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Towards Self-Organizing Mobility Robustness Optimization in Inter-RAT Scenario

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***Abstract*—The deployment of Long Term Evolution (LTE) system will be at first concentrated on areas with high user traffic overlaying with legacy second (2G) or third generation (3G) mobile system. Consequently, the limited LTE coverage will result in many inter-radio access technology (RAT) handovers from LTE to 2G/3G and vice versa. Trouble-free operation of inter-RAT handovers is very important for mobile operators. However, the joint parameter optimization of different RATs is complex and difficult with traditional optimization means. Thus, an autonomous inter-RAT mobility robustness optimization (MRO) is required. In this work, inter-RAT mobility problems and related inter-RAT key performance indicators (KPIs) are identified. Based on simulative investigations, the impact of the mobility parameters on KPIs is analyzed. Results show that the performance of the network highly depends on the configuration of the mobility parameters and there is a potential for developing a self-organizing inter-RAT MRO algorithm.**

***Index Terms*—Mobility robustness optimization, inter-radio access technology, self-optimizing network.**

I. Introduction

The 3rd generation partnership project (3GPP) has defined self-optimizing network (SON) mechanisms aiming at reducing operational expenditures (OPEX) and capital expenditures (CAPEX) [1]. SON mechanisms react dynamically to the variation in performance measures and reduce the effort and the human involvement in maintaining and optimizing the network. Among the SON use cases defined in [2], mobility robustness optimization (MRO) aims at adapting automatically the mobility related cell parameters based on evaluation of key performance indicators (KPIs). It dynamically optimizes the network performance in terms of mobility and provides improved end-user experience as well as increased network capacity.

The focus of this paper is the inter-radio access technology (RAT) mobility which refers to the (vertical) handover between Long Term Evolution (LTE) and other legacy technologies such as the second generation (2G) or third generation (3G) mobile system. At initial deployment, the coverage of LTE will be rather limited and concentrated on relevant traffic hotspot areas overlaying with legacy 2G/3G coverage. Outside these areas, no LTE connection can be provided. In order to provide service continuity with a quality of service (QoS) at least as good as that of existing 2G/3G networks, handover mechanisms from LTE to 2G/3G are necessary when a user equipment (UE) leaves the LTE coverage area while having an active connection. Vice versa, an LTE capable UE connected to 2G/3G network benefits from the better QoS if the handover towards LTE can be carried out. Therefore, inter-RAT mobility offers the mobile operators the promise of extracting more value from their variety of different RATs and provides them with a powerful means for matching network resources to application requirements. This high degree of flexibility is possible only if the inter-RAT mobility parameters are properly configured. However, finding the appropriate parameter settings is difficult, especially if performed manually. Therefore, an autonomous inter-RAT handover parameter optimization is required in the near future.

The main contribution of this paper is the study of the sensitivity and impact of the inter-RAT mobility parameters on the network performance based on simulative investigations. In turn, these simulation results allow a clear understanding on how to tackle the inter-RAT MRO from the SON perspective.

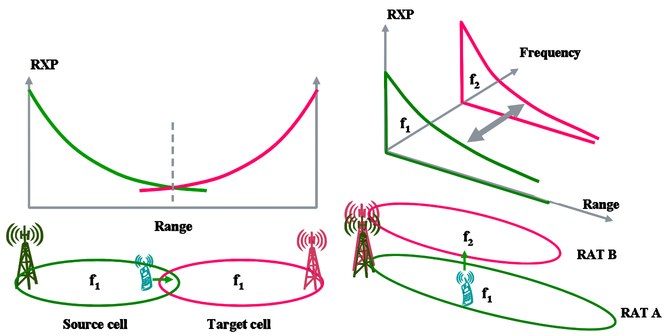
The paper is organized as follows. Section II provides an overview of inter-RAT mobility where we identify the main differences between intra-LTE and inter-RAT handovers and discuss specific inter-RAT mobility problems. In section III, the relevant cell-specific inter-RAT configuration parameters and KPIs are described. The SON capable inter-RAT system model is presented in section IV. The impact of each inter-RAT configuration parameter on the network performance is investigated in section V. The paper is then concluded in section VI.

