energy consumption through the implementation of energy efficient hardware, power saving protocols, and switching-off the BSs through efficient handover procedures.

Frequent and unnecessary handover by the users to low power BSs are a serious problem for the system performance. Indeed, they cause a high overhead due to the exchange of signalling messages with a consequent decreasing of system performance. Three different kinds of handover can be executed: (i) Outbound (femto $\rightarrow$ macro), (ii) Inbound (macro $\rightarrow$ femto) and (iii) inter-Femto-Access-Point(FAP) (femto $\rightarrow$ femto) [8]. Both Inbound and Inter-FAP handover are quite complex since there are hundreds of possible target FAPs. Vice versa the Outbound handover is more simple, because there is only one macrocell target in the considered coverage area.

In this paper, we propose a new handover algorithm based on green policies in order to guarantee an efficient management of the BSs transmitted power and to reduce the unnecessary handovers. The proposed algorithm rejects the Inbound handover requests from the users with high mobility and allows only the handovers that do not increase the overall transmitted power of the BS target. It will be demonstrated that the proposed scheme increases the power saving and minimizes the number of unnecessary handovers.

The remainder of the paper is organized as follows. In Section II we briefly discuss the related work of the handover procedures in LTE HetNets. In Section III we introduce the proposed green handover algorithm, whereas the simulation campaign and the achieved results are given in Section IV.

Finally, conclusive remarks and future works can be found in Section V.

II. RELATED WORK

Conventional handover schemes do not assure an optimal management of the handover procedures over the HetNets and the handoff from Macrocell to femtocell is still an open issue. UEs need to select the appropriate target femtocell among many candidates by taking into account the interference level, UE speed and the available resources of the target cell. Power consumption is one of the most important problems affecting new generation systems. In fact, most of energy consumption of the telecommunication networks is caused by the base stations.

Since there are several femtocells within a macrocell area, the femtocell deployment increases the energy consumption. The 3GPP TS 36.927 (release 10) [9] identifies as potential solutions for energy saving (ES) three alternatives: (i) the totally switch-off of the base stations when there are not users, (ii) the trigger of the ES procedures in case of light traffic, and (iii) the use of the femtocells in "idle" mode.

Ashraf et al. in [10] proposed to improve the energy efficiency of femtocells via the user activity detection. The proposed procedure allows the femtocell to switch-off the radio transmissions in presence of no active calls involved. This method, however, does not foresees an effective procedure to reduce the ping-pong effect. Therefore, the total power consumption increases if idle femtocells makes the wrong decision to "wake up" in order to execute an unnecessary handover. In [11] a scheme for unnecessary handover minimization is presented. Authors proposed a Call Admission Control (CAC) technique to improve the handover process under particular conditions. Three parameters are taken into account: (i) the Received Signal Strength (RSS), (ii) the time in which a Mobile Station (MS) maintains the minimum required signal level, and (iii) the Signal-to-Interference Noise Ratio (SINR). The handover requests are triggered if the SINR from the femtocell is greater than the SINR from the macro and if the RSS from the femtocell is greater than a given threshold.

In [12] authors proposed a new handover algorithm based on the UEs speed and the QoS requirements. They consider a dense femtocell scenario where users with high mobility cross the femtocell coverage in a short time. Under these conditions, the authors consider that users with high speed do not need to make a handover, in particular when they support non-real-time services. Three different environments are analyzed: (i) low mobile state (from 0 to 15 km/h), (ii) medium mobile state (from 15 to 30 km/h) and (iii) high mobile state (above 30 km/h). In addition, they consider real-time and non-real-time traffics in the simulation campaigns for the evaluation of the proposed algorithm. Differently from [12], an handover decision policy based on mobility prediction is proposed in [13] by considering as maximum speed 10 Km/h. A reactive and proactive handover strategy is also proposed to mitigate the frequent and unnecessary handover.

