Self-Optimization for Handover Oscillation Control in LTE

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Abstract— **In this paper we analyze the performance of a self optimizing algorithm for handover parameter control which adjusts the settings depending on the oscillations experienced between different cell pairs. We compare the algorithm performance with two different reference cases. The first one allowing the system to trigger handover as soon as the best perceived cell changes, with the users connected always to the best server. The second one protecting the system against oscillations by setting default values for time to trigger (TTT) and handover margin (HOM). We observe that introducing the handover parameters reduces the oscillations but has a strong negative effect on the performance. With the self-optimizing algorithm the system performance is better while the oscillations are mitigated at similar levels.**

Index Terms—**Handover, LTE, SON, Self-Optimization, Oscillation, Ping-pong.**

I. Introduction

The interest in self-organizing features for cellular wireless networks has grown in recent years. Handover parameter optimization was included in [1] as one of the use cases defined by the operator's alliance NGMN (Next Generation Mobile Networks) for Self Organizing Networks (SON). Handover parameters optimization is also considered as a SON use case by the 3rd Generation Partnership Project (3GPP) [2].

The basic requirements for handover parameters optimization are defined in [1] where three optimization objectives are described: minimize handover failures, minimize unnecessary handovers and increase the load balancing capability of the network. These three optimization objectives are in line with the ultimate goal of SON features which is to reduce OPEX and CAPEX by minimizing manual operation and/or increasing the network performance. This paper is focused on the second SON target for handover optimization -to minimize the oscillations of handovers and their negative effects- on the scope of 3GPP Long Term Evolution (LTE).

Handover initiation algorithms are usually based on the received signal strength or quality from different base stations [3], in LTE Reference Signal Received Power (RSRP) or Reference Signal Received Quality (RSRQ) [4]. In general, when a target cell is perceived with a better quality than the current serving cell, the user equipment (UE) sends a measurement report to the network which decides whether or not to perform a handover.

In practice, due to the varying nature of the radio signals, it is possible that what appears to be an increase of the received radio signal power or quality of a target neighbor cell due to movement is actually a fast signal fluctuation that lasts for only a short period of time. Such fast signal changes typically do not follow a long term average trend of the path loss for a given UE movement pattern, and as a result, may create a series of handovers in a relatively short period of time. These series of handovers are often not beneficial or needed (due to the cost associated to each handover) and are referred to as "handover oscillation" or "ping-pong". Cellular radio access technologies make use of handover parameters in order to avoid oscillations.

There are many examples in the literature where the problem of optimizing parameters related to handover is addressed, but in most of them, the solution is not applicable to SON because is based on individual predictions or field measurements, for example [5], [6], [7] and [8] to name some. There are also a few examples of handover optimization contributions where the objective is applicable to SON. For instance, in [9] and [10] the authors propose an optimization mechanism based on minimization of blocked call ratio and/or downlink transmitted power and in [11] the optimization goal is to minimize the network's outage probability, but in these works the problem of unnecessary handovers is not addressed. In this paper, the handover parameters are optimized on a per cell-relation basis (a different value for each cell and each of its neighbors is calculated) in order to meet an oscillation rate criteria; this tuning is based on the oscillations experienced by the users during normal network operation thus making it appropriate for a SON feature.

Section II describes the handover parameters and their effects. In Section III we introduce two different use cases and an adaptive algorithm for handover parameter setting for oscillation control. Section IV presents simulation results that are used to perform an analysis of the three defined strategies. Finally, conclusions are presented in Section V.

II. Handover Parameter Setting

The objective of the handover parameters is to add reliability to the UE measurements, making it more "certain" that the variations in signal levels are stabilized before triggering handover, thus preventing oscillations.

The most relevant handover parameters in 3GPP LTE are Time to Trigger (TTT) and Handover Margin (HOM). The HOM is usually measured in decibels and is defined as the minimum received power or quality between a candidate cell and the serving cell needed for triggering a handover. The TTT is usually measured in seconds and defined as the minimum time the HOM condition has to be fulfilled for the handover to be triggered. In other words, the condition for handover triggering is that the candidate cells must be at least HOM decibels better than the serving cell during at least TTT seconds. More details about handover parameter settings in LTE can be found in [12]. The following sections describe the considerations needed in order to find an appropriate setting of the handover parameters.