II. Overview of Inter-RAT Mobility

In this section, the main differences between intra-LTE and inter-RAT handovers are highlighted and the inter-RAT mobility problems are discussed using two typical failure cases.

A. *Intra-LTE Versus Inter-RAT Handover*

Intra-LTE handover refers to the handover of a UE from an LTE source cell to another LTE target cell. As LTE adopts a frequency reuse factor of one, a handed over UE will suffer from the interference between source and target cells. This is schematically illustrated in Fig. 1(a) that shows the received signal powers (RXPs) of a UE from both source and target cells dependent on its distance from the base stations. If a UE



(a) Intra-LTE and intra-frequency: The target cell is an interferer.

(b) Inter-RAT and inter-frequency: No interference between different frequency bands.

Fig. 1. Impact of interference during the handover of a UE in intra- and inter-RAT scenarios.

is handed over to the target cell before it reaches the source cell border (dashed line), determined by the mobility handover parameter settings, the interference induced by the previously serving cell would be large, which in turn can cause a radio link failure (RLF). Thus, intra-LTE handover is sensitive to the handover execution time and may lead to an RLF due to a too early handover, i.e., handover executed before the UE reaches the cell border, or to an RLF due to a too late handover, i.e., handover executed after the UE has crossed the cell border.

In contrast to intra-LTE handover, a UE does not experience any interference from the source cell if handed over to a target cell of a different RAT. This is illustrated in Fig. 1(b) which shows a UE attempting to hand over from a source cell in RAT A to a target co-sited cell in RAT B. In inter-RAT handover, there is no so-called "cell edge problem" as source and target cells operate at different frequencies. Moreover, there is a large area where the UE can connect either to source or target cell with good signal quality.

In case of inter-RAT handover, RLF affected handover problems such as too late handover can be avoided by using a conservative handover parameter setting at the expense of coverage of one RAT and increasing the number of inter-RAT handovers. Moreover, the inter-RAT handover is quite often policy driven (traffic steering) and not dominantly caused by radio condition as in intra-LTE handover.

B. Inter-RAT Mobility Problems

In this section, we study two important inter-RAT mobility problems after introducing some general definitions.

1) General Definitions: A UE is handed over from LTE to another RAT, e.g., 3G, if its LTE measurement event B2 is triggered [3]. The entering condition of event B2 is fulfilled when the reference signal received power (RSRP) of the serving cell becomes worse than B2_1_thr threshold and the received signal code power (RSCP) of the inter-RAT neighboring cell is better than B2_2_thr threshold [3]. These are the entering condition thresholds of LTE measurement event B2. Vice versa, a UE is handed over from 3G to LTE if its measurement event 3A is triggered [4]. The entering

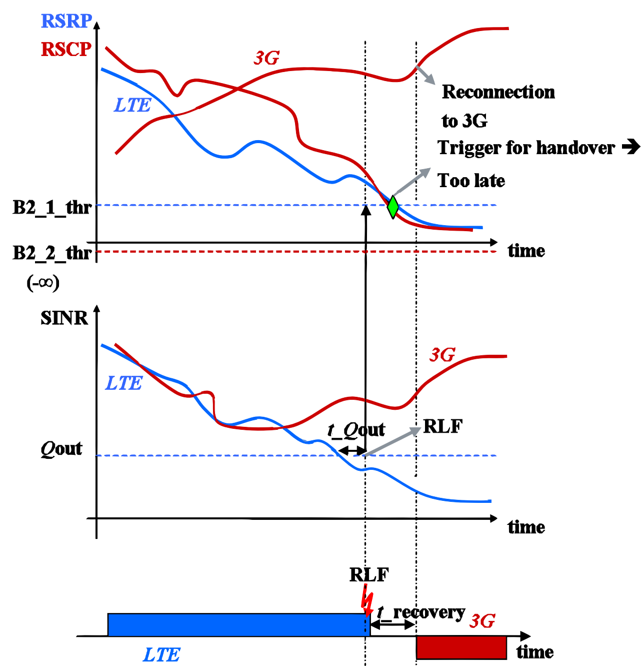


Fig. 2. Example of a too late handover from LTE to 3G.