In [14] the authors proposed a new handover procedure between macrocell and femtocell based on the use of the UEs

residence time in a cell and by exploiting two different thresholds for the serving and the target cell, respectively. Authors demonstrated that such an approach allows to reduce the number of unnecessary handovers. Two different thresholds are exploited

In [15] authors developed a green handover protocol in two-tier OFDMA networks (macrocell and femtocell). This is mainly based on the prediction of the dwell time (t_{dwell}) and average expected transmission time ($t_{expected}$) of the UE. The algorithm consists of three phases: (i) free spectrum configuration, (ii) transmission time estimation, and (iii) green handover decision. In order to improve the energy efficiency of the network, the handover framework proposed in [15] wake-up periodically the BSs from the idle mode. In this way, they have a timely response to the network changes.

III. THE GREEN ALGORITHM

Much of the power consumption takes place in the base stations. In addition, in a high density femtocell deployment, the signaling overhead due to frequent handovers between macrocell and femtocells causes the decrease of network performance. Following these considerations, we propose a handover algorithm based on green policies in order to guarantee an efficient management of the transmitted power of the base stations and the reduction of the unnecessary handover procedures.

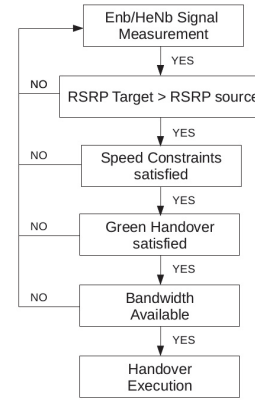


Fig. 1: Algorithm Flowchart

The algorithm is composed of two parts. In the first part, a CAC technique rejects handover requests from macrocell to femtocell of the users with high mobility. In the second part, a green power control scheme named Green Handover takes into account the average SINR of the femtocell. Since a weak SINR causes the increase of transmitted power, only users that not decrease the performance in term of average SINR of the UEs of the femtocell are allowed to hand-in in the cell.

The algorithm proposed in this paper starts with the collection of the UE measurements of the downlink channel (i.e.: CQI, SINR, SNR, RSRQ, RSRP) in order to evaluate if a handover procedure has to be performed. As mentioned in

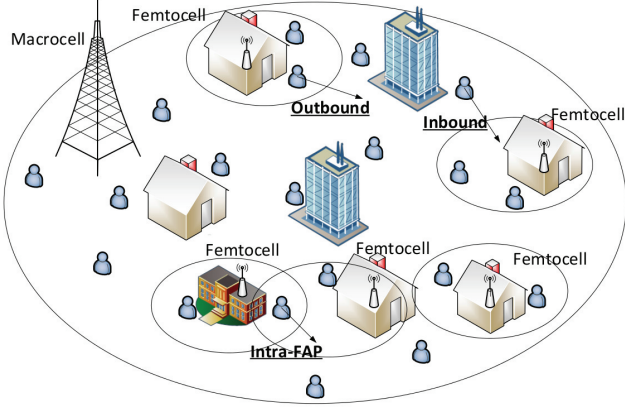


Fig. 2: Adopted scenario

the introduction, three different kinds of handovers can be executed: (i) Outbound, (ii) Inbound and (iii) inter- FAP. In the bound case, the handover is always accepted without any constraint. In the last two cases, a Call Admission Control (CAC) technique based on the user speed is considered as shown in the Fig. 1 according to the following three different situation:

- 1) if the UE speed is faster than 10 km/h (vehicular user) handover is rejected.
- 2) if the UE speed is below than 5 km/h (pedestrian user) the handover is executed.
- 3) if the UE speed is in the range 5, 10 km/h, the following green approach is executed in order to guarantee the power saving.

In the proposed green approach, the base station target accepts the new user only if it does not increase the intra-cell interference. Furthermore, the base station assigns the power and the appropriate modulation and coding scheme (MCS) in order to guarantee the minimum $SINR_{min}$ related to the CQI forwarded every Transmission Time Interval (TTI). In this phase, in order to select the most suitable $SINR_{min}$ we use the mapping reported in Table 1.

