WP2-M8 : Handover strategies between femto and macrocells

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Abstract

This work aims at presenting an optimizing algorithm that tunes the handover (HO) parameters for an outdoor-indoor network in order to improve the overall network performance. The main targets are to diminish number of ping-pongs, and HO failures between an outdoor macrocell to indoor femtocells. For the purpose of this study, an office park scenario for joint outdoor and indoor coverage is simulated using wireless network planning and optimization suite, Ranplan iBuildNet®. The handover performance based on the optimal handover control parameters is evaluated. Algorithm is aimed to be self-optimizing to picks the best hysteresis and time-to-trigger (TTT) combination for the current network status. The self-optimizing algorithm is introduced. An improvement from the static manually value settings is achieved. However, handover control parameter optimisation for different scenarios and different operating points need to be researched further.

I. Introduction

Handover is one of the key procedures for ensuring that the users move freely through the network while still being connected and being offered quality services. Since its success rate is a key indicator of user satisfaction, it is vital that this procedure happens as fast and as seamlessly as possible. In currently deployed mobile networks, handover (HO) optimisation is done manually over a long time frame, e.g. days or weeks, on a need basis only. This approach is both time consuming and may not be carried out as often as needed.

This work aims at introducing an online self-optimising algorithm that tune the parameters of the HO process considering overall network performance and user QoS improvement. The main targets are reducing the number of HOs that are initiated but not carried out to completion (HO failures), repeated back and forth HOs between two base stations (ping-pong) and calls being dropped.

The self-optimization of future radio access networks is one of the main topics in current research [1, 2]. Handover can be described by a very precise flow of events and some might argue that there is little if anything to be improved in it. In our targeted approach we are looking not at modifying this flow but rather at making the parameter settings that control it flexible and modifying them accordingly. The main challenges facing such an algorithm is finding the perfect balance between the control parameters of the HO process and ensure that the network is in a stable operating point for a long time.

The rest of the report is organized as follows. Firstly, the assessment and simulation metrics that have been used in the simulation is presented. The realistic simulation scenario simulated by a wireless network planning and optimization suite, Ranplan iBuildNet® [9] propagation simulator, is then described. The optimization algorithm that tunes the handover parameters is introduced. Finally simulation results and the conclusion and outlook on future work are given.

II. Metrics

The metrics that are used in the HO parameter optimisation algorithm are subdivided in system metrics, control parameters and assessment metrics. The reference signal received power (RSRP) and signal-to-interference and noise ratio (SINR) are system metrics. They are used to select the connected femtocell and possible handover candidates. The control parameters are tuned by the optimization algorithm to increase the handover performance of the network. The assessment metrics are used as measurements during the optimization process and as performance indicators for the optimization algorithm evaluation. The metrics are described in detail below.

A. System metrics

1) RSRP: The RSRP is calculated from the cell transmit power (P_c), the pathloss values from the users to the different cells (L_u) and additional shadow fading with a log-normal distribution and a standard deviation of 3 dB (L_f). The resulting RSRP values are calculated per cell c and user u by:

$$RSRP_{c,u} = P_c - L_u - L_f \tag{1}$$

2) SINR: The SINR values are calculated from the RSRP of the connected cell ($RSRP_{conn}$) and the RSRP values of the strongest interfering cells plus the thermal noise ($RSRP_{int,noise}$). The resulting SINR values are calculated by:

$$SINR_u = RSRP_{conn} - RSRP_{int,noise} \tag{2}$$

It is assumed that all cells transmit with 46 dBm over the complete simulation time (transmit power taken from [8]).

B. Control parameters

A handover is initiated if two conditions are fulfilled: the RSRP of a cell is greater than the RSRP of the connected cell plus the hysteresis value and this condition holds at least for the time specified in the time-to-trigger parameter. The hysteresis and time-to-trigger will be tuned by optimization algorithm.

1) Hysteresis: In the simulations the valid hysteresis values vary between 0 and 10 dB with steps of 1 dB, resulting 11 valid hysteresis values.

2) Time-to-Trigger (TTT): The valid time-to-trigger values are specified by 3GPP (see [5] Section 6.3.5). The values are 0, 40, 64, 80, 100, 128, 160, 256, 320, 480, 512, 64, 1024, 1280, 2560, 5120 (ms). These 16 values are the only valid TTT values. Hence, there are 11×16 valid control parameter combinations from the 11 valid hysteresis values and 16 valid TTT values.

C. Handover performance indicators (HPIs)

1) Handover failure ratio: The handover failure ratio is the ratio of the number of failed handovers to the number of handover attempts (sum of the number of successful and the number of failed handovers).

2) Ping-Pong handover ratio: If a call is handed over to a new cell and is handed back to the source cell in less than the critical time (T_p), this handover is considered to be a ping-pong handover. In the other words, the occurrence of a ping-pong is determined by the time duration that a user stays connected to a cell directly after a handover, namely time-of- stay. The time-of-stay starts when the user sends a handover complete message to the cell, and ends when the user sends a handover complete message to another cell. If a user has a time-of-stay less than the threshold T_p, e.g. 1 s, and the new target cell is the same cell as the source cell when handing over to the current serving cell, then the handover that terminates this time-of-stay is considered an unnecessary handover, i.e. a ping-pong [10], [11].
The ping-pong handover ratio is the ratio of the number of ping-pong handovers to the total number of handovers (the number of ping-pong handovers, the number of handovers where no ping-pong occurs and the number of failed handovers).