condition of event 3A is fulfilled if the RSCP of the serving cell becomes worse than 3A_1_thr threshold and the RSRP of the inter-RAT neighboring cell is better than 3A_2_thr threshold. Moreover, for a UE in LTE, an RLF occurs when the signal-to-interference and noise ratio (SINR) is continuously below Qout threshold for a time interval of duration $t_Q$out. This is a simplified RLF detection compared to that specified in the 3GPP standard [5].

2) Example of a Too Late Handover: The handover of a UE is triggered based on the signal strength, i.e., RSRP and RSCP in case of LTE and UMTS respectively, whereas an RLF occurs when the SINR is below Qout for time interval of duration $t_Q$out. In Fig. 2, an example of a too late handover from LTE to 3G is shown. According to the chosen traffic steering policy, the second B2 threshold B2_2_thr is set to $-\infty$ and is always fulfilled. At first, the SINR of a UE connected to a cell in LTE falls below Qout for a time interval of duration $t_Q$out and an RLF occurs. Later, the RSRP of the UE falls below B2_1_thr which should trigger the B2 measurement report and in turn the inter-RAT handover. However, this handover cannot be executed as the UE has already lost its connection and reconnected to a cell of the overlaying 3G network after a certain time interval of duration t_recovery. The corresponding problem is identified as a so-called too late handover. If the B2_1_thr threshold had been set to a higher value, the handover would have been triggered before the RLF occurred.

3) Example of a Ping-Pong: A ping-pong refers to an event where a UE is immediately handed over to another cell after a successful inter-RAT handover. In Fig. 3, a ping-pong event is illustrated between cells of different RATs. Assume that the mobile operator has a traffic steering policy in 3G which

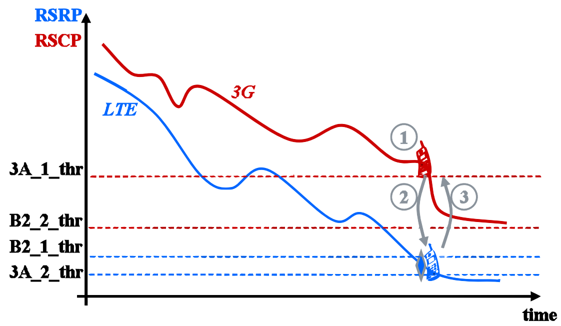


Fig. 3. Example of a ping-pong between cells of different RATs.

allows the handover of a UE to LTE whenever there is enough LTE coverage irrespective of the 3G signal quality, i.e., a handover occurs only if the RSRP of the neighboring inter-RAT cell is higher than 3A_2_thr. A UE being set up in 3G realizes that the measured LTE signal strength is higher than 3A_2_thr. The UE is then handed over to LTE where it turns out that the inter-RAT thresholds of event B2 are also fulfilled. As a result, the UE is handed over back to 3G resulting in a ping-pong. Typically, the reason is a mismatch of the mobility parameters of the two RATs.

III. Inter-RAT Mobility Parameters and KPIs

In this section, the inter-RAT mobility configuration parameters which should be automatically adjusted by an MRO SON algorithm are identified. In addition, the inter-RAT specific KPIs used for mobility performance evaluation are described.

A. Inter-RAT Mobility Configuration Parameters

The parameters having impact on handover are elements of measurement events and briefly discussed in the following.

