Enhanced weighted performance based handover optimization in LTE

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Abstract: This paper presents an enhanced version of a self-optimizing algorithm that tunes the handover (HO) parameters of a LTE (Long-Term Evolution) base station in order to diminish the negative effects that can be introduced by handover (radio link failures, HO failures and ping-pong handovers) and improve the overall network performance. While the default algorithm selects the best hysteresis and time-to-trigger combination based on the current network status, the enhancement aims at improving its convergence time. We examined the effects of this enhancement in a rural scenario setting and compare it to the original algorithm; the results show an improvement from the static value settings of this algorithm and faster convergence with due to the enhancement.

Keywords: LTE; Self-Organization; Handover

1. Introduction

In a world moving ever faster, the demand for services that can keep up with the needs of the client is increasing. This determines mobile operators to look for new solutions for providing their services faster and better than ever before. The promise of auto-tunable functions that control different network mechanisms, such as handover (HO), load balancing, admission control and others, is becoming a very tempting reality, for operators and vendors alike. The self-optimization of future radio access networks, such as LTE, is one of the main topics of today's research [1],[2] .

Handover is a vital procedure in any mobile network that guarantees users' freedom of movement while still being provided high quality services. The more successful and seamless this procedure is, the higher the user satisfaction. In currently deployed networks, the control parameters that govern HO are set to static values and their updates are done on a long timescale (days/weeks), as part of maintenance operations. This approach is both time and effort consuming and it might not be carried out as often as necessary, resulting in sub-optimal network performance.

The aim of the previously proposed algorithm proposed (Weighted Performance based handover optimization algorithm (WPHPO)) is to dynamically modify the settings of the control parameters according to the current network performance situation, as opposed to them being set to fixed values at all times. The main challenges facing such an algorithm is finding the optimal balance between deriving the proper parameter settings of the HO process in a short amount of time and ensuring that the network is in a stable operating point for a long time afterwards. The objective of this paper is to enhance this algorithm in order to improve it's convergence time and implications that has on network performance.

The benefits of self-organizing networks (SON) have been proven by several studies in recent years. Similar work in this field [3],[4],[5] usually only considers only one of the HO performance indicators (HPIs), such as Radio Link Failures(RLFs), HO ping-pongs (HOPP) or HO failures (HOFs) and aims to minimize them in hopes of improving network performance. But since the interaction with between these HPIs is very strong, one must consider them as a whole when trying to optimize HO performance. A control parameter setting that, for example, diminishes the occurrence of ping-pong HOs will also most likely increase the number of RLFs.

The rest of this paper is structured as follows. In Section 2. we briefly present previous work and propose an enhancement approach. Section 3. presents the simulator tool and the investigated scenarios. A short sensitivity analysis is depicted in Section 4.. The comparative simulation results of both the default algorithm and the enhanced version are included in Section 5. Conclusion and outline of future work are given in Section 6. The work has been carried out as part of the EU FP7 SOCRATES project.

2. Handover algorithm and performance metrics

The WPHPO algorithm uses various input measurements, performance indicators and control parameters. The network is constantly being monitored and input measurements are collected. These input measurements are used for triggering HO and assessing the current link quality. During the simulation assessment metrics are calculated and fed to the algorithm, which in turn sets the control parameters to appropriate values.

2.1 Input measurements and control parameters

RSRP

The Reference Signal Received Power (RSRP) is computed based on the transmit power of a cell, the pathloss value associated with the current location of the user and correlated shadow fading a zero-mean Gaussian distribution in the log-domain with a standard deviation of 5dB.

SINR

The signal-to-interference noise ratio is derived from the RSRP value of the current serving cell (SeNB) and the RSRPs of all the other eNBs in the scenario plus thermal noise. If the SINR of a call is under the minimum threshold (-10dB) for a certain amount of time (1s, similar value to the T310 timer [6]), the call is dropped.

Hysteresis

A handover is initiated when the following condition is met: the RSRP of the a neighbouring cell is greater than the RSRP of the SeNB plus the hysteresis (Hys) value for at least for a certain amount of time. The valid hysteresis values varies between 0 and 10 dB with steps of 0.5 dB, resulting in 21 valid hysteresis values.

Time-to-Trigger

The time the RSRP condition has to hold in order for a handover to be initiated is specified by the Time-To-Trigger (TTT) parameter. The TTT values for LTE networks are specified by 3GPP (see [6], section 6.3.5): 0, 0.04, 0.064, 0.08, 0.1, 0.128 ,0.16, 0.256, 0.32, 0.48, 0.512, 0.64, 1.024, 1.280, 2.560 and 5.120 in [s]. These 16 values are the only valid TTT values.