3) Call dropping ratio: The call dropping ratio is the probability that an existing call is dropped before it was finished, e.g. during handover, if the user moves out of coverage. It is calculated as the ratio of the number of dropped calls to the number of calls that were accepted by the network.

III. Simulation scenario

For the handover simulations, an office park scenario, for joint outdoor and indoor coverage, is chosen. The scenario is simulated using a wireless network planning and optimization suite, Ranplan iBuildNet® [9]. The Pathloss data is provided by the simulator.
Fig. 1 shows the simulation layout. A macro cell covers outdoor area in an industrial park. It provides poor indoor coverage in Building B near macro RRU. Even worse indoor coverage in the distant building A is provided.
Femtocells are deployed for complementary coverage and higher capacity in the buildings A and B. For simplicity of simulations, one femtocell in each building in first floor is deployed, as shown in Fig. 2.
Fig. 3 depicts that signal level within the in-building area gets better benefit from Femtocell deployment.
To study mobility managements, it is assumed that users are moving around the buildings with femtocells at the speed of 5km/h on the trajectory path shown in Fig. 2. If the user arrives the border of simulation scenario, will bounce back and move toward the opposite direction. Handover performance for this scenario is investigated. And handover failure ratio, handover ping-ping ratio, and call dropping ratio are given in next section.

IV. Handover process

The handover process can typically be divided into four phases: measurement, processing, preparation, and execution. Handover measurements and processing are performed by the UE. Handover measurements are usually based on downlink reference signal received power (RSRP) estimations, while processing takes place to filter out the effects of fading and estimation imperfections in handover measurements. After processing, if according to the filtered measurements a certain handover event entry condition is met, the UE alerts the serving cell and feeds back handover measurements through a measurement report. Then, the preparation phase starts, in which the serving cell initiates the handover process, and prepares the handover execution together with the target cell. Finally, in the execution phase, the serving and target cells perform necessary network procedures with the assistance of the UE to transfer its connection from the former to the latter.

The UE performs handover measurements and processing in Layer 1 (physical) and Layer 3 (network), as shown in Fig. 4 [12]. For handover measurements, the UE generally takes RSRP estimations over the cells included in its neighboring cell list. In order to remove the effects of fading from RSRP estimations, the UE obtains each RSRP sample as the linear average over the power contributions of all resource elements that carry reference symbols within one subframe (i.e. 1 ms) and the considered measurement bandwidth (e.g. six resource blocks), and thereafter further averaging over several RSRP samples. This linear averaging is performed in Layer 1, and is known as L1 filtering. For a typical setup (Fig. 4 (a)), in order to obtain an

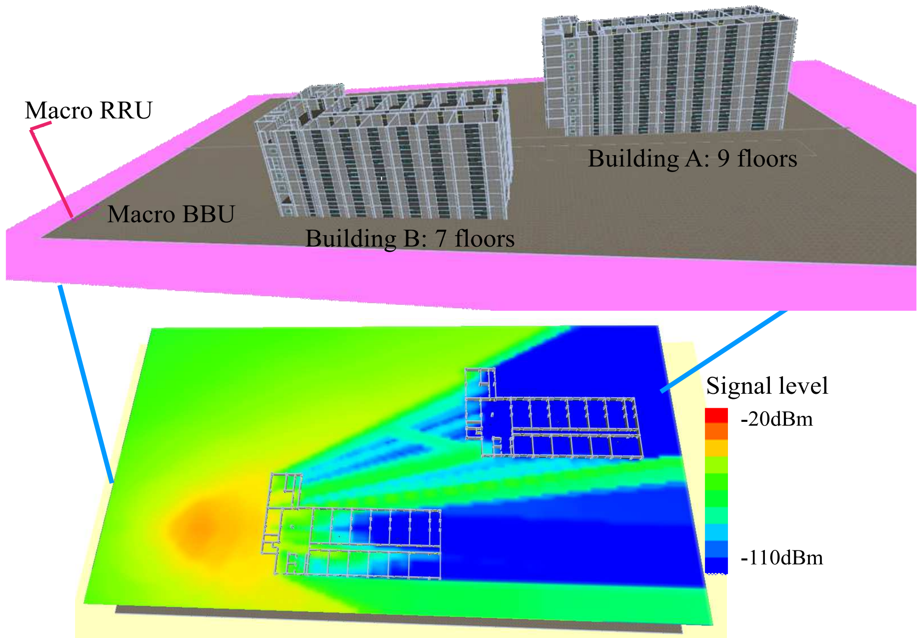

Figure 1: A macro cell covers outdoor area in an industrial park.

