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Controllability for Self-Optimisation of Home eNodeBs

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Controllability for Self-Optimisation of Home eNodeBs

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I. INTRODUCTION

In LTE, so called home base stations, home eNodeBs (HeNBs), are expected to be used widely. HeNBs will create or extend coverage and/or capacity in the area where it is installed. The HeNBs will differ from macro eNBs in several aspects. For example, potentially there will be a large number of HeNBs. Further, a HeNB may have closed access, meaning that only User Equipments (UEs) belonging to the Closed Subscriber Group (CSG) of the HeNB can connect to it. The home eNBs will also use a lower maximum transmit power than macro eNBs, as they are meant to cover smaller areas than the macro eNBs, Due to the small coverage areas, different handover settings compared to what is used in the macro network, may be needed. This is because fast moving UEs may leave the HeNB coverage area quickly and it is therefore not always beneficial to hand over to the HeNB. Closed access will also lead to interference from the HeNB to the macro network, and vice versa, both in uplink and downlink. As the HeNBs are installed by the customer, the deployment cannot be planned, and parameter settings cannot be optimised, by the operators. HeNB self-optimisation functionality will therefore be crucial. Such functionality would aim at maximising the gain of the HeNBs, in terms of increased capacity, coverage and quality in the area where they are deployed, while limiting the negative influence on the macro network.

In the literature, the impact and feasibility of 3G home base stations, HNBs, and to some extent also LTE HeNBs have been examined. Feasibility and interference for HNBs, is investigated in [1][2]. Further, the importance of self-organisation in the area is pointed out in [3][4]. Self-optimisation of HNBs is discussed in [5][6][7], focusing on open access HNB power settings to optimise coverage in order to minimise the increase in core network mobility signalling.

In the SOCRATES project (Self-Optimisation and self-ConfiguRATion in wirelEss networkS) [8], self-organisation methods are developed to enhance the operations of 3GPP LTE radio networks. For HeNBs, self-optimisation of HeNB interference and coverage, and self-optimisation of HeNB handover have been studied [9]. This paper presents results from the controllability analysis for these two HeNB use cases, i.e. investigating how and to which extent different settings for the relevant control parameters affects the performance of the combined macro cell and HeNB deployment. The analysis has been done by simulations of an LTE network with deployed HeNBs. The interference and coverage controllability study results are discussed in Section II, while the results for handover are discussed in Section III. Finally, conclusions and recommendations for further work are given in Section IV.

II. INTERFERENCE AND COVERAGE

The aim of the HeNB interference and coverage self-optimisation is to provide HeNB coverage while minimising the interference on the macro network. In the following, co-frequency, closed access HeNBs are considered, i.e. HeNBs operating on the same frequency as macro eNBs, but only allowing certain UEs to connect to it. This deployment set-up is selected because such HeNBs are foreseen to give the most challenging interference situation.

One major issue when deploying co-channel closed access HeNBs is so called 'dead-zones', i.e. zones where UEs not part of the CSG of a HeNB (non-CSG UEs), cannot access the macro network due to interference caused by the HeNBs. The HeNB maximum transmit power, including the reference signal power, and the HeNB connected UE power have been identified as possible parameters to control the trade-off between HeNB coverage and the size of such dead-zones. In order to investigate how and to what extent different settings on these parameters affect the performance and the coverage - dead-zone trade-off, simulations have been run, varying these parameters.

The simulations were run in a static, Monte-Carlo simulator with hexagonal scenarios. In one of the cells, a grid of 10x10 houses was added, and HeNBs were placed in 10% of the houses. Non-CSG UEs were spread uniformly in the macro cells with no HeNBs. In the HeNB area, on average one CSG UE and one non-CSG UE was placed in each HeNB house in order to capture interference between macro and HeNBs and their connected UEs. Additional non-CSG users were spread out uniformly in the cell(s) containing the HeNBs, with a density resulting in, on average, the same amount of non-CSG UEs in all the macro cells. A CSG UE accessed the HeNB only when the HeNB Reference Signal Received Power (RSRP) was higher than the macro RSRP. Three different scenarios were considered. Two scenarios had a coverage driven deployment, both with a site-to-site distance of 1732 meters, while one had the HeNBs placed close to the closest macro eNB (A), the other had the HeNBs placed far away from the closest macro eNB (B), see Table 1. The third scenario was capacity driven with the HeNBs close to the closest macro eNB, see Table 1. For the different scenarios, power settings were varied from a minimum setting up to a maximum setting in steps of one dB, according to Table 2. When varying one of the parameters, the other was set to the maximum value as default.

