A SON Function for Steering Users in Multi-Layer LTE Networks Based on Their Mobility Behaviour

Bart Sas, Kathleen Spaey, Chris Blondia
iMinds/University of Antwerp
Antwerp, Belgium
Email: {bart.sas,kathleen.spaey,chris.blondia}@uantwerpen.be

***Abstract*—In cellular networks, users that make frequent handovers and have a low time-of-stay in a cell (i.e., highly mobile users) might have a negative impact on the network performance. Furthermore the Quality of Service (QoS) experienced by these users might be low. This paper introduces a Self-Organising Network (SON) function, called the *High Mobility SON function*, that aims at reducing the amount of short stays in a multi-layer Long-Term Evolution (LTE) network. It does this by predicting the mobility behaviour of currently active users based on measurements, which were collected by users that were active in the past. Based on these predictions, the SON function aims at refraining from handovers to cells in which the user is likely to stay for a small amount of time, and at steering the user more appropriately. To assess the ability of the SON function to achieve its goals, simulations were performed in a scenario in which both macro and micro cells are deployed. Results show that the developed SON function is able to reduce the number of handovers by 17–23% and the number of short stays by as much as 43–49% at the cost of reducing the spectral efficiency by 13–15%.**

Keywords*—*Self-Organising Network (SON); Traffic Steering; Long-Term Evolution (LTE); Multi-layer; High Mobility

I. Introduction

In cellular networks like Long-Term Evolution (LTE), service continuity in the presence of mobility is ensured by performing a handover when a user moves from one cell to another. When a User Equipment (UE) makes frequent handovers and the amount of time a UE stays in a cell (time-of-stay) is low (order of magnitude of 10 seconds), for instance when there is a dense deployment of cells or when users move at a (relatively) high velocity, there will be a negative impact on user and network performance. This impact might be seen in a reduced Quality of Service (QoS) experienced by the users with high mobility due to a long data outage period relative to the cell stay time, an increased number of call drops and an increased signalling and data overhead in the core network due to handover signalling and data forwarding.

This paper presents and evaluates a Self-Organising Network (SON) function [1], called the High Mobility SON function, that aims to reduce the negative effects of high mobility by decreasing the handover frequency and increasing the time-of-stay of a user. The SON function does this by steering active UEs more intelligently between different cells and layers (i.e., different frequency bands within the same Radio Access Technology (RAT) technology) and by finding a good handover sequence for them. For that, it will predict the mobility behaviour of a user based on measurements collected by users that were active in the past. As an example, the algorithm can steer fast-moving users to macro cells so they can stay camped on a single cell for a longer time while steering slow-moving users to smaller cells.

This paper is structured as follows: in Section II an overview is given of related work. The general architecture of the developed High Mobility SON function is presented in Section III. Subsequently, the different components of the SON function, namely the Trajectory Classifier, the Trajectory Identifier and the Traffic Steerer, are detailed in Sections IV, V and VI respectively. Section VII describes the simulations performed to assess the ability of the SON function to achieve its goals. The results of these simulations are presented in Section VIII. Finally, Section IX concludes this paper and outlines the way forward.

II. Related Work

The work in this paper builds on our earlier work that was described in [2]. That paper presented the algorithm that is used in the Trajectory Classifier component of the High Mobility SON function for identifying users that follow similar trajectories through a cell. It showed that the algorithm is able to distinguish between users that follow similar trajectories and users that follow different trajectories. The current paper will use the information provided by this algorithm to predict the future mobility behaviour of users and steer them appropriately. A summary of the Trajectory Classifier is given in Section IV.

In [3] a handover algorithm is presented that bases its decisions on the predicted moving direction of the UEs. It uses the Global Positioning System (GPS) location of a user to determine the direction in which it is travelling. Based on this information the most suited handover target is identified. Also [4] describes two position-assisted handover schemes: one that aims to reduce the handover delay and one that aims to reduce the handover frequency and improve the handover success rate. The goal of these schemes is not targeted at users with high mobility in general, but to high velocity users only. The work presented in the current paper does not require the GPS location of users in order to determine a suitable handover target. Instead, it uses measurements that are part of the LTE standard.

[5] and [6] are concerned with applying scanning narrow beams to LTE networks that contain fast moving mobiles.