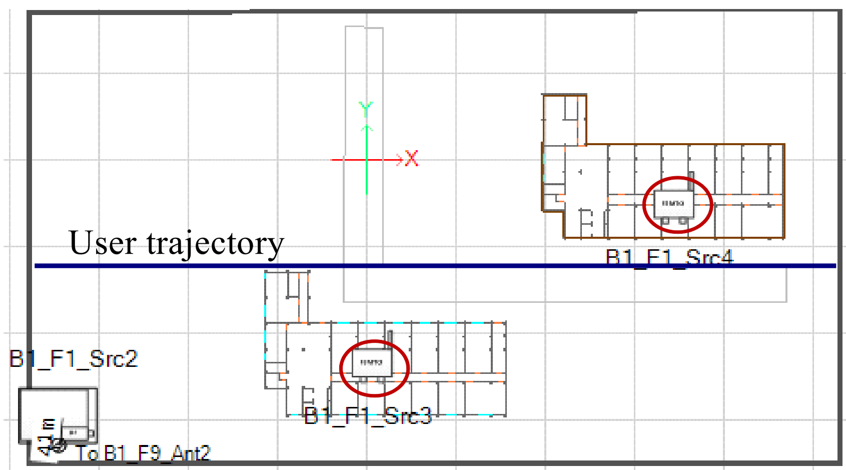

Figure 2: Femtocell deployment inside building A and B shown in Fig. 1. Users walk around the buildings at the speed of 5km/h on the trajectory path shown with solid line.

L1 filtered handover measurement, downlink RSRP samples may be taken every 40 ms, and then averaged over five successive RSRP samples.

The L1 filtered handover measurements are updated every handover measurement period (e.g. 200 ms) at the UE, and averaged through a first-order infinite impulse response (IIR) filter, as defined in Fig. 4 (a) [12], to further mitigate the effects of fading and estimation imperfections. This moving averaging is performed in Layer 3, and is known as L3 filtering. Since successive log-normal shadowing samples are spatially correlated, the L3 filtering period is preferred to be adaptive to the degree of shadowing correlation in the received signal. For high-mobility UEs, log-normal shadowing samples are not highly correlated, and thus it would be better to have a shorter L3 filtering period than that for low mobility UEs. A typical L3 filtering period is 200 ms.

A handover is then triggered if the L3 filtered handover measurement meets a handover event entry condition. There are

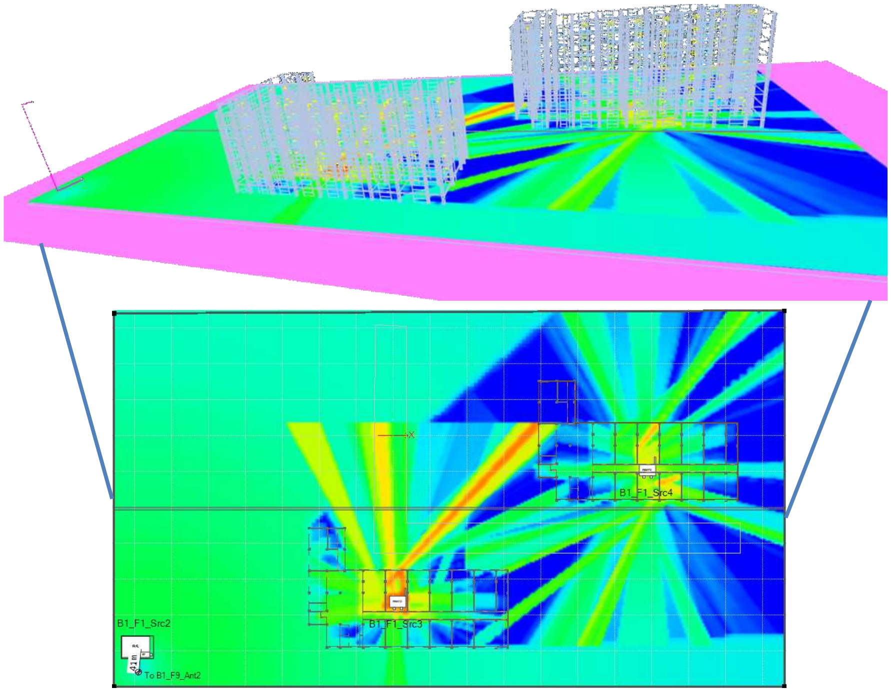

Figure 3: Femtocells signal coverage.

eight types of handover event entry conditions (see [13], Section 5.5.4).

Once the event A3 (Neighbor becomes offset better than server.) condition is met, i.e. the L3 filtered RSRP of the target cell is larger than that of the serving cell plus a hysteresis margin (also referred to as event A3 offset), the UE starts the TTT timer (Fig. 4 (b)). Only if the event A3 condition is satisfied throughout the TTT, the UE alerts the serving cell and feeds back this event A3 condition through a measurement report, thus initiating the handover preparation process. Small values of TTT may lead to too early handovers, increasing ping-pongs, while large values of TTT may result in too late handovers, increasing handover failures. Therefore, the optimization of the TTT according to the UE velocity carries capital importance in mobility management, as it will be shown later.