A. *Effects of handover parameters on performance*

Reducing oscillations is desirable because each handover is tied to a number of procedures that have a cost to the system.

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Too many handovers could generate unwanted effects such as: additional processing load coupled with the handover process (e.g. admission control, bearer setting, path switch, etc); increased use of radio and transport network resources (e.g. dedicated random access channel preambles, packet forwarding, etc.); decreased service and network performance during the detached time coupled to the handover process; increased complexity of relevant load and mobility statistics collection. The reduction of oscillations can be achieved by using the mentioned handover parameters at the cost of making the handover procedure slower. This will retain users not being served by the best cell for longer time, thus increasing the interference, which could possibly translate in the following effects: Decreased service performance due to a reduction of the achievable bit-rates; decreased handover performance due to higher probability of handover failure with higher interference levels.

Hence, the optimal handover parameter setting is a trade-off between number of oscillations and radio network performance.

B. Variations of trade-off settings

A good trade-off setting of the handover parameters depends on how often the oscillations take place. This, in turn, depends on the network environment (radio propagation, moving pattern of the users, etc). Moreover, this trade-off will be different depending on the cell pair and direction; in real networks some cell pairs experience a high number of oscillations, while some others do not experience oscillations at all.

For example, the trade-off setting of the handover parameters between two cells that cover a highway may not be the same as the one setting between two cells that cover a city centre. In the city centre case, the radio propagation could be influenced by reflections in buildings and the users move at slow speed which likely increase the probability of oscillations. In the highway scenario however, the open space reduces the reflections and the users move at high speed which makes it more unlikely that the users suffer oscillations.

Moreover, the optimal handover parameter settings may vary over time. Changes in antenna tilt, UE movement pattern, transmission power, new buildings, addition of new cell sites, etc. are possible causes of such variations.

C. Current situation

In practice, operators set default values for the handover parameters and only adjust those default values if a problem is detected. This solution may result in a suboptimal handover parameter setting. First, because with default handover parameter values, the cells that experience a high number of handover oscillations may only be able to reduce those oscillations to a certain extent, and sometimes, not sufficiently. In addition, cells that do not experience handover oscillations would benefit from having handover parameter settings with a faster reaction time, thereby reducing interference to neighboring cells.

In this paper we investigate the benefits of automatic setting of handover parameters on a per-cell-relation approach based on statistics collected over a long period of time.

III. Studied Scenarios

In order to investigate the potential advantages and disadvantages of an automated algorithm for handover parameter setting we define two reference scenarios and one adaptive algorithm.

A. Reference Scenario 1

The first reference scenario consists of the absence of handover parameters (i.e. the value for HOM is set to 0dB while the value for TTT is set to 0s). In reality this configuration is not realistic because it is likely that some cell pairs need protection against oscillations. In this paper we will use it only as an upper boundary for the maximum reachable radio performance (i.e. all UEs are connected always to the best server).

B. Reference Scenario 2

For the second reference case we use default fixed values for HOM and TTT. Choosing the optimal default values for a given network is not a trivial task, but values of HOM typically range from 2dB to 5dB depending on the operator. In principle there are no limitations for the value of this parameter apart from the measurement accuracy of the UE. Regarding TTT values ranging from 200ms up to 1s are typically used. In LTE, the allowed accuracy for TTT is limited by the cadency in which measurements from layer 1 are processed, in our case 66ms.

The values chosen for the second reference case are HOM=4dB and TTT=0.6s, which are placed in the conservative end of the range and are expected to offer an effective protection against oscillations.

C. Self-Optimizing Algorithm

The underlying assumption is that UEs moving from one cell to another cell will experience a similar oscillation probability. It is however possible that two cells have two or more different areas where their coverage overlap (handover areas). In the latter case, the optimization will adapt to the most restrictive of those handover areas (i.e. the one with the highest probability of oscillation).

The optimization is based on long term statistics collected in the network under normal operation, thus optimizing the setting for network deployment and average usage of cells. The algorithm does not take into account specific UE behavior, as speed, and applies the same policy to every UE moving between a particular cell pair.