III. General Architecture

The general architecture of the developed High Mobility SON function is shown in Figure 1. It operates at a per-cell

DOI: 10.1109/VTCSpring.2015.7145646

level and consists of three components: the Trajectory Identifier, the Trajectory Classifier and the Traffic Steerer. The Trajectory Classifier classifies users based on their trajectory through the cell by mapping them on users that were active in the past and that followed a similar trajectory through the cell. The Trajectory Classifier is extensively described in a previous paper [2] and a short overview is given in Section IV. The Trajectory Identifier is responsible for collecting the set of trajectories that will be used by the Trajectory Classifier to map users on and is discussed in Section V. The Traffic Steerer steers users based on information it receives from the Trajectory Classifier and Trajectory Identifier aiming to reduce the amount of unnecessary handovers, i.e., handovers that are not required in order to maintain connectivity or avoid serious QoS degradation. The Traffic Steerer is presented in Section VI.

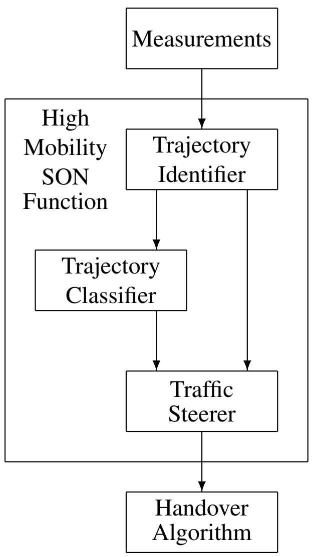

Figure 1. The High Mobility SON function consists of 3 components: the Trajectory Identifier, the Trajectory Classifier and the Traffic Steerer.

The High Mobility SON function in general and the Trajectory Classifier in particular make extensively use of measurement reports. Measurement reports are a part of the LTE standard [7] and were introduced in the original LTE release, namely release 8. Measurement reports allow the Serving eNodeB (SeNB) of a UE to configure a number of measurement and reporting configurations on the Reference Signal Received Power (RSRP) (or Reference Signal Received Quality (RSRQ)) of its SeNB and the Neighbouring eNodeBs (NeNBs). The UE will then monitor the RSRP of these eNodeBs (eNBs) and report the configured events to its SeNB. These events can, for instance, be a NeNB's RSRP becoming higher than a certain threshold or higher than the SeNB's RSRP. In this paper A4 events [7] will be used which provide information about the RSRP of the NeNBs in comparison to a fixed threshold.

The decisions that are taken by the Traffic Steerer are communicated to the handover algorithm. This algorithm is responsible for performing the actual handovers. Apart from executing the commands coming from the Traffic Steerer, the handover algorithm is also responsible for handing over users for which the SON function did not provide instructions as the SON function will only deal with users for which it sees an opportunity to optimise the handover behaviour.

IV. Trajectory Classifier

The Trajectory Classifier component of the High Mobility SON function was extensively described in [2]. This section summarises its tasks and the algorithm on which it is based.

The Trajectory Classifier is responsible for classifying users based on the trajectory they follow through the cell. It does this by comparing measurement traces that are made by currently active users (active traces) to measurement traces that were made by users that were active in the past (reference traces), and as such identifying matching traces of measurements. The focus lies on matching the more recent past of the active trace with some interval of a reference trace as the more recent past will have a larger influence on the future behaviour of the active user. The measurements that are used to compare the traces are the consecutive measurement reports that are sent by the UE to its SeNB as discussed before.

In order to match measurement traces, in [2] we developed a modified version of the Dynamic Time Warping (DTW) algorithm, called the Modified Dynamic Time Warping (MDTW) algorithm. The DTW algorithm is an algorithm that, amongst others, is used in signal processing and speech recognition to find an optimal alignment between two time series. It is able to deal with slight variations in the input measurements, which is important for our purposes as this will be the case with the measurements that are used. The downside of the DTW algorithm is that it matches two entire series and does not search for similar partial series. Therefore, in [2] we introduced several modifications to the original DTW algorithm to circumvent this restriction. The MDTW algorithm takes two discrete time series as an input and outputs the matching parts of both series (a suffix of the active trace and an interval of the reference trace), together with a distance metric that indicates how similar the matched parts are. In order to do this, the MDTW algorithm finds the so-called optimal warping path through a cost matrix whose elements express the distance between the elements of the active and reference series. More information about the MDTW algorithm can be found in [2].

