Comparison between measurement events for LTE handover in rural and urban scenarios involving femto-cell deployment

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***Abstract*—**As open access femto-cells have been deployed as means to enhance the Long Term Evolution (LTE) network capabilities, handover schemes have been proposed to reduce the possible negative impacts of femto-cell deployment. In this article, we analyze the impact of measurement events and signaling in the LTE handover process, aiming to offer further opportunities for handover optimization. Simulation results show that handover parameter optimization, as well as LTE network optimization may benefit from combining measurement events and user profiling in the handover process.

***Keywords*—** handover, long term evolution, measurement events, open access femto-cells.

I. Introduction

As Long Term Evolution (LTE) continues its deployment around the world, the goal of providing seamless voice and data services remains a challenge to this day, because of the increasing demands and needs of the customer base, and the difficulties arising from environmental constraints, mainly in urban scenarios, where allocated demand, multipath fading and femto-cell deployment introduce further elements to the network optimization.

As femto-cells have been proposed as alternatives to prevent cell congestion in LTE, as means to achieve load balance over the network, these do bring additional considerations to be addressed in the design and optimization of LTE networks, such as interference between cells and handover parameter optimization.

In this last regard, most of the research has been focused in the usage of a particular handover signaling set as a benchmark for other "soft" handover algorithms proposed, as shown in [1]-[3]. In [4]-[7], further self optimization of the LTE Network is introduced, by using the same signaling (A3-event) parameters for further control and optimization of the network and the reduction of Radio Link Failures (RLF).

This article explores the usage of both A3 and A2-A4 events for signaling in LTE UE handover, in rural and urban scenarios, taking into account the impact of femto-cell deployment for the different simulation scenarios, using NS-3 as simulation engine.

Both sets of events are further analyzed, regarding user's profiles in terms of download/upload traffic, as well as varying velocities, ranging from pedestrian to automotive speeds. A combined approach is proposed for usage in adaptive self-optimization for LTE networks as future work.

The rest of this document is organized as follows: Section II, introduces an overview of hard handover signaling is presented, Section III presents the simulation scenarios used, while Section IV shows the results obtained from them. Finally Section V proposes an approach to enhance handover parameter optimization algorithms.

II. Overview of hard handover signaling events

Regarding handover optimization, it is important to consider the deployment of open access femto-cells, this is, femto-cells allowing its usage or attachment from any user equipment (UE), thus having means for appropriate signaling for other eNodeB's (Macro or femto-cells).

The aforementioned signaling includes, but is not limited to, the reporting and communication capabilities of each eNodeB to perform the handover of any UE, as long as such handover is allowed (considering eNodeB load, etc.). For these purposes, measurements are performed by the UEs and reported to eNodeBs constantly.

As part of the 3GPP definitions of LTE, the measurements are reported as a series of events, mainly the A3 event (neighbor cell becomes offset better than serving), and the A2-A4 pair of events (Serving becomes worse than threshold – Neighbor becomes better than threshold).

There is however a key difference involving the previous measurement events. A3 event is mainly related to Reference Signal Received Power (RSRP), while A2-A4 event is related to Reference Signal Received Quality (RSRQ). RSRP, is a measure of the average power received by the UE, while RSRQ provides additional information from the channel quality, taking into account inter-cell interference, thermal noise, etc[2].

Figure 1 shows the signaling involved for an A3-Event based handover.

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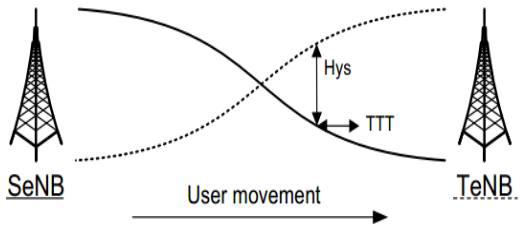

Fig. 1, A3-event based handover [8]

Though the usage of A3 event for signaling may put less stress on the UE, as only one measurement must be done by it, the A2-A4 pair of events may introduce further optimization opportunities, as they may be triggered quickly, thus reducing the possibility of performing handovers too late.

The opposite however, remains true for the A3 event. A2-A4 events may trigger more handovers, and depending on the UE speed and trajectory, these additional handovers may lead the UE to "ping-pong" between serving eNodeBs, resulting in the waste of radio link resources, and the reduction of the perceived Quality of Service (QoS), by the UE.