1) B2_1_thr and 3A_2_thr Thresholds: The thresholds B2_1_thr and 3A_2_thr belong to inter-RAT measurement event B2 (LTE) and 3A (3G), respectively. According to the chosen traffic steering policy that a UE should be connected to LTE whenever LTE coverage has been detected, one of the thresholds in each measurement event can be neglected, namely B2_2_thr from event B2 and 3A_1_thr from event 3A. The lower the value of B2_1_thr, the higher is the possibility of having too late handovers as RLFs might occur before the handovers are triggered. On the other hand, a high value for B2_1_thr avoids RLFs on the expense of the coverage of LTE. The same applies for 3A_2_thr, however, from 3G perspective. Using these two thresholds, we define a third configuration parameter

$$\Delta = \text{3A\_2\_thr} - \text{B2\_1\_thr}. \quad (1)$$

A high value of Δ delays the handovers of the UEs from 3G to LTE, and consequently shrinks the LTE coverage. On the other hand, a small value of Δ enlarges the LTE coverage on the expense of increasing the number of ping-pongs. With the aforementioned assumption that an inter-RAT handover relies only on LTE signal strength, the inter-RAT handover between LTE and 3G can be controlled by two parameters, Δ and B2_1_thr.

2) Time-to-trigger: Time-to-trigger (TTT) is a period of time in which specific condition for an event needs to be met in order to trigger the measurement report [3]. Only if the condition is permanently fulfilled for TTT period, the UE sends a measurement report. For instance, in the example of Fig. 2, the handover would be triggered only if the RSRP of the UE is below B2_1_thr for TTT period, i.e., the TTT is assumed to be zero in the figure. A low TTT value ensures that fast decisions are taken in case of fast changing channel condition on the expense of an increasing number of unwanted handovers such as ping-pongs. On the other hand, a high TTT value might lead to many RLFs due to too late handovers.

3) Filter Coefficient: A layer 3 (L3) filtering can be applied to smoothen the measurements received from layer 1 (L1). 3GPP defines an exponential moving averaging method based on a filter coefficient [3]. The impacts of random measurement errors and fast fading channels can be suppressed. In this way, unreliable handover decisions can be minimized, however, may yield a delay in the decisions.

B. Inter-RAT Related KPIs

Inter-RAT mobility problems need to be properly identified with dedicated KPIs. In accordance to the KPIs defined for the intra-LTE case [2], two categories of KPIs are specified in inter-RAT: The first captures RLFs and the other the unwanted handovers such as ping-pongs. Although ping-pongs are not considered as handover failures, they can yield performance degradation. This is because inter-RAT measurements require measurement gaps leading to service interruption and in turn capacity loss. From that perspective, unnecessary handovers such as ping-pongs are more critical in inter-RAT case than intra-RAT and have to be avoided. The KPIs used to evaluate the performance in inter-RAT scenario are described in what follows.

1) Ping-Pong to Same Cell (PPSC): Immediately after a successful inter-RAT handover, the UE is handed over back to the source cell of the former RAT.

2) Ping-Pong to Different Cell (PPDC): Immediately after a successful inter-RAT handover, the UE is handed over back to the former RAT, however, to a different cell.

3) Short Stay (SS): Immediately after a successful inter-RAT handover, the UE is handed over to another cell in the new RAT.

4) Too Late Inter-RAT Handover (TLH): An RLF occurs in the source cell before the handover is initiated or concluded and the UE reconnects to a new cell of different RAT.

5) Too Early Inter-RAT Handover (TEH): An RLF occurs short time after a handover to a new cell of a different RAT has been completed and the UE reconnects to a cell of the former RAT, i.e., either source or other cell.

6) Handover to Wrong Cell of New RAT (HWC): An RLF occurs short time after a UE has been successfully handed over to a new cell of a different RAT and the UE reconnects to another cell within the new RAT.

IV. Inter-RAT SON Capable System Model

In this section, the network layout is presented along with the simulation parameters.

A. Network Layout

A typical irregular network layout for partly overlaying inter-RAT deployment is used, see Fig. 4, namely an urban area with an adjoining sub-urban area. The complete area (urban and sub-urban areas) is served by 3G technology (light gray), while LTE covers only the urban area (dark gray).