CQI	Modulation	Code Rate	SINR	SE
CQI 1	QPSK	1/12	-6.50	0.15
CQI 2	QPSK	1/9	-4.00	0.23
CQI 3	QPSK	1/6	-2.60	0.38
CQI 4	QPSK	1/3	-1.00	0.60
CQI 5	QPSK	1/2	1.00	0.88
CQI 6	QPSK	3/5	3.00	1.18
CQI 7	16QAM	1/3	6.60	1.48
CQI 8	16QAM	1/2	10.00	1.91
CQI 9	16QAM	3/5	11.40	2.41
CQI 10	64QAM	1/2	11.80	2.73
CQI 11	64QAM	1/2	13.00	3.32
CQI 12	64QAM	3/5	13.80	3.90
CQI 13	64QAM	3/4	15.60	4.52
CQI 14	64QAM	5/6	16.80	5.12
CQI 15	64QAM	11/12	17.60	5.55

TABLE I: CQI values [16]

The choice to exploit the minimum $SINR_{min}$ instead of

the actual $SINR_{actual}$ ¹ for each handover user allows to reduce the base station transmitted power. Indeed, after that the minimum level of the SINR is selected, the power gain (P_G) for each user within the BS coverage is calculated as follow:

$$P_G = SINR_{actual} - SINR_{min} \quad [Watt] \quad (1)$$

Then, the new transmitted power of the BS is evaluated by taking into consideration the following equation:

$$P_{BS_{new}} = P_{BS} - \sum_{k=1}^{n_{UE}} P_G(k) \quad [Watt] \quad (2)$$

where $\sum_{k=1}^{n_{UE}} P_G(k)$ is the sum of all the power gain of the users within a BS and P_{BS} in the transmitted power.

IV. SIMULATION RESULTS

Performance evaluation of the proposed algorithms have been conducted through the usage of the Lena module of the well-know Network Simulator 3 (NS-3) [17]. NS-3 is used because is capable of carrying out large-scale network simulations in an efficient way. In addition, it is able to emulate and simulate the entire LTE protocol stack and the most used wireless telecommunication standard.

In order to evaluate the system performance of the proposed algorithm, we consider an LTE HetNets scenario with a dense deployment of femtocells within the macro cellular coverage. It is worth nothing that high and low power nodes have different transmission powers. In particular, we consider a transmitted power equal to 46 dBm and 20 dBm for macrocell and femtocell, respectively. Users are uniformly distributed with different speeds and the total bandwidth (i.e., 20 MHz) is equally divided with 50 RBs² for the macrocell and 50 RBs for all the femtocells. The mobility of the users and their speed varies in a randomly from 3 m/s to 20 m/s. Since the users are free to move in all direction all three type of handover (outbound, inbound, and intra-FAP) are considered.

Outputs have been achieved by averaging a sufficient number of simulation results in order to guarantee a 95% confidence interval. The Path Loss models, different for macro and femtocell, exploited during the simulation campaign are reported below:

$$PL_{macro} = 15.3 + 37.6 \log_{10} R \quad [dB] \quad (3)$$

$$PL_{femtocell} = 38.46 + 20 \log_{10} R + L_w \quad [dB] \quad (4)$$

where R is the distance between the transmitter (BS) and the receiver (UE) in meters and L_w is the wall penetration loss of the wall separating apartments. In order to evaluate the system performance, the LTE throughput and the energy

¹it is worth noting that the $SINR_{actual}$ is the real SINR estimated by the users every TTI.

²The RB corresponds to the smallest time frequency resource that can be allocated to a user (12 sub-carriers) in an Long Term Evolution (LTE) system. For example, a channel bandwidth of 20Mhz corresponds to 100 RB.

efficiency achieved by the proposed algorithms are computed as:

$$T = \frac{\sum_{i=1}^N TB_{RB_i}}{TTI} \quad [Kbps] \quad (5)$$

$$EE = \frac{Th}{P_t} \quad [\frac{bits}{Joule}] \quad (6)$$

where TB_{RB_i} is the transport block size referred to the i th RB, and N is the total number of RBs available in the system, while TTI is the scheduling time. As specified in 6, EE represents the ratio between the overall amount of bits received respect the total power consumption of the system.