III. Simulation Scenarios

For simulation purposes, 5 scenarios where considered: 3 for rural and 2 for urban analysis. These scenarios where designed to be able to determine the main differences from each handover signaling method, and as baselines for comparison of results. All scenarios where simulated in NS-3.20, using the LTE modules developed by the Centro de Telecomunicaciones de Cataluña (CTTC), as part of the LTE-EPC Network Analyzer project (LENA) [9].

For the different scenarios, radio environment maps (REM) where generated, in order to be able to determine appropriately the positioning of femto-cells, in the cases where they were allocated. The REM's where generated with GNUPLOT, and traces generated by NS-3.

The first scenario, considered as a baseline or benchmark for comparison of the rural scenarios, consists of 80 UEs roaming on a 2.24 squared kilometers area, served by seven macro-cells and no femto-cells deployed on the area.

The UEs are set with random walk mobility patterns with speeds up to 60km/h, and symmetric data applications of 1Mbps, in order to provide congestion to the LTE network. Figure 2 shows the REM for the base scenario.

The rural scenarios consisted of 80 UEs roaming on a 2.24 squared kilometers area, served by seven macro-cells, with 20 femto-cells deployed on the same area, allocated in clusters of a maximum of 4 femto-cells. This scenarios were designed to resemble rural areas where macro-cells are deployed over the area to guarantee coverage and femto-cells may be deployed in large farms facilities, or in small towns found in the area.

For these scenarios, random walk mobility patterns were set for the UEs, with velocities around 60km/h (vehicular velocity), and symmetric data applications for each UE of 1Mbps, in order to maximize the stress of the network to observe flow interruptions for the different UEs set up in the scenario. Figure 3 shows the REM for the rural scenarios.

The urban scenarios, consisted of 150 UEs roaming on a 0.7 squared kilometers area, served by two macro-cells, with 30 femto-cells deployed on the area, distributed among 30 concrete, glass-windowed residential/commercial buildings. The scenario is designed to resemble a downtown area or a residential area, where this kind of buildings dominate the landscape.

For these scenarios, velocities vary from 5 km/h (pedestrian speed), to 60km/h (vehicular speed), as in urban areas both types of speeds need to be taken into account. As for applications, 8Mbps symmetric data applications are set for each UE, accounting for video conferencing, file downloading and uploading operations (syncing of files, etc.). Figure 4 shows the REM for the urban scenarios.

In the urban scenarios, the operation of femto-cells is turned on/off, in order to measure its impact on the LTE network performance.