B. Simulation Parameters

Both technologies operate in same frequency band and are subject to same radio propagation conditions. In this work, the standard deviation of the shadowing is set to 3 dB and the de-correlation distance to 50 m. The transmit antennas of the base stations are mounted at height $h_{\text{BS}} = 30$ m whereas a UE is assumed to be located at ground, i.e., UE height is zero. The transmit antenna pattern is modeled in 3-dimensions (3Ds). It is approximated using the model defined in [6] by summing up the azimuth and vertical patterns. In addition, the antenna parameters are according to those recommended by 3GPP in [7].

The total number of UEs is assumed to be 720, i.e., 10 UEs per cell. Each UE has a constant data rate requirement equal to 512 kbps and moves randomly at a speed of 30 km/h. The SINRs of the UEs are computed according to the model described in [8]. In this work, a simple traffic steering approach is used based on LTE availability. This approach increases the LTE coverage area, and consequently the number of UEs receiving LTE service. The handover of a UE from 3G to LTE is executed irrespective of the signal strength of the serving cell, i.e., 3A_1_thr is set to $+\infty$, and a UE in LTE is handed over to 3G if the signal strength of the serving cell is below B2_1_thr irrespective of the threshold B2_2_thr which is set to $-\infty$.

V. Simulation Results

In this section, the impacts of the inter-RAT mobility parameters on KPIs are investigated. The parameters that are varied and investigated are B2_1_thr, Δ and TTT. The filter coefficient is set to 4 in all simulations and will be investigated in future work. To visualize the impact of each change in a parameter value, the resulting KPIs are compared to those of a reference scenario.

A. Reference Scenario

The parameter settings that are considered in the reference scenario are $\Delta = 6$ dB, B2_1_thr$= -117$ dBm and TTT$= 0.1$ second (s). Δ is set to 6 dB to overcome the shadow fading with standard deviation of 3 dB. The value of B2_1_thr is set to a value which is slightly higher than the receiver sensitivity threshold equal to -119 dBm. The value of TTT is set to 0.1 s in order to account for fast channel variations and take quick handover decisions. The KPIs resulting from applying these parameter settings are shown Fig. 4. According to the figure,

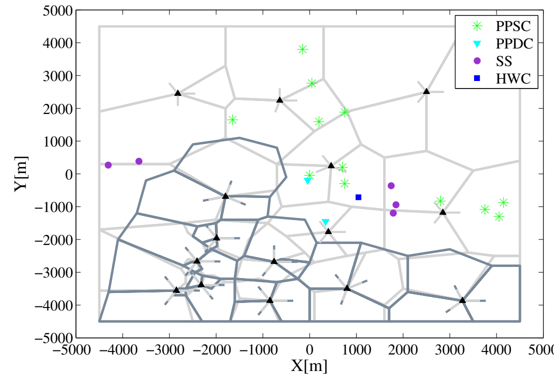


Fig. 4. Reference scenario: $\Delta = 6$ dB, B2_1_thr$= -117$ dBm and TTT$=$ 0.1 s. KPIs: 12 PPSC, 2 PPDC, 5 SS, 0 TLH, 0 TEH and 1 HWC.