Once the TTT successfully expires, as shown in Fig. 4 (b), the handover preparation phase starts. The source cell issues a handover request message to the target cell, which carries out admission control procedures according to the quality of service requirement of the UE. After admission, the target cell prepares the handover process, and sends a handover request acknowledge to the source cell. When the handover request acknowledge is received at the source cell, data forwarding from the source cell to the target cell starts, and the source cell sends a handover command (within a RRC message) to the UE.

Finally, in the handover execution phase, the UE synchronizes with the target cell and accesses it [14]. The UE sends a handover complete message to the target cell when the handover procedure is finished. The target cell, which can then start transmitting data to the UE, sends a path switch message to inform the network that the UE has changed its serving cell. Thereafter, the network sends a UE update request message to the serving gateway, which switches the downlink data path from the source cell to the target cell. The network also sends end marker packets through the old path to the source cell, asking it to release any resources previously allocated to this UE.

A UE is considered to be out of synchronization when its wideband SINR (also referred to as channel quality indicator (CQI)) falls to Q_{out} (in dB), and to be back in synchronization when it reaches Q_{in} (in dB). For tracking radio link failure (RLF) [8], a UE u uses two moving average windows, which have depths of 200 ms and 100 ms to compute its CQI values $Q_{out,u}$ and $Q_{in,u}$, respectively. Both windows are updated once per frame, i.e. once every 10 ms. When $Q_{out,u}$ is lower than the threshold Q_{out}, a synchronization problem occurs, and the T310 timer (usually of 1 s duration) is triggered as shown in Fig. 4 (b). The T310 timer is stopped once $Q_{in,u}$ is larger than the threshold Q_{in}, and the UE is considered back in synchronization. However, if the T310 timer runs until it expires, the UE is considered out of synchronization, and an RLF is declared [15]. Accordingly, a handover failure happens if one of the following three conditions is met [15]:

- RLF happens during the time between satisfying the event A3 condition and receiving a handover command (Fig. 4 (b)).
- T310 timer is triggered and still running when a handover command is sent.