1) Collected Statistics

The main input to the adaptive algorithm is information about how frequent are oscillations for a given cell pair. In a straightforward approach, we define oscillation as a handover that is initiated less than 1s after the UE started the connection to the cell from a previous handover. We also define the handover oscillation rate (OR) between cell i and cell j as the number of oscillations from cell i to cell j divided by the total number of handovers between cell i and cell j.

The OR rate is calculated continuously for all cells and all neighbors. Every time a modification is made to the TTT or HOM, the counters are reset and a new OR is calculated corresponding to the new configuration.

2) Optimization Loop

The optimization process is done by adjusting the values of TTT and/or HOM in an iterative mode, depending on the experienced OR in that particular cell pair and direction. The value of the parameter subject to optimization (P) for an iteration *k*, depends on the own value and the experienced and target OR at the previous iteration *k-1*. The increment of P for the next iteration ΔP, is proportional to the difference between the experienced OR and the target OR (Target_OR) towards which the optimization is performed. If the experienced OR has reached the target value, P remains unchanged for the next iteration. The following expression defines the calculation of the value of P for an iteration *k*.

$$\Delta P = \Delta P_{MAX} \cdot \left(OR_{Ci\_Cj}(k-1) - Target\_OR_{Ci\_Cj} \right)$$
$$P_{Ci\_Cj}(k) = P_{Ci\_Cj}(k-1) + \Delta P$$
$$where: j \in i, j \neq i$$

A new value is calculated each iteration, a new iteration starts when the minimum number of handovers between the two cells is reached (Min_Handovers). For practical reasons, a limit on the maximum step allowed between two values of consecutive iterations is defined by the parameter ΔP_{MAX}. Similarly, the maximum and minimum absolute values for the parameter and defined by Max_P and Min_P respectively.

IV. Performance Analysis

We evaluated the performance of the two reference cases and the self-optimizing algorithm by means of simulations. On a first performance criterion, we examined the OR for the different cell pairs and directions with the three described configurations. On a second criterion, we evaluated the network performance by comparing the experienced UL and DL throughput with the different configurations. Due to the focus on oscillations, the simulation scenario was chosen in order to achieve a negligible number of handover failures.

We used an LTE dynamic simulator with detailed models for protocols and radio interfaces. All the Radio Resource Control (RRC) messages related to handover are sent with the highest priority using the Downlink Shared Channel (DSCH) or the Uplink Shared Chanel (USCH). The users download or upload a 1MB file, the number of users is constant through the simulation (i.e. a new user is created as soon as one is finished). The most relevant simulation settings are described in Table 1. The settings used for the self-optimizing algorithm are described in Table 2.

Figure 1 represents the Cumulative Distribution Function (CDF) of the OR for all the cells in the network and their six most relevant neighbors. The two reference cases and the self-optimizing algorithm are presented in the figure. We observe that the oscillation rate is very high for the first reference case (0dB, 0s), with a minimum of 33% and up to 90% in some cell pairs. This is the main reason why the first reference case is not a realistic option in a real deployment. The second reference case shows that oscillations are highly mitigated by using handover parameters, but we can still observe that some cell pairs experience oscillations in up to 10% of the handovers. On the other hand, 42% percent of the cell pairs do not experience oscillations at all.

TABLE 1
SYSTEM SIMULATION PARAMETERS

System	LTE FDD 5MHz at 2.0GHz
Max DL Power	20W
Number of cells in hexagonal grid	7 sites, 3 sectors each (21 cells)
Cell radius	500m
Antenna type	SCM3GPP max gain = 12.2dB
Shadowing sigma	8dB
Noise Factor	8dB
Propagation Model	Typical Urban
Number of users	100xWebDL + 100xWebUL
RSRP measurement period	200ms
RSRP reporting period	66ms
Layer3 filter coefficient	4 (last sample weights 50%)
UE Moving Pattern	Straight
UE speed	3m/s
Traffic Model	Web download and upload

TABLE 2
SELF-OPTIMIZING ALGORITHM PARAMETERS

Parameter (*P*)	HOM	TTT
ΔP_{MAX}	2dB	0.3s
Initial P	0dB	0s
Max_HOM	4dB	0.6s
Min_HOM	0dB	0s
Min_Handovers	50	
Target_OR	0.05	