Interference and Coverage Simulation Scenarios			
	Coverage Driven Scenario A	**Coverage Driven Scenario B**	**Capacity Driven Scenario A**
Site-to-site distance (m)	1732	1732	500
Macro-to-HeNB distance (m)	285	705	64

Table 1 – Scenarios used in the interference and coverage controllability study

Interference and Coverage Control Parameter settings		
	Start value	**End (default) value**
HeNB maximum transmit power	3 dBm	13 dBm
Maximum HeNB connected UE power	13 dBm	25 dBm

Table 2 – Control parameter settings for the interference and coverage controllability study

Figure 1, shows the results for varying the HeNB power for the Capacity Driven Scenario A. The top plot shows the ratio of CSG UEs within HeNB houses that can connect, i.e. detect the reference signal and get non-zero throughput in uplink and downlink, to HeNBs. It should be noted that CSG UEs that cannot connect to the HeNB may still be able to connect to the macro network. The bottom plot shows the ratio of non-CSG UEs within the HeNB houses that can connect to the macro eNB. The HeNB maximum transmit power given on the x axis is expressed in dB, as the difference from the maximum power setting. It can be seen that the number of CSG UEs that can connect to the HeNB increases and the number of non-CSG UEs that can connect to the macro network decreases with an increased HeNB power. The same trend is seen for all the scenarios.

For the studied scenarios, with a medium non-CSG user density and only one CSG user per HeNB house, it can be seen that the maximum uplink power for HeNB connected UEs has a small impact on the number of non-CSG UEs that can connect to the macro network, but a large impact on the number of CSG UEs that can connect to the HeNB. The results for the Capacity Driven Scenario A are shown in Figure 2, where the top plot shows the ratio of CSG UEs within HeNB houses that can connect to HeNBs and the bottom plot shows the ratio of non-CSG UEs within the HeNB houses that can connect to the macro eNB. The HeNB connected UE maximum power given on the x axis is expressed in dB, as the difference from the maximum power setting.

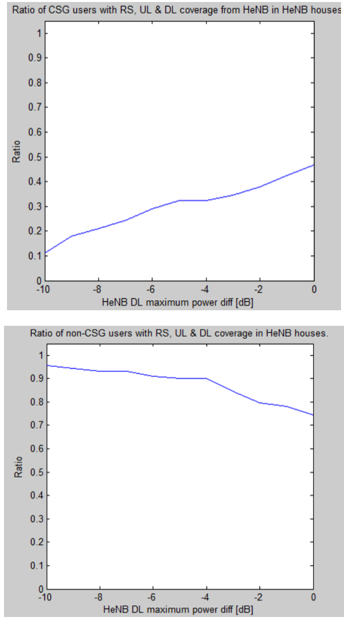

Figure 1 – Ratio of UEs in the HeNB houses with RS and UL and DL throughput versus HeNB maximum power for Capacity Driven Scenario A.

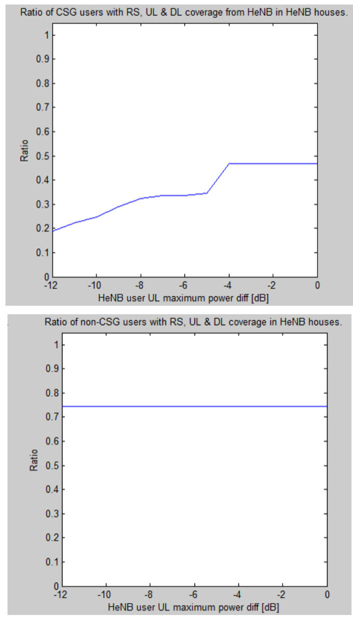

Figure 2 - Ratio of UEs in the HeNB houses with RS and UL and DL throughput versus HeNB connected UE maximum power for Capacity Driven Scenario A.