The further main system parameters are summarized in Table 2:

Parameter	Macro-cell	Femtocell
1-st sub-channel frequency	2110MHz	
Downlink Bandwidth	10MHz	
Sub-Carrier Bandwidth	15kHz	
Doppler Frequency	60Hz	
Resource block bandwidth	180kHz	
Resource block carriers	12	
Resource block OFDM symbols	7	
BS downlink TX power	30dBm	8dBm
Noise spectral density	-174dBm/Hz	
Pathloss (distance R)	$PL_{macro} = 15.6 + (35 \cdot \log(R))dB$ $PL_{femto} = 38.46 + (20 \cdot \log(R))dB$	
Shadow fading	$\log - normal, \sigma = 8 \text{ dB}$	
Wall penetration loss	10dB	7, 10, 15dB
Frame duration	10ms	
TTI (sub-frame duration)	1ms	
Target Bit Error Rate	5×10^{-5}	
Cell coverage	500m	50m
BS distance	400m	
UE	1, 2, 5, 10, 15, 20, 25, 30	

TABLE II: Main system parameters

Fig. 3 shows the overall transmitted power of the femtocell in the system. The power increases proportionally with the number of low power nodes and the proposed green algorithm introduces a gain in average equal to 55% when the traffic load of the system is high (20 users within the femtocell). As we expected, the amount of total power consumption is always lower introducing the green handover algorithm. In addition, the figure shows that the gap increases with the number of cells.

In any case, in all analyzed scenarios we have a considerable gain with respect to the no green case due to the low power of the femtocell that is in the order of 0.1 Watt. Therefore, greater is the number of the low power nodes into the macro cellular coverage and better are the performance of the algorithm. Best

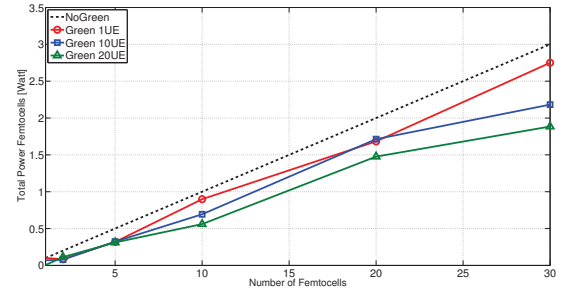


Fig. 3: Femtocells Total Power

results are obtained in the configuration with 30 femtocells and 20 users per femto and appreciable power saving is achieved with 10 users too.

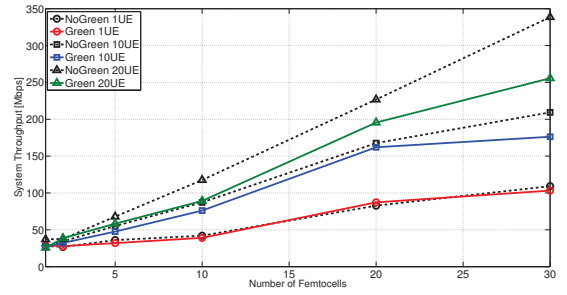


Fig. 4: Total Throughput of the system

The average system throughput by considering the green and no green case is shown in Fig. 4. The gap with the no green case increases with the number of the femtocells and the users of the system. In fact, with a low-density scenario the trend by considering both cases (green and no green) is the same and it means that our algorithm enhances the system power consumption without decreasing the BS performance.

Fig. 5 shows the average throughput per UE by considering three different numbers of femto-users and by varying the number of the femtocells per macrocell. The performance decreases proportionally with the number of the low power nodes. Moreover, the behavior of the proposed handover algorithm is similar to the non-green case. In this case, the performance seems to be better with few users inside the cell. But it is an expected result. The performance reduction in terms of average UE throughput is mainly due to the use of $SINR_{min}$, in particular when the number of the system users is high.