V. Trajectory Identifier

The Trajectory Identifier component of the High Mobility SON function is responsible for identifying the traces that will serve as reference traces. These reference traces are used by the Trajectory Classifier to match the measurement trace of an active user to.

When a user arrives in a cell, either by starting a call or because it is handed over to the cell during an ongoing call, it becomes either a tagged user with probability p, the tagged user probability, or an untagged user with probability $1 - p$, as is shown in Figure 2. Tagged users are used to collect reference traces and are therefore not subject to traffic steering by the High Mobility SON function. However, the Traffic Steerer will still advise the handover algorithm against handing over these users between different layers as it will do with untagged users. Furthermore, tagged users are subject to all other SON and non-SON functions that are active in the cell and to handovers within the same layer which are carried out to maintain connectivity and avoid call drops.

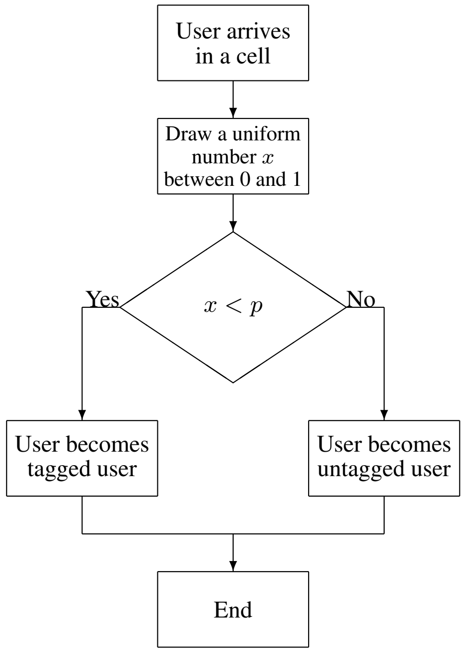

Figure 2. A new user becomes a tagged user with probability p or an untagged user with probability $1 - p$.

When a tagged user leaves a cell, either by stopping its call or because it is handed over to another cell, the measurements that were collected by it are turned into a reference trace. This reference trace is then added to the set of reference traces. In order to avoid that the set of reference traces grows without bounds, a maximum size is imposed on this set. In this paper a maximum size of 20 reference traces is used. When, after adding a new reference trace to this set, the size of the set is larger than the maximum size, a trace is removed from the set. In this paper, when a reference trace needs to be removed, one of the two reference traces that resemble each other the best will be removed. It is important that the set of reference traces covers as many trajectories that run through the cell as possible in order to be able to properly steer all or most of the users in the cell. At the same time it is not beneficial to have many similar reference traces as this will only decrease the performance of the algorithm. It is also important that the set of reference traces is kept up-to-date as the environment covered by the cell will evolve over time, for instance because traffic patterns change.

The reason why tagged users are not subject to traffic steering by the High Mobility SON function is to be able to obtain as much measurements for the tagged user as possible. Consider the situation that is depicted in Figure 3 where a micro cell B lies within a larger macro cell A. If a tagged user in A that travels through the area that is covered by B would be handed over to B the set of collected reference traces for cell A will never contain measurement traces that cover the entire path in A that is depicted in Figure 3. This will unnecessarily limit the ability of the High Mobility SON function to make a good traffic steering decision for future active users. For instance, there might be another micro cell C in which a user can stay for a longer time and in which it will experience an even higher throughput than in B, but the traffic steerer of cell A will only be able to assess this if it has a reference trace available which covers the entire path in A.

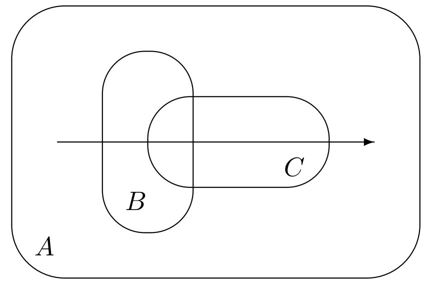

Figure 3. A user that travels through macro cell A passes the coverage areas of micro cells B and C.