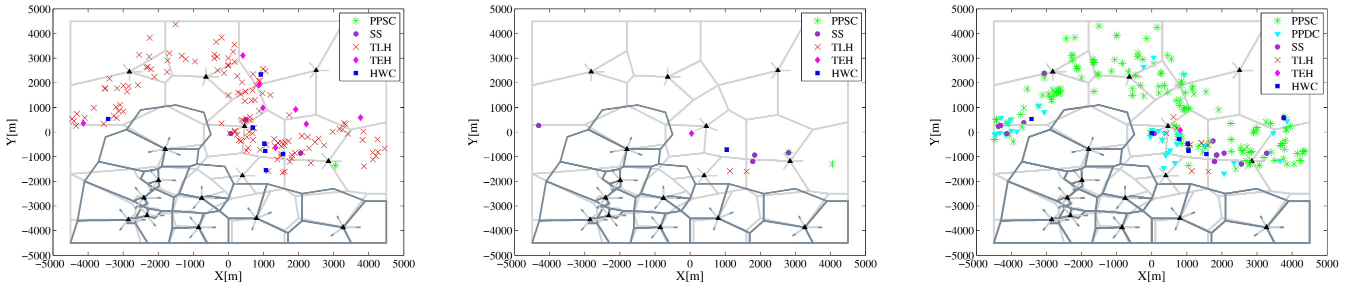
there are 12 PPSC, 2 PPDC, 5 SS, 0 TLH, 0 TEH and 1 HWC. Note that due to low B2_1_thr some of the PPSC events occur in areas far from the drawn LTE cell border. In addition, the coverage of LTE border cells is larger as the outmost border of the LTE serving area is only noise limited.

B. Impact of B2_1_thr on KPIs

Increasing LTE coverage can be achieved by reducing the threshold B2_1_thr. In order to keep Δ constant, both B2_1_thr and 3A_2_th have been reduced by 5 dB in Fig. 5(a). It can be seen that these thresholds are definitely too low leading to plenty of handover failures, in particular TLH. This is because B2_1_thr is lower than the receiver sensitivity and RLF is most likely to occur before the inter-RAT handover is triggered. The resulting KPIs are summarized in Fig. 6(a). The total number of ping-pongs has reduced compared to the reference scenario, however, the number of TLH has increased from zero to 132, TEH from zero to 8 and HWC from 1 to 7. Besides, a too low B2_1_thr leads to a degradation in QoS as the UE would be longer connected to the cell with the lower received signal. On the other hand, a high B2_1_thr shrinks the coverage of LTE and may even cause TEH if the 3G coverage is weak. This trade-off has to be considered by any future inter-RAT MRO algorithm.

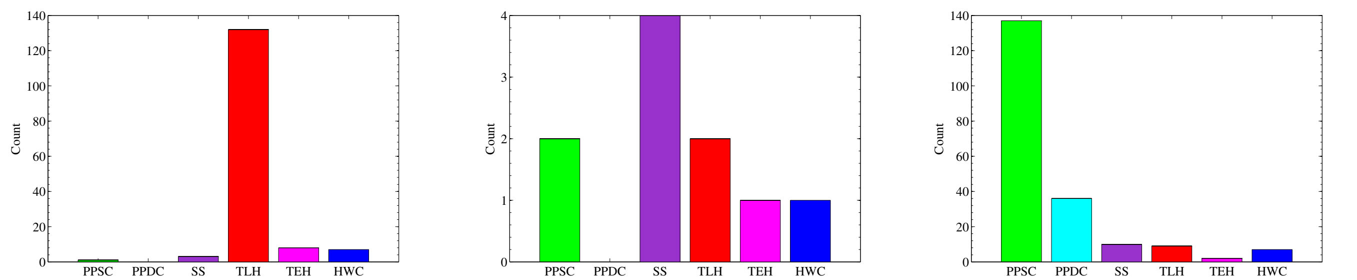
C. Impact of TTT on KPIs

The quite large number of ping-pong KPIs occurring in the reference case could be considerably reduced by increasing TTT from 0.1 s to 1 s on the expense of more critical RLF based KPIs, see Fig. 5(b). The resulting KPIs are summarized in Fig. 6(b). The total number of ping-pongs has been reduced from 19 to 6, however, the total number of RLFs has increased from 1 to 4. A high TTT value avoids unreliable handover decisions and the UE is handed over only if the condition is stable for TTT period of time. However, a higher TTT value might lead to an increase in the number of RLFs as the UE may drop before the handover is even triggered. Considering this trade-off is another challenge for an inter-RAT MRO algorithm.



(a) Parameters: $\Delta = 6$ dB, B2_1_thr$= -122$ dBm and TTT$= 0.1$ s.
(b) Parameters: $\Delta = 6$ dB, B2_1_thr$= -117$ dBm and TTT$= 1$ s.
(c) Parameters: $\Delta = 0$ dB, B2_1_thr$= -117$ dBm and TTT$= 1$ s.