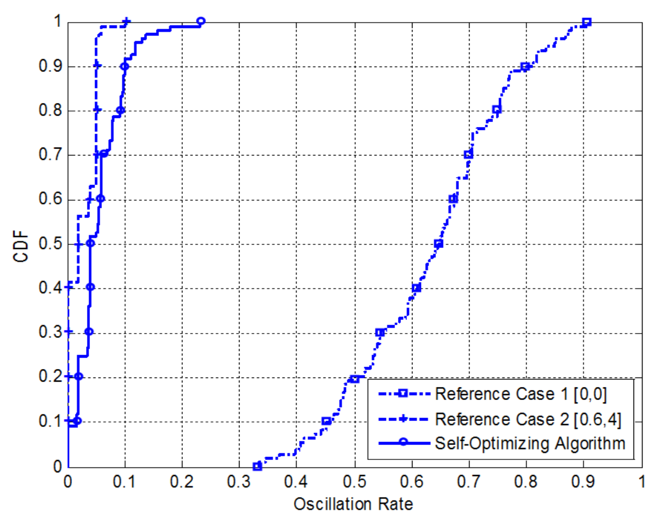

Figure 1: CDF of OR experience by different cell relations

In the third case, with the self-optimizing algorithm the achieved protection against oscillations is similar to the second reference case with only 10th percentile of the cell pairs experiencing oscillation rates higher than 10%.

In order to understand the effects of the algorithm, we investigate the actual values of HOM and TTT that were used during the simulation. The values for the adaptive algorithm change over time, Figure 2 shows the CDF of the values used in the last time instant after a simulated period of 1 hour. These values are close to convergence, since the network deployment and usage did not change during the simulation.