VI. TRAFFIC STEERER

Once a sufficiently reliable match of the trajectory of a currently active user onto a reference trace has been made by the Trajectory Classifier, the Traffic Steerer will make a traffic steering decision. By assuming that events that occur to one user will also occur to another user that follows a similar trajectory through the cell, the Traffic Steerer can decide whether it is beneficial to hand over the user to another cell or to keep it in the current cell. Events mean new RSRP measurements and thus possible changes in Signal to Interference and Noise Ratio (SINR) and consequently achievable throughput. Before the Traffic Steerer decides to steer the user to another cell, or not, it will extrapolate and project events that occurred to the reference user in the period after the match on the active user, in order to make an estimate of the future achievable throughput of the active user in each of its NeNBs as well as in the SeNB itself. Based on these predictions of the UE's future throughput in the neighbouring cells, a traffic steering decision will be made.

Figure 4 summarises the general idea of the extrapolation and projection of events of the reference user on the time line of the active user. The x-axis of this plot shows the time line of the reference user while the y-axis shows the time line of the active user. The beginning of the match of the measurements of the reference and active users corresponds to $x = r_s$ and $y = a_s$ respectively, while the end of the match corresponds to $x = r_e$ and $y = a_e$ respectively. Using linear extrapolation, the time

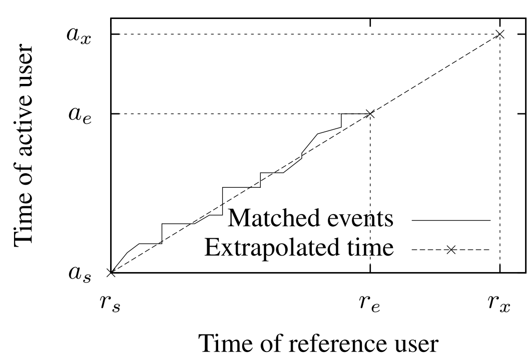

Figure 4. Future events x that occur to the reference user are extrapolated linearly between s and e and projected on the active user.

$x = r_x$ of an event that occurred to the reference user during the period after the match can be projected on the future of the active user, yielding $y = a_x$:

$$a_x = \frac{r_x - r_e}{r_e - r_s}(a_e - a_s) + a_e. \quad (1)$$

Based on the predicted times of future events for the active user, the future throughput of this user in the NeNBs as well as in the SeNB can now be estimated. Each measurement is of the form (t_i, m_i), where t_i is the time of event i and m_i is a list of NeNB IDs and their associated RSRP measurements at that time. As measurements are generated each time the RSRP of an NeNB crosses the threshold of an A4 event, the RSRP of each NeNB j is only known within an interval between the bounds of 2 consecutive A4 events. The lower bound of this interval is $q_{i,j}$ and the the upper bound is $q_{i,j} + \delta_q$, where δ_q is the width of the interval. A worst-case value for the SINR at time i of each NeNB j as well as for the SeNB can then be calculated by using the minimum possible value of the signal and the maximum possible value of the interferers, which are the eNBs that operate in the same frequency bands:

$$\text{SINR}_{i,j} = \frac{10^{\frac{q_{i,j}}{10}}}{N + \sum_{k \in I_j} 10^{\frac{q_{i,k}+\delta_q}{10}}}. \quad (2)$$

In this equation N is the noise value and I_j represents the set of interferers for NeNB j. Using the SINR estimate, a prediction of the future throughput of the user in its NeNBs and in its SeNB can be made by applying the modified Shannon formula [8]:

$$\text{Thr} = \begin{cases} 0 & \text{if SINR} < \text{SINR}_{\min} \\ \alpha S(\text{SINR}) & \text{if SINR}_{\min} \leq \text{SINR} < \text{SINR}_{\max} \\ \alpha S(\text{SINR}_{\max}) & \text{if SINR}_{\max} \leq \text{SINR} \end{cases}, \quad (3)$$

where $S(\text{SINR}) = \log_2(1 + \text{SINR})$ is the Shannon bound. α is the attenuation factor, representing implementation losses, which is set to 0.6. $\text{SINR}_{\min}$ is the minimum SINR that is required for the lowest Modulation and Coding Scheme (MCS), below this SINR no communication is possible and $\text{SINR}_{\max}$ is the maximum SINR that is required for the highest MCS, above this SINR no higher throughput can be achieved. This equation will yield a prediction for the future spectral efficiency, expressed in bit/s/Hz which will be used as an indication for the future throughput.