The impact on achievable throughput for HeNB connected and macro connected UEs respectively was found to be rather small for both changes in downlink and uplink power. It could also be seen that the throughput was close to, or equal to, the requested throughput for all connected UEs.

Based on the results of the controllability study, it can be concluded that the HeNB power is a suitable parameter for controlling the trade-off between HeNB coverage and the size of the created dead-zones, since it has an effect on both the ratio of HeNB connected CSG UEs and on the ratio of connected non-CSG UEs. The HeNB connected UE maximum power only affects the ratio of HeNB connected UEs and is therefore not a very effective control parameter, but should rather be set to its maximum value.

III. HANDOVER

The aim of the HeNB handover self-optimisation is to provide seamless handover between HeNBs and from a HeNB to a macro eNB and vice versa. As HeNBs have small coverage areas, handover should preferably be performed only if the UE is expected to stay in the coverage area and the HeNB can provide better throughput than the macro eNB. The handover optimisation study performed within SOCRATES focuses on open access HeNBs. This was selected because an open access HeNB allows all UEs within the coverage area to connect to it. Hence, also UEs passing through the small coverage area of the HeNB, could connect to it, but this may not always be beneficial.

To assess how handover parameters affect the HeNB handover performance, simulations were run in a dynamic simulator, varying hysteresis and time-to-trigger (TTT), according to the values given in Table 3. A hexagonal scenario, with a site-to-site distance of 500 m and a row of houses containing HeNBs in one of the cells, was used. In the cells, UEs moved with a random start location and direction. One UE moved along the row of HeNBs and results were collected for this UE.

Handover Control Parameter settings					
Hysteresis (dB)	0	3	6	9	12
TTT (ms)	0	100	320	640	1280

Table 3 – Control parameter settings for the interference and coverage controllability study

Figure 3 shows the SINR and the serving cell for the considered UE when moving at a speed of 30 km/h. In the plots, each blue dot corresponds to a measured SINR value, while the red line shows the serving cell. Note that the same y axis is used for two completely different values, i.e. the SINR and the serving cell number. Cells number 3 to 12 are the ten HeNBs and cell 0, 1 and 2 are macro cell sectors, each carrying a load of 5 UEs per sector. Cell 1 is the sector in which the additional, deterministic UE is located. While the upper plot illustrates the situation when using the minimum settings on hysteresis and TTI, i.e. 0 dB and 0 ms, respectively, the lower plot illustrates the situation using a hysteresis of 12 dB and a TTT of 640 ms.

It can be seen that for low handover parameter values, the UE is connected to a HeNB most of the time and handover is often performed. For high handover settings, it occurs that UEs do not handover at all to a particular HeNB, even when moving through its coverage area.

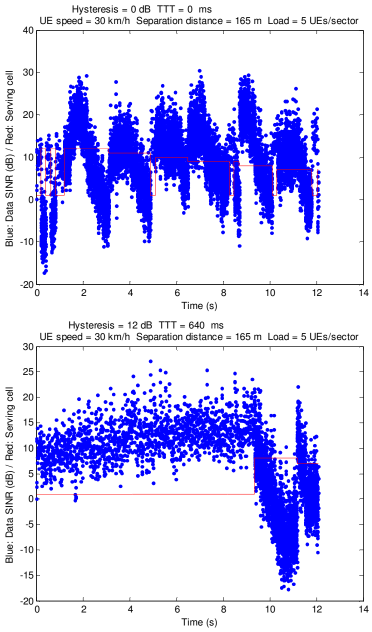

Figure 3 – SINR and serving cell for a UE moving along the row of HeNBs at a speed of 30 km/h

Changing the handover parameters also has an impact on SINR, and subsequently there will also be an impact on the throughput that UEs experience. In the following, different combinations of TTT and hysteresis settings and their impact on the UE throughput are evaluated for varying UE speed, distance from the macro eNodeB and macro network load.