The energy efficiency achieved by the system is shown in Fig. 6. Good performance is obtained when the number of the femtocells is low. It is due to the low performance achieved by the system. In scenario with dense number of low power nodes and low number of users the proposed algorithm does not introduce any significant gain.

The transmitted power of the base stations plays an important role to guarantee an efficient usage of the system energy. Furthermore, in Fig. 6 differently by the No-Green case, with the proposed algorithm the energy efficiency is constant by

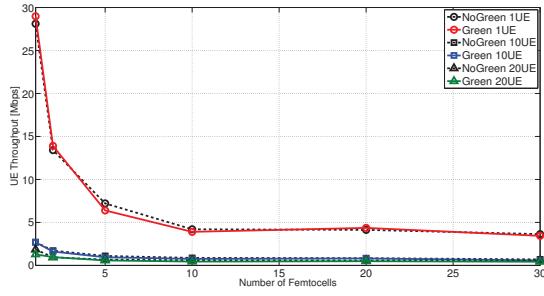


Fig. 5: Average UE Throughput

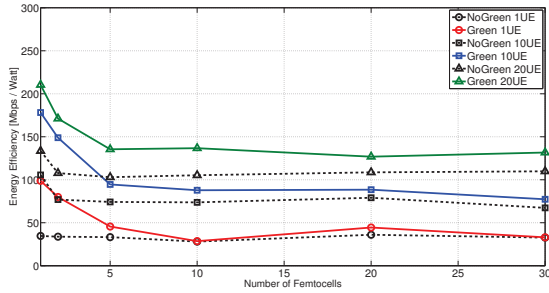


Fig. 6: System Energy Efficiency

increasing the number of users and femtocells.

Finally, the overall handover performed in the system are shown in Fig. 7. For sake of simplicity, only the case with 10UEs is shown due to the fact that the other cases (1UE and 20 UEs) have the same trend. The proposed algorithm is able to reduce the unnecessary and frequent handovers that cause the decreasing of system performance due to the overhead generated by signaling.

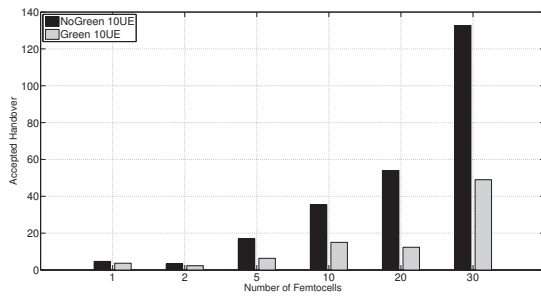


Fig. 7: Overall Handover: Green vs No-Green

It is clear that increasing the number of femto increases the amount of handovers, especially without the green handover algorithm. Greater is the deployment ratio of the femtocells and bigger is the probability that a UE passes through the overlapping area. As shown In Fig. 7, in all cases the number of handovers executed increases with the increasing of femto-cells deployed either using the proposed algorithm either not.

V. CONCLUSION AND FUTURE WORKS

In this work is investigated a possible solution to improve the handover performance in LTE-based HetNets. A handover algorithm based on green policies is proposed in order to efficiently manage handover procedure guaranteeing power saving. In addition, the algorithm allows the reduction of unnecessary and frequent handovers.

The obtained results show that the performance achieved by our algorithm increase linearly with the number of the femtocells and the system users. In particular, a considerable gain in term of power consumption at cost of low system performance loss is reached. Respect to the no green case, it is shown that the introduction of green policies allows the decreasing of the system power consumption and, as a consequence, unnecessary handover procedures are avoided.

A possible future extension of this work could takes into consideration the effect of green policies in high power nodes. An extended scenario with more than one macrocell and different types of low power nodes (such as picocells, microcells and relate nodes) could be evaluated in order to understand the impact of power saving schemes in the handover procedures. Finally, the proposed algorithm could be used in different networks standard and paradigm such as the Vehicular Ad-hoc NETWORK (VANET) and machine type communication such as Machine-to-Machine (M2M) and Device-to-Device (D2D) paradigms.

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