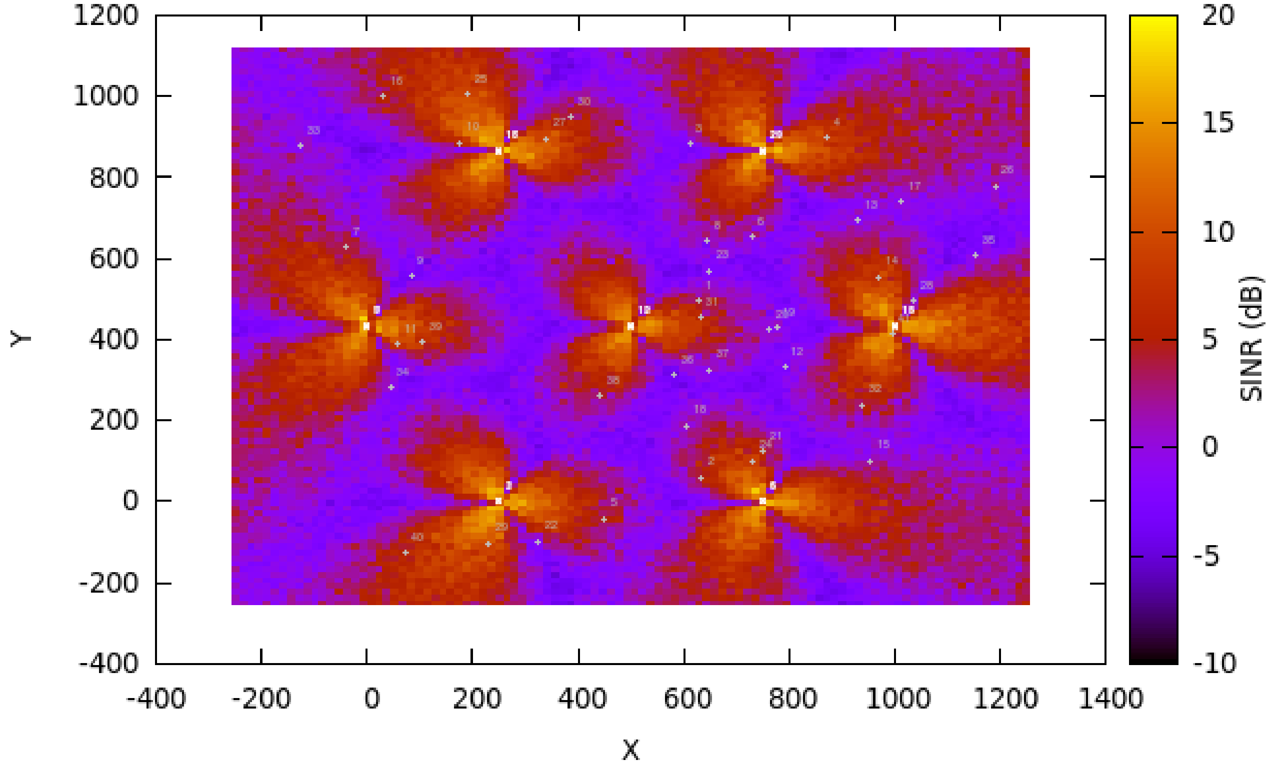

Fig. 2, REM for base scenario

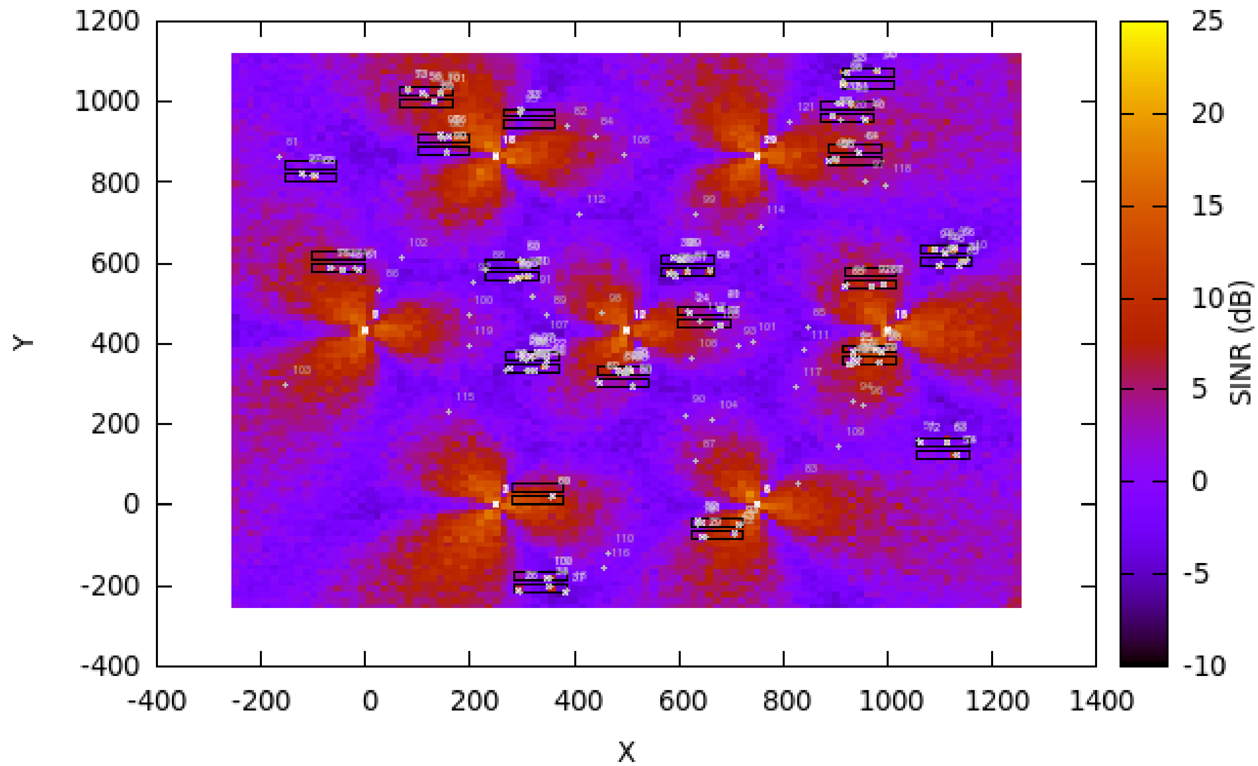

Fig. 3, REM for rural scenarios

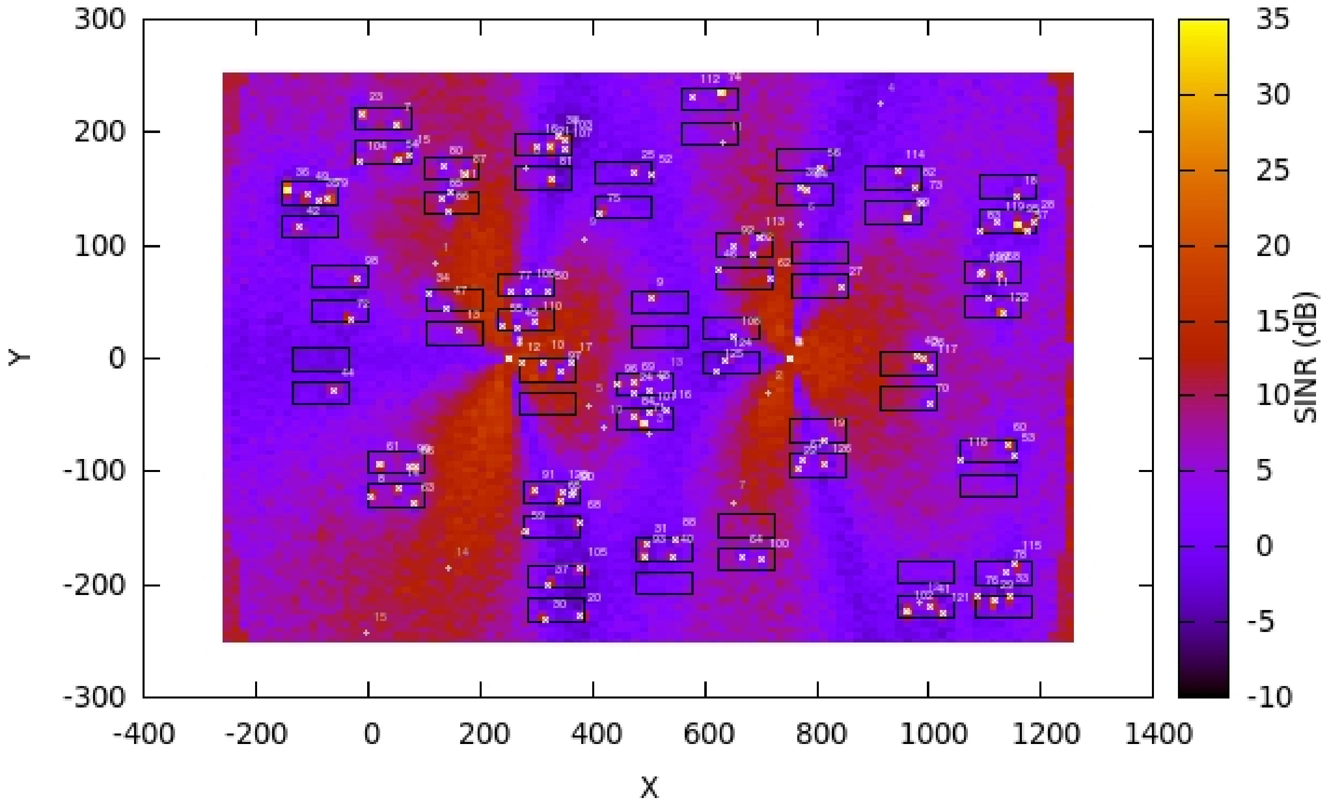

Fig. 4, REM for urban scenarios

IV. RESULTS AND DISCUSSION

For the previously described scenarios, simulations were performed by taking into account the usage of A3-event based handover mechanism, and A2-A4-event based handover mechanism (HOM). The overall throughput was observed, as well as 3 Key Performance Indicators (KPI), related to the QoS for the user.

The KPIs measured for the simulations were the packet loss rate (PLR), the delay and the jitter for each case. These measurements were done using the “FlowMonitor” module of the NS-3 simulation engine, and the tracing capabilities of the LENA module [10].

Tables I and II show the results obtained for the rural scenarios in downlink and uplink, Table III and IV show the results obtained for A3-event signaling in urban scenarios in downlink and uplink, and Tables V and VI show the ones obtained for A2-A4-event signaling, again in downlink and uplink.