2.2 Default WPHPO algorithm

The default WPHPO algorithm changes the current HO Operating Point (HOP)(unique combination of Hysteresis and TTT values) based on the current performance of the network. The metric used to quantify this performance is the HP with the weighting factors. The following four HO performance indicators (HPIs) are collected in order to assess the impact the changes of the HOP have on the network.

Handover failure ratio

The handover failure ratio (HPI_{HOF}) is the ratio of the number of failed handovers to the number of handover attempts. The number of handover attempts is the sum of the number of successful and the number of failed handovers. A handover is considered to have failed when the user tries to connect to the Target eNodeB (TeNB) but fails due to poor radio conditions. The user will then try to handback to its SeNB.

Ping-pong handover ratio

If a call is handed over to a new eNB and it then is handed back to the source eNodeB in less than the critical time (T_{crit} =5s) this handover is considered to be a ping-pong handover. The ping-pong handover ratio (HPI_{HPP}) represents the number of ping-pong handovers divided by the total number of successful handovers.

Radio Link Failure (RLF) ratio

The RLF (HPI_{RLF}) is the probability that an existing call is dropped before it was finished, if the user moves out of coverage ($SINR < -10dB$ for 1s). It is calculated as the ratio of the number of RLFs to the number of calls that were accepted by the network.

Handover performance (HP)

The HP (Handover performance) is an operator policy based weighted sum of the three metrics described above and offers an overall performance evaluation. The HP is calculated according to equation 1.

$$HP = (w_{HOF} * HPI_{HOF} + w_{HPP} * HPI_{HPP} + w_{RLF} * HPI_{RLF})/(w_{HOF} + w_{HPP} + w_{RLF}) \tag{1}$$

The values for these weights are a direct translation of the operator policy. The combination chosen for our studies, $[w_{HOF} = 1, w_{HPP} = 0.5, w_{RLF} = 2]$, for example, gives priority to the reduction of RLFs, while HO failures are to be avoided but ping-pong HOs are just tolerated as inevitable side effects of the RLF reduction. Thus, the operator of a mobile network can influence the performance of the WPHPO algorithm by manipulating the weight mix.

The WPHPO will look for an optimal HOP by following a diagonal through the grid of Hysteresis and TTT values, determined by the initial HOP setting. During a certain amount of time (called SON interval),the three HPIs are collected and the HP is calculated and compared to the value of the HP observed in the previous interval. If performance is worse (larger value is observed), the direction of crossing the diagonal through the HOP space is switched. Either way, one of the two control parameters (and thus the current HOP) is changed in every time step. More details on the default WPHPO algorithm can be found in [7] and [8].

2.3 *Enhancement*

The WPHPO algorithm presented above, changes the direction in which it looks for a new HOP if the HP of the current interval is larger (worse) than the one calculated for the previous HOP observation interval. This may cause slow convergence, since a small number of events (like ping-pong HOs or handover failures) may determine the direction to be changed and return to a previous point.

In order to avoid this behaviour, and thus improve convergence time, we introduce an extra threshold that will allow the direction to be switched only if performance degrades with more than a certain Performance Degradation Percentage (PDP%) compared to the previous value. By tolerating worse performance, needless changes of optimisation direction due to isolated incidents are avoided. Also, this means that valuable changes of the HOP will not be wasted by ping-ponging between two HOPs, but instead, in the same amount of time, the WPHPO will reach a better HOP than before. The HOP has to be allowed to change in every time step, even if the PDP is applied, in order to allow performance to actually degrade and the direction to be changed (if indeed) when moving away from the optimal performance region.

3. Simulator and scenarios

The results presented below have been obtained using an OPNET® based simulator in a rural scenario. This simulator models eNBs, users and the communication between eNBs. The main simulation parameters are given in the Table 1. The users are initially distributed within the simulation area and can start moving according to a random walk mobility model, all at the same speed. During the simulations, the users will alternate between an active (a call is ongoing) and an inactive state (idle state). After the user has been idle for an appropriate amount of time (drawn from an exponential distribution), it will start a call. The values of this mean determines the load of the network. The larger mean of the distribution, the lower the load, as fewer users will be simultaneously active in the network. When the users have finished the call or if it has been dropped due to poor radio link conditions, it will retry to make a new call with a certain probability.

We investigated the following scenarios, in which speed and load can be varied:

- Scenario 1: A constant speed and load scenario where the user speed is 50km/h and idle duration mean is 300s.
- Scenario 2: A scenario with changes in speed and load: abruptly from 50km/h to 120km/h and 300s mean idle duration to 0s.
- Scenario 3: Highway congestion scenario: the speed changes from 120km/h to 3km/h and the load rises by modifying the mean idle duration from 300s mean idle time to 0s, during the first hour of simulation.