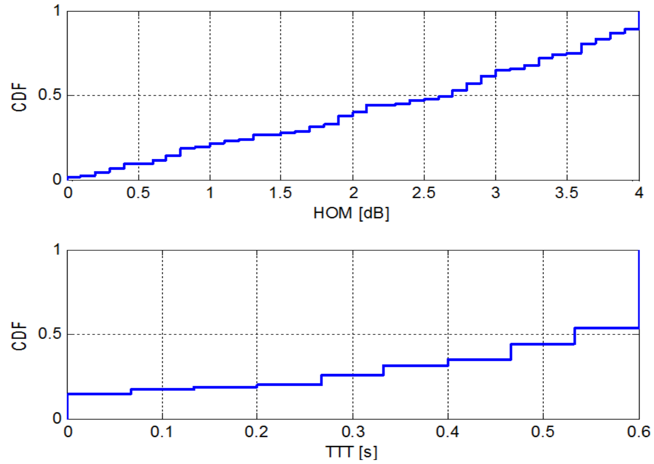

Figure 2: CDF of HOM and TTT used in different cell relations

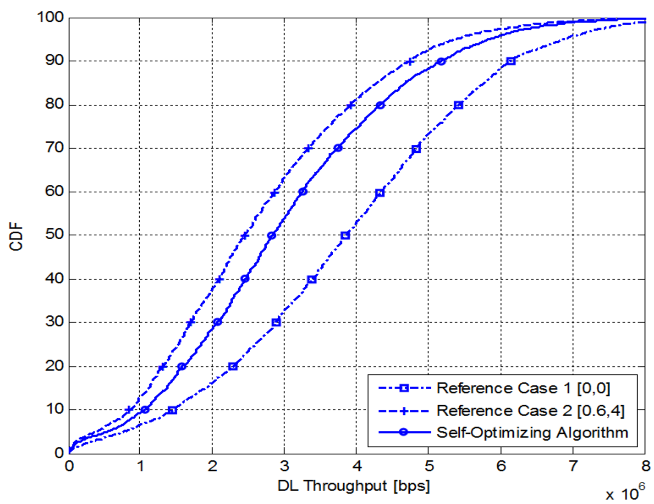

Figure 3: CDF of DL user throughput for all users in the network

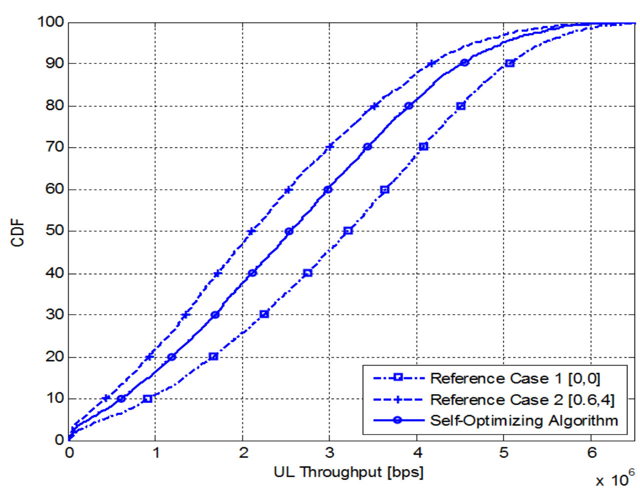

Figure 4: CDF of UL user throughput for all users in the network

With the adaptive algorithm only a fraction of the cell pairs use the maximum allowed values for HOM and TTT (which correspond to the second reference case) yet providing a similar protection against oscillations.

In Figure 3 and Figure 4, we analyze the benefits of reducing the value of the handover parameters in cells that do not need a strong protection against oscillations. Both figures show a strong degradation of the user throughput when handover parameters are introduced. The performance of reference case 1 is ~65% higher than the reference case 2 and ~45% higher than the adaptive algorithm in both UL and DL. This indicates that the use of handover parameters has to be avoided whenever it is possible and suggests high potential gains for solutions that mitigate the negative effects of oscillations described in section II.A. The self optimizing algorithm shows a gain of ~20% in UL and DL with respect to the second reference case while keeping a similar level of protection against oscillations. This gain is achieved by using handover parameters only on those cell pairs that experience oscillations, thus reducing the interference levels and providing an overall gain in the network.

V. CONCLUSIONS

We analyzed the performance of a self-optimization algorithm for handover oscillation control based on statistics collected over a long period of time. The performance was compared against two reference scenarios, the first one with no protection against oscillations and the second one with strong protection. We observed that the adaptive algorithm offers similar protection against oscillations as the second reference case while increasing the network performance 20% in terms of DL and UL throughput. In general, we see a strong potential for oscillation control by means of self-optimizing algorithms instead of sub-optimal default values or manual tuning.

In a more general conclusion, we have observed that the network suffers a strong degradation when protection against oscillations is used as compared to the ideal case where all the UEs are always connected to the best cell. There is also a strong potential for improving radio performance by adding features that reduce the negative effects of oscillations.

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REFERENCES

[1] Next Generation Mobile Networks. Recommendation on SON and O&M Requirements. *2008.*
[2] 3GPP TR 36.902, "Self-configuring and self-optimizing network use cases and solutions. v0.0.1", *2008.*
[3] G. P. Pollhi "Trends in Handover Design". *IEEE Communications Magazine March, 1996.*
[4] E. Dahlman, S. Parkvall, J. Sköld, and P. Beming, 3G Evolution HSPA and LTE for Mobile Broadband, *Elsevier, 2007.*
[5] Vanghi, V.Chevallier, C. "WCDMA handover parameters optimization", *IEEE International Conference on Communications, 2004.*
[6] Sang-Jo Yoo et al. "LMS predictive link triggering for seamless handovers in heterogeneous wireless networks" *IEEE MILCOM'07.*
[7] S. F. Chien et al. "Smart Predictive Trigger for Effective Handover in Wireless Networks" *IEEE ICC proceedings, 2008.*
[8] A. Markopculos et al. "Optimized Handover Procedure based on Mobile Location in Cellular Systems" *IEEE PIMRC* 2003.
[9] Flanagan, J.A.; Novosad, T., "WCDMA network cost function minimization for soft handover optimization with variable user load," *Vehicular Technology Conference, 2002.*
[10] Schröder, A. et al. Distributed Self-Optimization of Handover for the Long Term Evolution. *Proceedings of the 3rd international Workshop on Self-Organizing Systems,* 2008
[11] Christina Werner et al "Handover parameter optimization in WCDMA using fuzzy controlling", IEEE *PIMRC 2007.*
[12] 3GPP TS 36.331 V8.5.0, *2009.*