Fig. 5. Locations where the inter-RAT mobility problems have occurred in the network for different parameter configurations.



(a) KPIs for $\Delta = 6$ dB, B2_1_thr$= -122$ dBm and TTT$= 0.1$ s.
(b) KPIs for $\Delta = 6$ dB, B2_1_thr$= -117$ dBm and TTT$= 1$ s.
(c) KPIs for $\Delta = 0$ dB, B2_1_thr$= -117$ dBm and TTT$= 1$ s.

Fig. 6. Number of KPIs for different inter-RAT mobility parameter configurations.

D. Impact of Δ on KPIs

The importance of an adequate Δ is demonstrated in Fig. 5(c) where Δ and TTT are set to 0 dB and 1 s, respectively. As expected, it can be shown that the number of ping-pongs has remarkably increased and they cannot be reduced even by increasing TTT. The resulting KPIs are summarized in Fig. 6(c). The numbers of PPSC and PPDC have increased if compared to the reference scenario and even for other RLF related KPIs. Thus, Δ has a quite important impact on the ping-pong resilience as well as on the coverage of the LTE.

VI. CONCLUSION

In this paper, we have studied the inter-RAT mobility with focus on end of coverage scenario, i.e., LTE as coverage limited deployment in fully covered 3G environment. Even though interference between source and target cell does not exist in this scenario, there are still both types of failures, namely RLF-affected handovers and unnecessary handovers such as ping-pongs, in case of inappropriate and misaligned parameter setting of two different RATs. In contrast to intra-LTE scenario, unnecessary handovers are rather critical in inter-RAT since inter-RAT measurements carried out by a UE prior the handover require a connection interruption, which can lead to packet loss and capacity reduction. Moreover, they are quite likely due to inconsistent parameter configurations among RATs as configuration parameters are often hold in different operation and maintenance (OAM) domains.

We have defined a set of inter-RAT mobility KPIs and investigated the impact of various inter-RAT mobility parameter configurations on them. Results have revealed that the signal measurement threshold and margin, i.e., B2_1_thr and Δ, are more sensitive than TTT and can yield a remarkable degradation in network performance if misconfigured. The investigations have also shown than an inter-RAT MRO algorithm has to work locally in a cell-pair manner as each cell-pair underlies different traffic and mobility conditions, and therefore, needs different parameter adjustments.

REFERENCES

[1] SOCRATES. Self-optimisation and self-configuration in wireless networks. [Online]. Available: http://www.fp7-socrates.org.

[2] 3GPP, "Self-configuring and self-optimizing network use cases and solutions," TR 36.902, Sophia-Antipolis, France, Tech. Rep., 2009.

[3] 3GPP, "Evolved universal terrestrial radio access (E-UTRA); radio resource control (RRC); protocol specification," TS 36.331, Sophia-Antipolis, France, Tech. Rep., 2009.

[4] 3GPP, "Technical specification group radio access network; radio resource control (RRC); protocol specification," TS 25.331, Sophia-Antipolis, France, Tech. Rep., 2010.

[5] 3GPP, "Evolved universal terrestrial radio access (E-UTRA); requirements for support of radio resource management," TS 36.133, Sophia-Antipolis, France, Tech. Rep., 2010.

[6] R. Hoppe, "Comparison and evaluation of algorithms for the interpolation of 3D antenna patterns based on 2D horizental and 2D vertical patterns," AWE Communications GmbH, V 1.0, Tech. Rep., 2003.

[7] 3GPP, "Physical layer aspects for evolved universal terrestrial radio access (UTRA)," TR 25.814, Sophia-Antipolis, France, Tech. Rep., 2006.

[8] I. Viering, M. Döttling, and A. Lobinger, "A mathematical perspective of self-optimizing wireless networks," in *IEEE International Conference on communication*, June 2009.