Table I, Results obtained for rural scenarios in downlink

HOM/KPI	No	A3	A2-A4
Throughput (Mbps)	18,58	19,42	19,61
Delay (ms)	100,25	103,34	102,29
Jitter (ms)	10,12	11,24	10,78
PLR (%)	0,10	0,32	0,22

Table II, Results obtained for rural scenarios in uplink

HOM/KPI	No	A3	A2-A4
Throughput (Mbps)	10,49	10,78	10,69
Delay (ms)	34,75	33,97	35,33
Jitter (ms)	6,9	6,5	7,1
PLR (%)	1,5	1,3	1,7

Table III, Results obtained for urban scenarios in downlink with A3-event signaling

HOM/KPI	Femto-cell off	A3
Throughput (Mbps)	24,27	25,03
Delay (ms)	125,55	138,29
Jitter (ms)	12,5	12,9
PLR (%)	0,78	0,99

Table IV, Results obtained for urban scenarios in uplink with A3-event signaling

HOM/KPI	Femto cell off	A3
Throughput (Mbps)	3,6	3,98
Delay (ms)	33,75	31,29
Jitter (ms)	6,8	6,1
PLR (%)	1.2	1.5

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Table V, Results obtained for urban scenarios in downlink with A2-A4-event signaling

HOM/KPI	Femto-cell off	A2-A4
Throughput (Mbps)	24,47	25,07
Delay (ms)	131,11	134,16
Jitter (ms)	12,8	13,7
PLR (%)	0,64	0,96

Table VI, Results obtained for urban scenarios in uplink with A2-A4-event signaling

HOM/KPI	Femto-cell off	A2-A4
Throughput (Mbps)	3,6	4,3
Delay (ms)	32,48	34,72
Jitter (ms)	7,9	8,1
PLR (%)	0,75	1,0

From the obtained results, for the downlink, the throughput obtained by the usage of any handover mechanism with femto-cell deployment is augmented, especially with A2-A4-event signaling. As it had been previously studied, this signaling triggers a handover faster than the A3-event signaling.

Note that in this case, the deployment of open access femto-cells impacts negatively other KPIs of the UEs. This is particularly important, in order to decide whether to perform a handover to a particular femto-cell, depending on the application or user profile being provided by the UE.

In the case of video streaming, as the handover might introduce further jitter in the stream, handovers might be undesirable, however, in the case of data applications, where throughput gains are greater than the jitter and delay losses, the handovers could be desired.

In uplink, on the other hand, A3-event based handover presents improvements in the overall quality of the signal, and the throughput of the link overall, getting better results than A2-A4-event, and than the “no femto-cell” scenarios.

This particular result can be explained by the handover mechanism itself. Since A3-event consists on the detection of a better-than-serving neighbor, it keeps the UE attached to the best cell available.

Also, as LTE radio resource allocation depends strongly on UEs transmission power, the usage of RSRP as a channel indicator is more appropriate and will produce better results for a handover mechanism that utilizes it as a measure of channel quality for uplink.

As higher modulation and coding schemes (MCS) are not available for LTE uplink radio resource allocation, performing fewer handovers is desirable, since these handovers won’t usually get to MCS that enhance the observed radio link KPIs. However, it is clear that in particular zones, where macro-cells may not provide of enough QoS, a handover may improve the overall QoS provided to the UE.

In the overview of the handover mechanisms, it had been pointed out, the possibility of A2-A4-event triggering a larger amount of handovers than A3-event. This further explains the better performance of the latter in uplink. Furthermore, Table VII shows the amount of handovers for A2-A4-event and A3-event with femto-cell deployment in the urban scenario.

The obtained results may be integrated in more complex and robust handover mechanisms and LTE network optimization, particularly in the aspects regarding handover parameter optimization.

Table VII, Amount of handovers for different handover mechanisms on urban scenarios with femto-cell deployment

	A2-A4	A3
Handovers	724	512

V. Proposed approach for LTE Network Handover Parameter Optimization

Handover parameter optimization is a key to the provision of seamless voice and data services to the growing demands of consumers, and several authors have already tackled into different approaches for this matter.

The main approach by the aforementioned authors has been the utilization of Self-Organizing Maps (SOMs) [11]-[14], where different handover performance calculations are done, in order to improve the handover parameter tuning.

From the drawn conclusions of the previous sections, further opportunities for parameter tuning may arise, if the user’s profile (i.e. the uplink/downlink usage by each user), and the application served to each user are taken into account.

A coding scheme for the application and profile might be added to the entire signaling existing between the UEs and the eNodeBs. Since switching between handover mechanisms on a real-time basis might not be feasible, it is proposed to aggregate the user profile and the application in the UEs hourly, with a report being sent then to the serving eNodeB each hour. The handover mechanism, whose optimization is integrated within the SOM algorithm, will be fixed as well on an hourly basis, providing a solution better fitted for each user, as opposed to a one-fits-all solution.

As future work, this approach will be taken into account into the development of a time-adaptive approach [15] for handover parameter optimization for LTE networks.

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