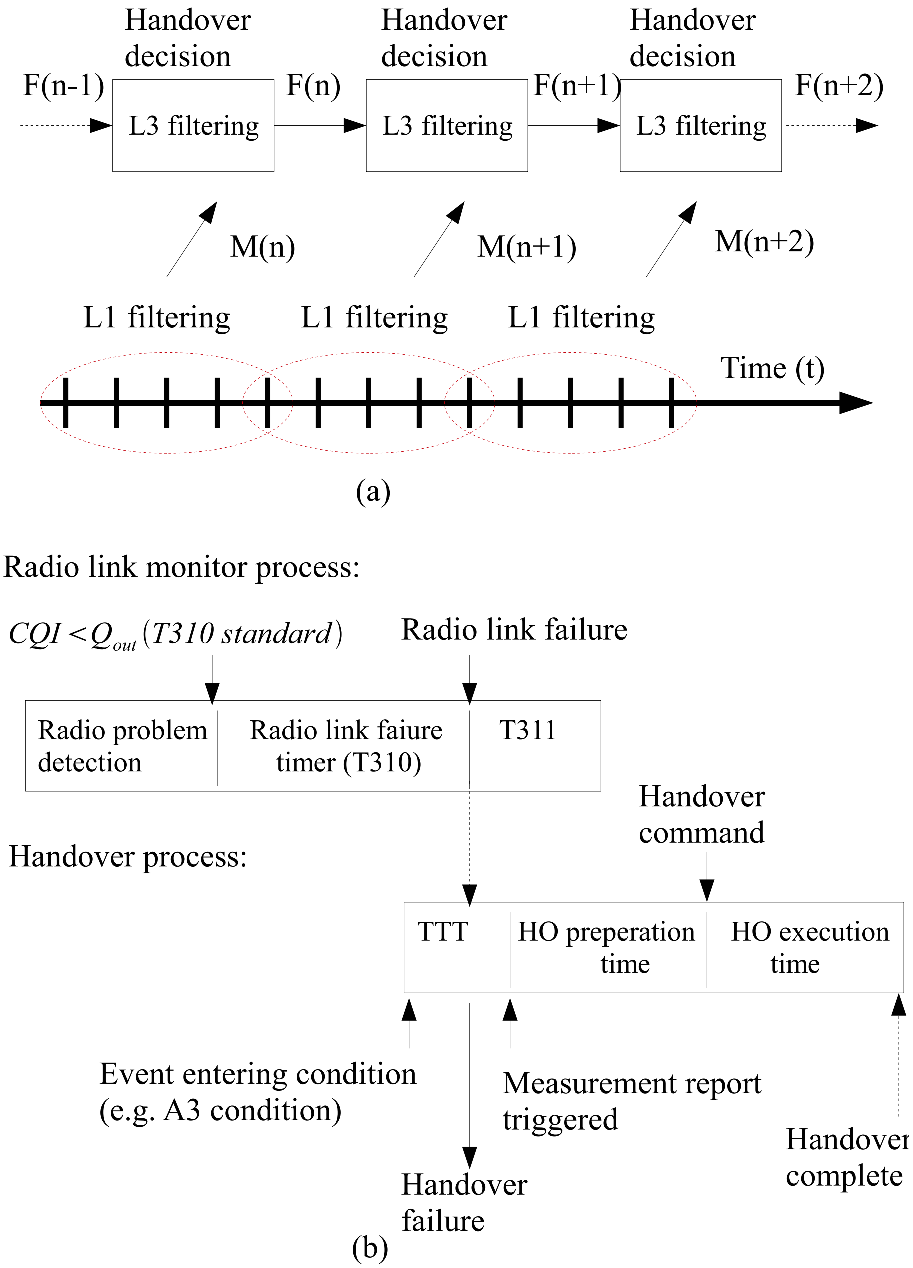

Figure 4: L1 and L3 filtering procedures, radio link monitor process, and handover process.

- The UE wideband SINR $Q_{out,u}$ is lower than Q_{out} when a handover complete message is sent.

Note that if condition 2 or 3 occurs (which are not shown in Fig. 4 (b) for brevity), a packet data control channel (PDCCH) failure is declared. The occurrence of a ping-pong is determined by the time duration that a UE stays connected to a cell directly after a handover, namely time-of- stay. The time-of-stay starts when the UE sends a handover complete message to the cell, and ends when the UE sends a handover complete message to another cell. If a UE has a time-of-stay less than the threshold T_p, e.g. 1 s, and the new target cell is the same cell as the source cell when handing over to the current serving cell, then the handover that terminates this time-of-stay is considered an unnecessary handover, i.e. a ping-pong [10].

System simulation assumption and mobility specific simulation parameters are given in Table I and II. Layer 1 filtering and layer 3 filtering parameters are taken from [11].

Table I: Simulation Assumptions: System

Items	Description
Simulation time	128s
Femto cell placement	At fixed location
Cell loading	70 %
Time-To-Trigger (ms)	0, 40, 64, 80, 100, 128, 160, 256,320, 480, 512, 64, 1024, 1280, 2560, 5120
a3-offset (dB)	0 to 10 dB with step of 1 dB
T Measurement Period, Intra, L1 filtering	200ms
Layer3 Filter Parameter K	4
Handover preparation (decision) delay	50ms
Handover execution time	40ms
T310	1000ms
Qout	-8dB
Qin	-6dB

Table II: Simulation parameters: Mobility specific

Items	Macro cell	Femto cell
ISD	500m	
Distance dependent path loss	iBuildNet RRPS propagation Modeling	iBuildNet RRPS propagation Modeling
Number of sites/sectors	1	2
BS Antenna gain including Cable loss	15dB	5dB
MS Antenna gain	0 dBi	0 dBi
Shadowing standard deviation	8 dB	10 dB
Correlation distance of Shadowing	25 m	25 m
Shadow correlation	0.5 between cells	0.5 between cells
Antenna pattern	The same 3D pattern as is specified in TR 36.814, Table A.2.1.1-2 [8].	Omni, as is specified in TR 36.814, Table A.2.1.1.2-3 [8].
Carrier Frequency/Bandwidth	2.6Ghz/ 10Mhz	2.6Ghz/ 10Mhz
BS Total TX power	46 dBm	20dBm
Penetration Loss	20dB	20dB
Antenna configuration	1× 1	1×1
UE speeds	5km/h	
UE noise figure	7dB	
RSRP measurement bandwidth	100 resource blocks	
Minimum distance	The same requirements as specified in TR 36.814 [8].	

V. System performance of the non-optimized network

In the performance studies, the system performance of the non-optimized network for different handover parameter settings are examined. This study gives an insight in the effects of handover parameter changes on the system performance.
The system performance studies are carried out for all handover operating points (a combination of a certain hysteresis and time-to-trigger value) that are defined in Section II-B. The system simulations are carried out for 128s simulation time for every handover operating point.
The simulation results for the handover performance indicator handover failures is shown in Fig. 5. High handover failure ratio for small and big handover margin and time-to-trigger are achieved. 2dB-8dB handover margin can reduce the handover failure. 40ms-320ms time-to-trigger is proper time for handover.
Fig. 6 shows handover ping-pong ratio. Small time-to-trigger and margin may lead to too early handovers, increasing the ping-ping, especially in the HetNet scenario.
Fig. 7 shows call dropping ratio. Large values of time-to-trigger and handover margins may results in too late handovers, increasing call dropping.

In order to evaluate the overall system performance, the simulation results for handover performance indicators (HPI), which are handover failure (HOF), ping-pong handovers (HPP) and call dropping ratio (DC), can be combined into one figure. Thus, the following weighting function has been defined to examine the cooperation of the handover performance (HP) indicators:

$$HP = \omega_1 HOF + \omega_2 HPP + \omega_3 DC \tag{3}$$

As an example weights can be chosen to be $[\omega_1 = 1, \omega_2 = 0.5, \omega_3 = 2]$.
The different weights can be introduced to allow for operator policy inputs to the handover performance evaluation. Different

operators define different sets of indicators. One operator claim could be to avoid call drops by any cost. Another operator could accept a low call dropping ratio if the signalling overhead is largely reduced.
Note that in simulations the handover operating points have been changed in all cells at the same time.
The HPI values are normalized on the maximum value over all operating points before they are combined by the weighting function.
Our targeted optimization algorithm aims at finding the optimal handover operating points for every individual cell.
Fig. 7 shows handover performance ratio. Handover performance based on the weighting function between handover failure ratio, handover ping-pong ratio, and call dropping ratio can evaluate the effect each other. 2dB margin and 100ms time-to-trigger is the best control parameter for current HetNet scenario.