Based on these predictions of the future throughput of the user in its surrounding NeNBs as well as that in its SeNB, the Traffic Steerer will decide to steer the user to a different cell or not. On each new match that is made by the Trajectory Classifier, the Traffic Steerer will check for each NeNB whether it finds periods that satisfy the following conditions:

1) The periods start at the current time which is the time of the end of the active trace.
2) The periods last for a minimum amount of time, called the minimum stay duration.
3) During these periods the predicted throughput at the NeNB is at no point lower than a certain fraction of the predicted throughput at the SeNB, this fraction is called the minimum throughput fraction.
4) The average predicted throughput of the NeNB during these periods is greater than that of the SeNB.

If one or more periods that satisfy the aforementioned conditions are found, the traffic steerer will suggest to handover the user to the NeNB with the highest average predicted throughput; otherwise the handover algorithm is advised to keep the user in the current cell. The rationale behind condition (1) is that a handover will not be triggered prematurely but only if making a handover at the present time will immediately result in a better performance. If the NeNB remains a viable target for making a handover to, the handover will be triggered at a later measurement anyway. Condition (2) ensures that when a handover is triggered the user will be able to stay in the target cell and experience a good throughput for a sufficiently long amount of time. In order to assure that the throughput of the user will at no point become much worse than when the user would have stayed with the SeNB and that the overall throughput improves, conditions (3) and (4) are added. Note that multiple periods that satisfy these conditions can be found per NeNB.

VII. Simulation Description

In order to assess the ability of the High Mobility SON function to reduce the number of handovers, especially the ones that result in short stays, simulations were performed. The simulation scenario consists of a rectangular area measuring 1732 m wide by 2000 m high, contains 64 cells of which 48 are macro cells and 16 are micro cells and features wrap around. An overview of the simulation area is given in Figure 5. The macro sites all have three sectors and are placed in a 4×4 layout with an inter-site distance of 500 m. The macro base stations have directed antennas using the antenna pattern described in [9]. They operate in a 5 MHz-wide band in the 2.6 GHz band and transmit at 46 dBm. The micro cells are placed in a 4×4 grid with an inter-site distance of 433 m in the x-direction and 500 m in the y-direction. They have omnidirectional antennas and transmit at 30 dBm. Like the macro base stations they also operate in a 5 MHz-wide band in the 2.6 GHz band but not the same as the macro base stations.

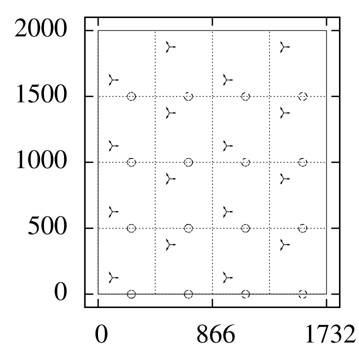

Figure 5. The simulation area consists of 64 cells: 48 macro cells, indicated by arrows and 16 micro cells, indicated by circles.

A single user moves through the simulation area according to the Manhattan Mobility model [10]. The crossroads are laid out in 4×4 grid and the distances between the crossroads is 433 m in the x-direction and 500 m in the y-direction. The horizontal roads run through the micro base station locations and the vertical roads are offset 253 m from the micro base station locations. The velocity of the user is chosen from a uniform distribution centred around 5 m/s and is re-evaluated each time the user reaches a crossroad. The width of the velocity interval itself is a simulation parameter. Each simulation lasts 20000 seconds (5h 33m 20s). The first 10000 seconds (2h 46m 40s) are used as warm-up time. During this period the Traffic Steerer is not active and the High Mobility SON function only collects reference traces by making every user a tagged user. No performance metrics are collected during this period. After the warm-up time the SON function operates as described in the previous sections.

In order to assess the performance of the developed SON function the influence of 5 parameters, 3 internal to the algorithm and 2 external to the algorithm, was investigated. These parameters are:

- The minimum amount of time a user is required to be able to stay in a target cell (minimum stay duration)
- The fraction of the throughput of the SeNB above which the throughput of the NeNB should lie (minimum throughput fraction)
- The probability p that a user becomes a tagged user (tagged user probability)
- The average velocity of a user (mean velocity)
- The width of the interval, centred around the mean velocity, from which the user velocity is chosen (velocity interval)

The results obtained from the simulations are given in the following section. In each simulation set one of the parameters is varied while the others remain constant. The values of these parameters are given in Table I, in the plots in Section VIII the default value is indicated using a vertical dashed line. Each time the results are compared to a baseline. This baseline has exactly the same parameters but without the SON function activated. As the minimum stay duration, minimum throughput fraction and tagged user probability are configuration parameters of the High Mobility SON function they have no impact on the results obtained in the baseline scenario. For each parameter configuration 20 runs were performed. The presented results show the average value of these 20 runs as well as the standard deviation.