Simulation results show that the impact of the handover parameters depends on UE speed as well as the distance from the macro eNB and the macro eNB load. Figure 4 shows the throughput for the considered UE, using different TTT and hysteresis settings for the same simulation snapshot. It can be seen that a low TTT and a small hysteresis gives higher throughput. The trends are more pronounced with higher UE speed. The same holds for a larger distance from the macro eNB, up until the point where the UE is so far away from the macro so that it is connected to HeNBs during most of the simulated time. At a speed of 30 km/h, varying the macro load considering 0, 1 and 5 UEs per sector respectively, no major difference in the trends could be seen. At a UE speed of 100 km/h, however, the impact of the macro load is more pronounced. At a macro load of 0 UEs per sector, throughput increases when the TTT is increased from 320 to 640 ms. This is due to the UE connecting to a macro cell with no load and with better SINR conditions. The same increase could not be seen at a higher macro load.

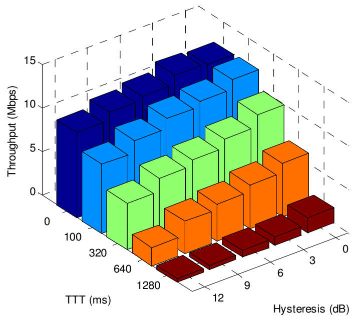

Figure 4 – Achieved throughput for a UE moving at 30 km/h, 165 m from the macro eNodeB with a macro load of 5 UEs/sector

Considering the results shown for UE throughput, both the TTT and the hysteresis should be set to their minimum values. However, also other aspects should be considered. Simulations have shown that the ratio of ping pong handovers is high for the lowest hysteresis and TTT settings. Considering both throughput and ping pong, it is found that the parameters should be set high enough to avoid ping pong, but apart from that as low as possible. If other aspects are also considered, such as call drops due to handover signalling failure in bad SINR conditions, it may be found that there are scenarios where it is best to use high handover parameter values, to completely avoid handing over to HeNBs.

IV. Conclusions and Further Work

The trade-off between the HeNB coverage and performance and the interference caused in the macro network is an important issue to tackle in order for closed access HeNBs to be feasible. In particular, the HeNB coverage and the size of so-called dead-zones need to be attended to. A suitable parameter to control this trade-off is the HeNB maximum transmit power. The second control parameter evaluated, the HeNB connected UE maximum transmit power, was found not to be suitable for controlling the size of the dead-zone.

In a further study, additional control parameters could be evaluated, such as the CSG UE connection margin, i.e. the difference in RSRP accepted by the UE in order to connect to the HeNB rather than a stronger macro eNB, HeNB frequency usage, and power settings on different frequency bands. Further work also includes the development of self-organising functionality controlling the HeNB interference and coverage. This work has to some extent already been performed within SOCRATES, but is not described in this paper.

An area with high density of open access HeNBs is challenging for handovers, especially in case of high speed UEs. The handover parameter settings have a large impact of the number of handovers performed when moving through an area with high HeNB density. Further, the SINR achieved, and hence also the throughput is highly dependent on the handover parameters. The impact of the settings varies significantly with the distance from the macro eNB, the UE speed, and the macro eNB load. When optimising the HeNB handover for rapidly moving UEs, two approaches are possible. Either the handover parameters could be set as low as possible in order to minimise the time that the UE is connected to the wrong cell, or they could be increased in order to avoid that the UE hands over to the HeNB at all. When setting the handover parameters low, it is important to still keep them above a level where a lot of ping pong handovers occur.

The study performed on the HO optimisation controllability considers high HeNB density and moving UEs. In further studies, it would also be of interest to consider static UEs, in particular effects on the number of ping pong handovers, and lower HeNB density, where subsequent handovers between macro eNB and HeNBs may occur. Also, as call drops are likely to occur due to failure of handover signalling at low SINR, this would be an interesting metric to consider together with the achievable throughput. Based on the results from the controllability studies, self-organising functionality controlling HeNB handover could be developed.

V. References

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