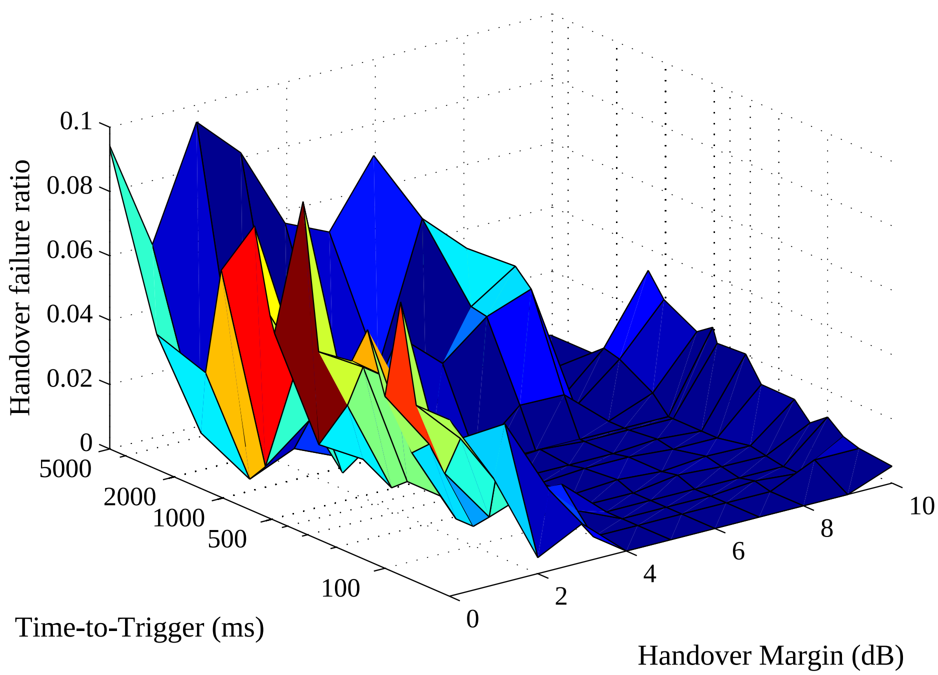

Figure 5: Handover failure ratio in the operating points.

VI. Handover optimization algorithm

The optimization algorithm that is explained in this section aims at finding the optimal handover operating points for every individual cell. The handover operating points are changed based on the current handover performance. The self organizing network (SON) optimisation algorithm flowchart is given in Fig. 9.

In order to adapt to the optimal possible handover performance, handover performance target thresholds for all handover performance indicators, i.e. the handover failure ratio, the ping-pong handover ratio and the call dropping ratio are set. The target thresholds are decreased by 33 % in this study if the HPIs stay below the target thresholds for a certain amount of time, called the good performance time. Good and bad performance time, can be set to 30 and 10 (s) respectively.
The initial handover performance target thresholds are influenced by an operator policy that defines the importance of the different HPIs. If the performance of HPI call dropping ratio and one or both of the other HPIs is above the HPI target threshold, the handover performance target thresholds are increased by 33 % again. The reason behind this is that the optimization criteria for these HPIs are contradictory in these cases. If the simulation parameter bad performance time exceeds a given threshold, i.e. the performance of one HPI overshoots the handover performance target for a certain amount of time, the handover operating point of the cell is changed according to the criteria given in Table III. The optimization criteria are derived from system simulations for all valid operating points.
The optimization direction, i.e. change of hysteresis and time-to-trigger, is based on the system performance of neighboring handover operating points. The system performance is calculated for every HPI individually. Hence the optimization direction can be lead off from these system simulations. The hysteresis value as well as the time-to-trigger values are changed by one step per handover parameter optimization only. Imagine the handover failure ratio and ping-pong handover ratio exceeded the