Table I. THE DEFAULT VALUES OF THE SIMULATION PARAMETERS.

Parameters	Value
Minimum stay duration	15 s
Minimum throughput fraction	0.8
Tagged user probability	0.1
Mean velocity	5 m/s
Velocity interval	0 m/s

VIII. PERFORMANCE ASSESSMENT

The performance of the High Mobility SON function will be assessed using 3 performance metrics: the *number of handovers*, the *number of short stays* and the *spectral efficiency*. The *number of handovers* is the number of handovers that are commanded by the handover algorithms in all cells during the simulation. This metric is meant to show the overall impact of the High Mobility SON function on the overall number of handovers that are performed. A *short stay* is defined as a stay of a user in a cell that lasts less than 10 seconds. As the main goal of the High Mobility SON function is to reduce the amount of short stays, the number of short stays during the simulation is an important performance metric. The *spectral efficiency* is the amount of bits that can be sent per second and per Hz of spectrum. It is a factor that has an influence on the throughput that can be achieved by a user. The user throughput is of course not determined by the spectral efficiency only, the cell load and the offered traffic also influence the experienced throughput. In cells that are not loaded a user with a lower spectral efficiency will still be able to achieve its desired throughput, it will however require more radio resources to achieve this throughput.

Figure 6 shows the influence of the minimum stay duration on the three performance metrics. As can be seen in this figure, the influence of the minimum stay duration on the performance is minimal. Furthermore, this figure shows that the High Mobility SON function reduces the number of handovers by 17–23% compared to the baseline where the SON function is not activated. The amount of short stays is reduced significantly by 43–49%. On the other hand, the throughput is also reduced in comparison to the baseline by 13–15%. The reduction of

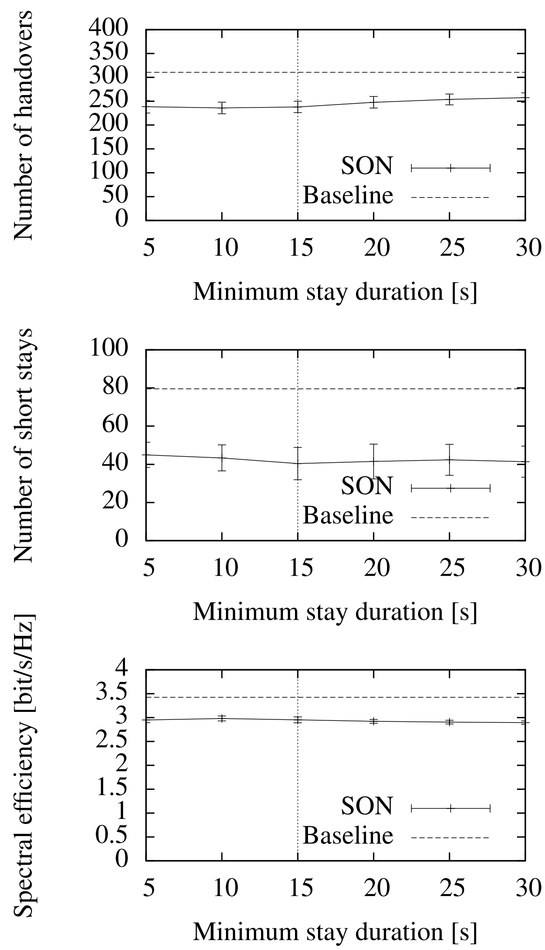

Figure 6. The number of handovers and short stays are reduced significantly when the SON function is enabled relative to the baseline at the cost of a lower spectral efficiency.

the throughput is explained by the fact that handovers are performed less frequently. If, in the scenario that is presented in Figure 3, the High Mobility SON function prohibits the user to be handed over to cell B while the handover algorithm would otherwise handover the user to cell B, the experienced signal strengths would evolve as in Figure 7. As can be seen in this figure, a user that goes from A to B and then to C will experience a higher RSRP and consequently SINR and throughput than a user that stays in A until it can go directly to C. This will cause the overall throughput to be higher in the baseline case than when the SON function is enabled, at the cost of an additional handover.