Table 1: Simulation parameters

Parameter	**Value**
Network layout	5x5 grid
Number of users	2500
ISD	1732m
System Bandwidth	5 MHz
Antenna type	omnidirectional
Pathloss model	Okumura-Hata model for open space (according to [10])
Shadow fading deviation	5dB (according to [9])
SON interval	3 minutes
Traffic mix	1/3 voice,1/3 video,1/3 web (according to [11])

4. Sensitivity analysis

The decision to work on a diagonal only was motivated by a sensitivity analysis that took into account all 336 possible combinations of Hysteresis and TTT values. The RLFs will be reduced for small HOP values, while the handover failure and ping-pong HO ratios in this case will be high and will be smaller for large HOP values. But since the biggest influence will be attributed to the RLFs ($w_{RLF} = 2$), the "optimal performance" region will be placed somewhere in the middle of the Hysteresis-TTT plane. Note that the lower the value of the HP (e.g. less unwanted events), the better the performance.

An example of such a sensitivity analysis outcome is presented in Figure 1. The position the the optimal HOP is mainly determined by the scenario conditions (user mobility and load) and the weight mix. For example, at higher speeds, a higher number of ping-pong HOs are observed (due to the shadowing fading). At the same time, the weight mix will have a direct impact on the HP values and thus on the optimization decisions.

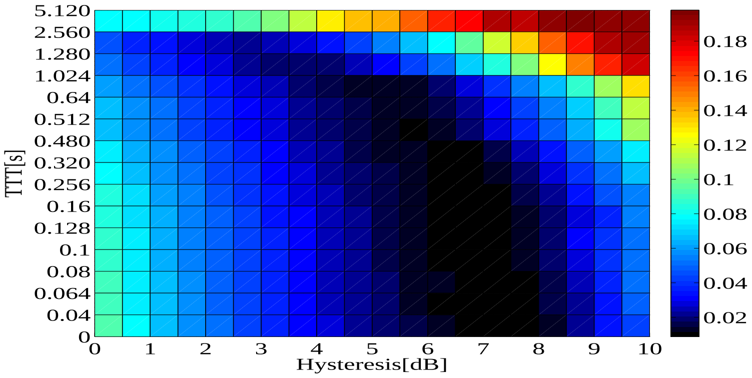

Figure 1: Example of HP values in Hysteresis-TTT value plane

5. Simulation results

In this section we present the results obtained in the three scenarios described above. We compare the results of the reference case (no self-optimization enabled) to those of the default WPHPO algorithm and 5 settings for the PDP value in the enhanced version (10% to 50%). In order to get a complete look at the situation before and after optimization, the evolution of the HP (calculated with equation 1 and normalized to the weight sum) in time is shown. As mentioned before, when modifying the HOP certain trade-offs must made and a balance between HPI must be achieved, based on the weights given to them, in accordance with the operator policy. Although every cell takes optimization decisions independently, the results presented below are averaged over all the cells in the simulation area (25). This permits the observation of the overall network performance and not of just one cell. This is of important since a change of the HO settings in one cell can shift more users to a neighbour cell and cause a drop of performance there.

5.1 Scenario 1

In this scenario, the speed of the users and the load they generate into the network are maintained constant during the simulation (50km/h and 300s mean idle time). Under these conditions, the most important thing is to derive proper HOP settings when starting from extreme initial settings. Figure 2 presents the evolution of the HP with such extreme initial HOP settings, namely 10dB and 5120ms (highest possible setting) and 0dB and 0ms (lowest possible setting).

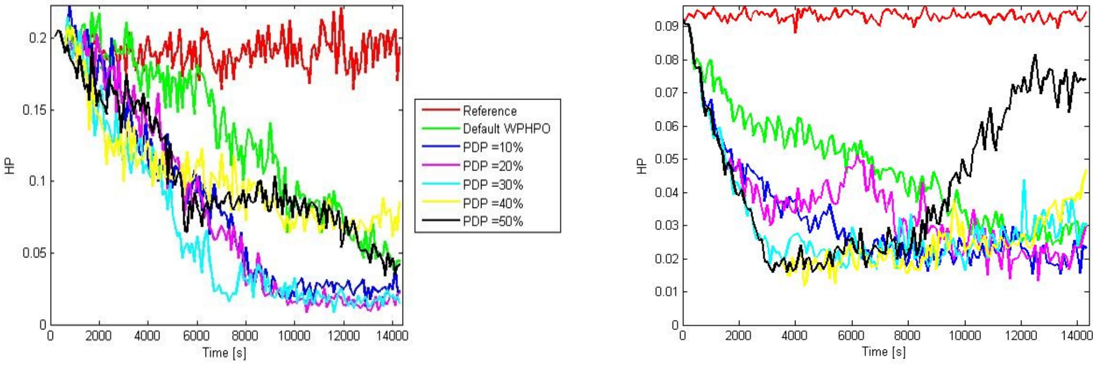

Figure 2: HP evolution with high (right) and low (left) initial HOP in scenario 1

As it can be seen from these two figures, applying the PDP improves convergence time considerably, allowing the algorithm to derive better HOP settings in the same amount of time. By setting the PDP to 10%, 20% or even 30%, better overall performance is achieved than with the default version of the WPHPO. Higher settings for the PDP value tolerate too much performance degradation and thus waste too many HOP changes before reacting and switching direction. In the following scenarios we will only consider the 10% and 20% settings, since they proved to offer the best performance.