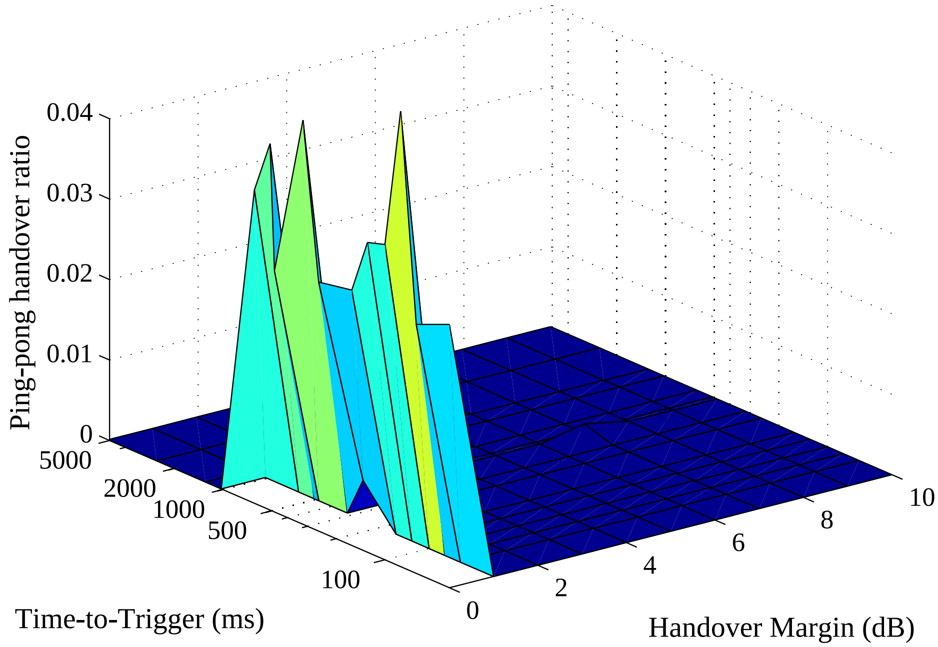

Figure 6: Handover ping-pong ratio.

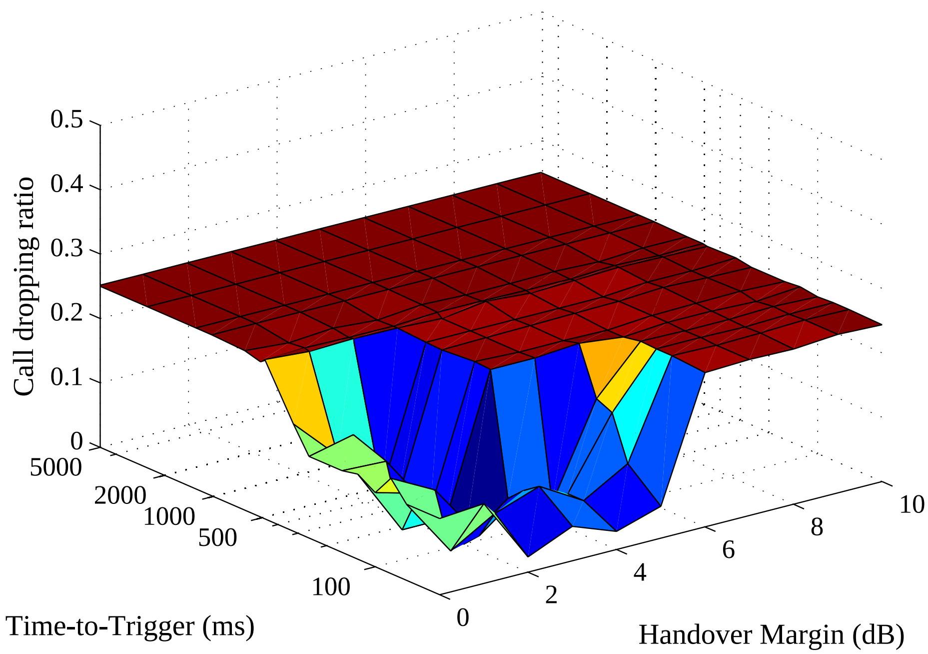

Figure 7: Call dropping ratio.

target threshold and the optimization criteria recommend to increase the hysteresis value. The hysteresis value is only changed by one step in this case.

VII. Concluding remarks

Mobility management faces technical challenges in HetNet scenario. In this work, handover control parameters individually are simulated for evaluation. The optimization algorithm is introduced which changes the values of the hysteresis and time-

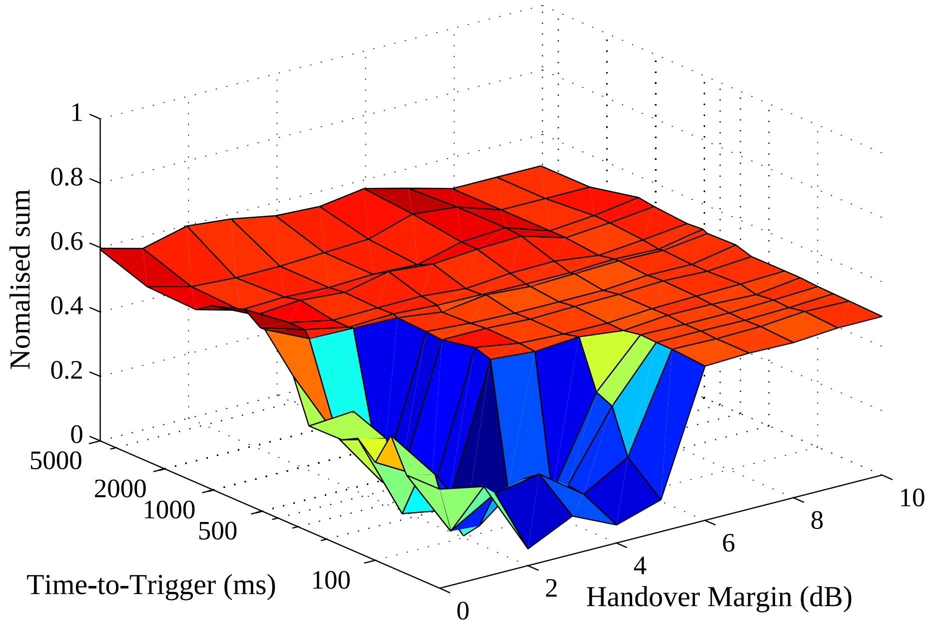

Figure 8: Handover performance (weights=[1 0.5 2]).