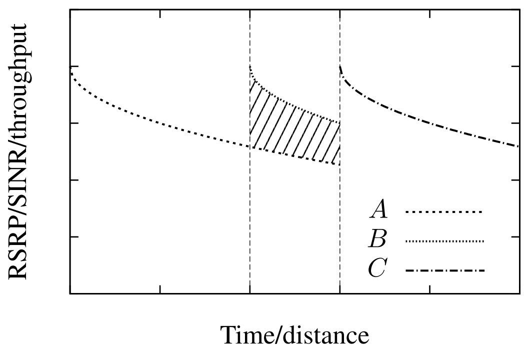

Figure 7. By avoiding handovers a user might not always be present in the cell in which it can achieve the highest throughput.

When varying the minimum throughput fraction or the tagged user probability similar results than when the minimum stay duration is varied are obtained as is shown in Figure 8 and Figure 9. The results are not influenced significantly by these parameters and the number of handovers and the number of short stays are reduced when SON is enabled at the cost of a lower spectral efficiency.

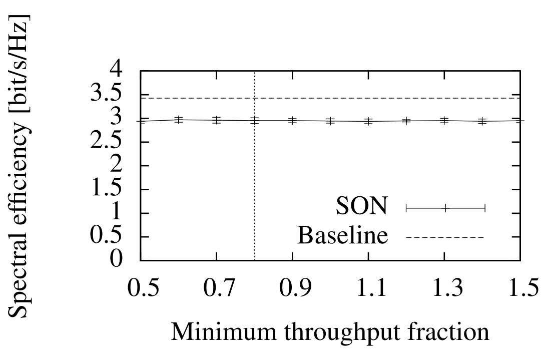

Figure 8. When the minimum throughput fraction is varied, similar results are obtained than when the minimum stay duration is varied.

When the *mean velocity* is varied, as is shown in Figure 10, the number of handovers and short stays rise as is expected because users cross cells much faster when their velocity is higher. The spectral efficiency is barely affected by the velocity of the user: it is somewhat lower at higher velocities due to the increased data outage time caused by the increased number of handovers. The High Mobility SON function is again able to

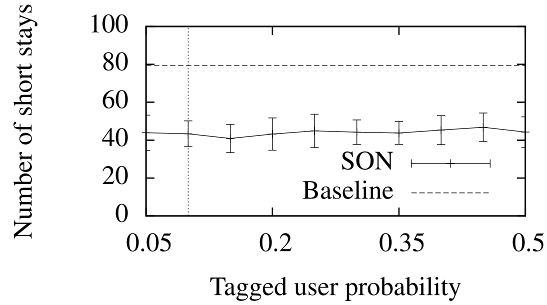

Figure 9. When the tagged user probability is varied, similar results are obtained than when the minimum stay duration is varied.

reduce the number of handovers and short stays by an amount ranging from 12 to 24% and 29 to 49% respectively, again at the cost of a reduced spectral efficiency.

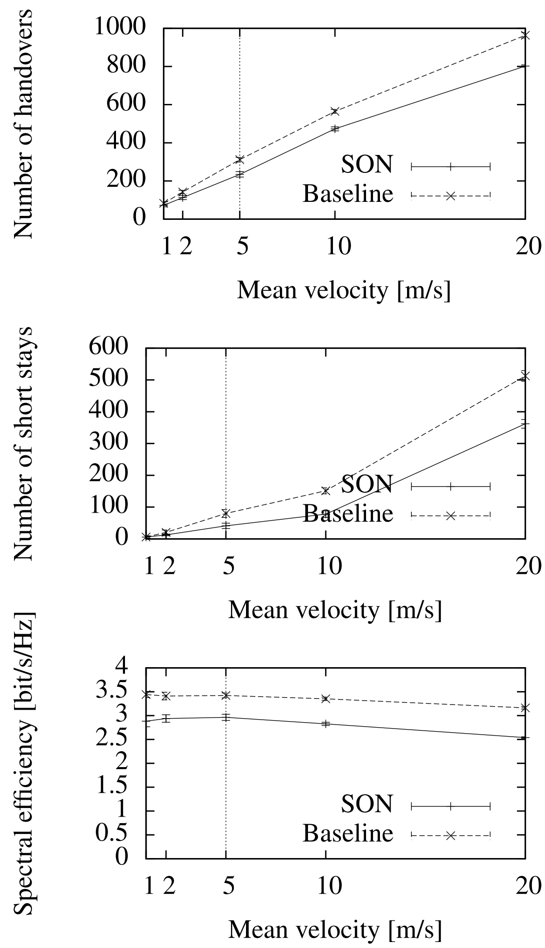

Figure 10. The High Mobility SON function is able to reduce the number of handovers and short stays for different user velocities.