5.2 Scenario 2

In this scenario, both the load and speed of the users rise after half an hour (1800s) from the simulation start(from 50km/h to 120km/h and from 300s mean idle time to 0s).This is an extreme situation where the user will practically always tries to be connected. The initial HOP is set to 4dB and 480ms in all cells. This particular HOP represents one of the optimal HOP settings for the initial state of the network (50km/h and mean load determined by 300s). The result of this test is shown in Figure 3. Since the initial HOP was already rather optimal (it is assumed that the algorithm reached convergence for the initial state), the improvement determined by the enhancement is less impressive. Still, the enhanced version of the algorithm achieves similar performance to the default.

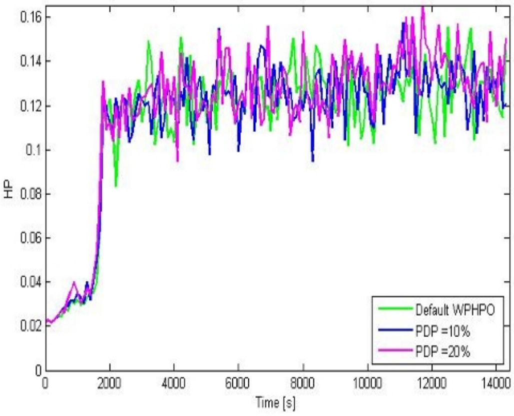

Figure 3: HP evolution in scenario 2

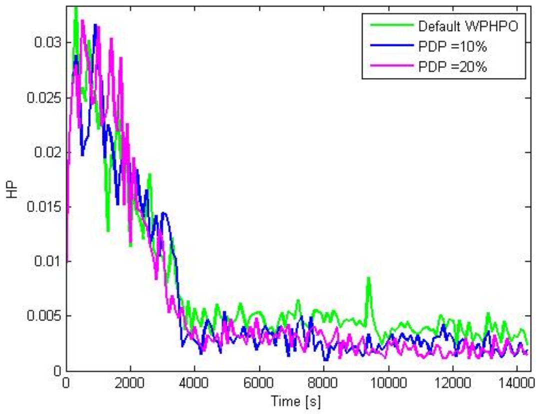

Figure 4: HP evolution in scenario 3

5.3 Scenario 3

Scenario 3 tries to model a congestion situation on a highway. As an accident happens, the speed of the users will drop (from 120km/h to 3km/h) and the load of the network will increase (as more of the users will start making calls). As Figure 4 shows, applying the PDP in this case is also improving performance. Of course, as optimization started in a more optimal HOP (8dB and 160ms), the improvement is not as significant as in previous cases.

6. Conclusions and future work

In this paper, an enhanced weight performance HO parameter optimization (WPHPO) algorithm is proposed. The algorithm tunes the HO control parameters (Hysteresis and TTT) based on the current performance in a cell by traversing a diagonal line through this space. The enhancement tolerates a higher percentage of performance degradation (PDP) before changing the optimization direction. This enhancement has been tested in various scenarios and proves to improve convergence time and performance level compared to the default WPHPO.

Given the starting HOP, the PDP could be set to different values to offer faster convergence time. If the current HOP is an extreme value, the PDP may be set to a larger values (i.e. 20% -30%). Once the algorithm reaches a region of optimal performance however, lower values for the PDP have to be considered (10% - 20%, even 0% as in the case of the default algorithm). However, a setting of 10% offers improved performance in all scenarios.

Performance wise, the PDP can no longer make a difference once in an optimal HOP setting region, since the algorithm will keep looking for an even better HOP. This will introduce oscillations around the same two of three points and determine unnecessary signalling. Since the performance will vary very little between HOPs in this region, a stop condition could be implemented in order to maintain the HOP in a stable state .

In order to address this issue, as part of future work, we propose adding a second threshold, called PVP (Performance Variance Percentage) which will resemble a Hysteresis value for the changing of the HOP in every step. Only if the current value of the HP shows an oscillation (around the previous value) greater than the PVP value, the HOP is allowed to change. This, in combination with the PDP, will assure finding a HOP that offers good performance fast and remain there, if it doesn't change considerably. This will also decreases the amount of signalling, which is also to be considered.

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