Table III: Optimisation criteria for handover performance indicators

HPI	Hystersis	TTT	Optimisation
HF ratio	<5dB		↑ TTT
	5dB-7dB		↑ TTT & ↑ HYS
	>7dB		↑ HYS
HPP ratio	<2.5dB		↑ TTT
	2.5dB-5.5dB		↑ TTT & ↑ HYS
	>5.5dB		↑ HYS
DC ratio	<6dB	>0.6s	↓ TTT & ↓ HYS
	$\leq$ 6dB	>0.6s	↓ TTT
	>7.5dB	$\leq$ 0.6s	↓ TTT & ↓ HYS
	3.5dB-6.5dB	$\leq$ 0.6s	↑ HYS
	<3.5dB	$\leq$ 0.6s	↑ TTT & ↑ HYS

to-trigger parameters in an automated manner in response to changes in the network performance. This algorithm takes into account the weighting factor given by the operator policy to different performance metrics (handover failure ratio, call dropping ratio and pingpong handover ratio). This feature makes the algorithm flexible and very appealing to operators. The simulation results show that the optimization algorithm increases the system performance. However the current results are limited to the used, realistic, simulation scenario. It has to be proved that the optimization algorithm works for other simulation scenarios as well.

VIII. Publications and software results

- New features are added to Ranplan iBuildNet® [9] current product to support the hanover simulation of this work.
- The results of this work will be submitted to the IEEE International Conference on Computer Communications (IEEE INFOCOM 2014), due on July 2014.

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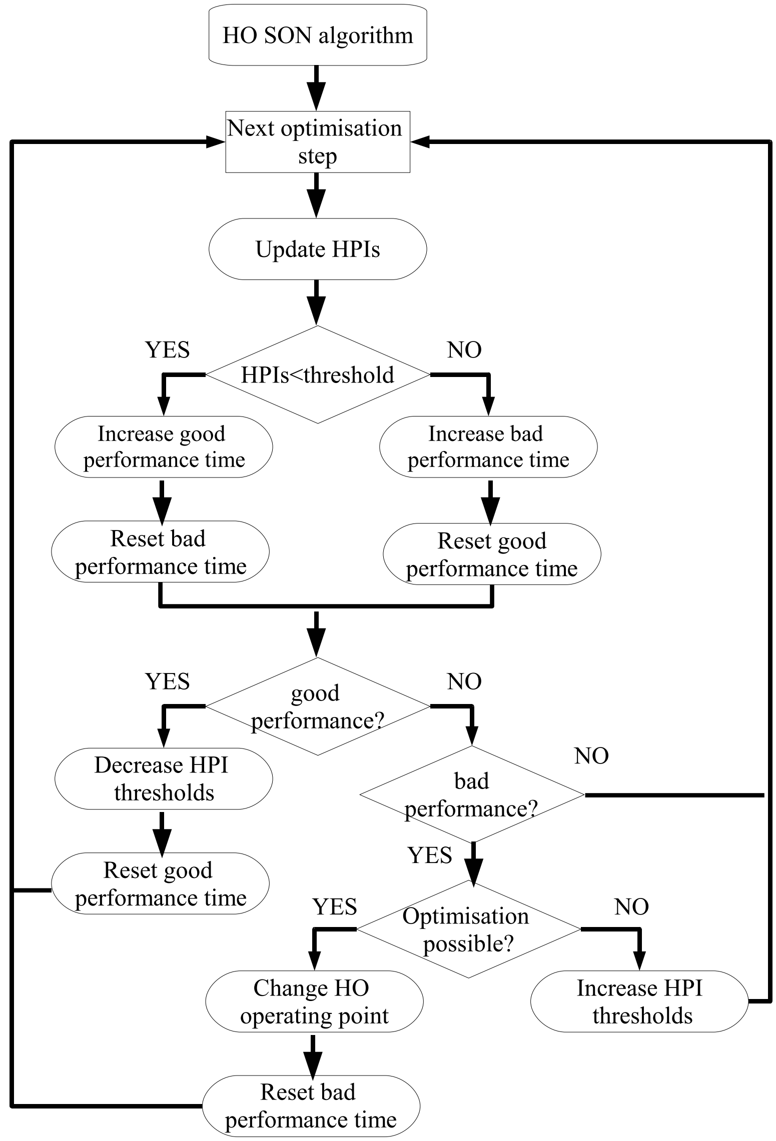

Figure 9: The handover optimisation algorithm.

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