Figure 11 shows the impact of different velocity ranges from which the user velocity is chosen. As can be seen in this figure, the performance of the High Mobility SON function is very similar, regardless of the width of the interval. This shows that the High Mobility SON function is able to deal with variations of the user velocity and consequently variations in the timing between measurements of different traces and even within a trace. This ability is due to the MDTW algorithm that is designed to deal with these variations.

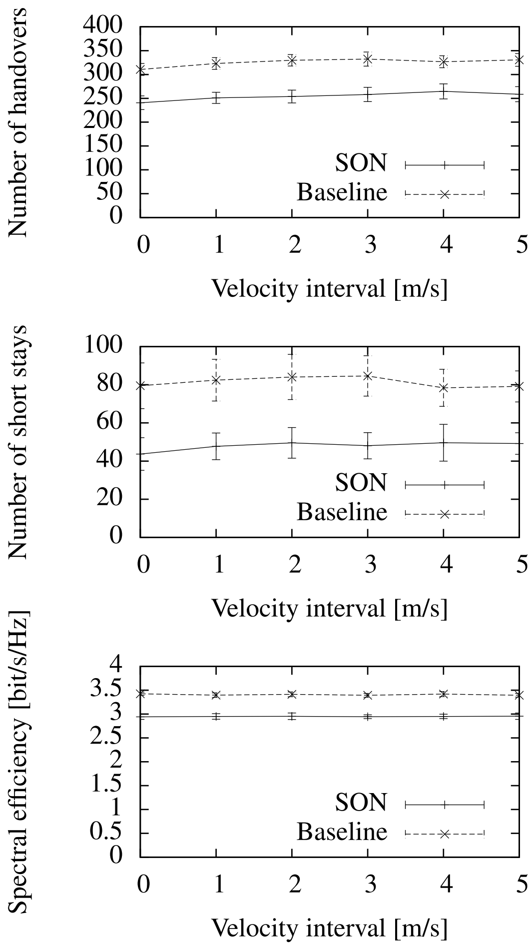

Figure 11. The High Mobility SON function is able to deal with variations in the velocity of the users.

IX. Conclusions and Way Forward

This paper presented a SON function that aims at reducing the number of short stays in a multi-layer LTE network. The results from various simulation runs show that the High Mobility SON function is effectively able to reduce the number of handovers and short stays. Especially the number of short stays is reduced significantly by values as high as 50%. As a consequence the spectral efficiency that is experienced by the users is reduced although within reasonable bounds.

In the future, the High Mobility SON function will be evaluated in a more realistic scenario than the hexagonal scenario that was used in this paper. Furthermore, the High Mobility SON function will be extended to support multiple RATs like Universal Mobile Telecommunications System (UMTS) or Wi-Fi. In this way the SON function will have more targets for steering users to, which will further improve the user and network performance. The SON function could also be improved by exchanging information between base stations such that more accurate decisions can be made by taking for instance the load situation in possible target cells or the mobility history of users in other cells into account.

Acknowledgement

The research leading to these results has been carried out within the FP7 SEMAFOUR project and has received funding from the European Union Seventh Framework Programme (FP7/2007-2013) under grant agreement n° 316384.

References

[1] S. Hämäläinen, H. Sanneck, and C. Sartori, *LTE Self-Organising Networks (SON): Network Management Automation for Operational Efficiency*, 1st ed. Wiley Publishing, 2012.

[2] B. Sas, K. Spaey, and C. Blondia, "Classifying users based on their mobility behaviour in LTE networks," in *ICWMC 2014, The Tenth International Conference on Wireless and Mobile Communications*, June 2014.

[3] H.-L. Wang, S.-J. Kao, C.-Y. Hsiao, and F.-M. Chang, "A moving direction prediction-assisted handover scheme in LTE networks," *EURASIP Journal on Wireless Communications and Networking*, vol. 2014, no. 1, p. 190, 2014. [Online]. Available: http://jwcn.eurasipjournals.com/content/2014/1/190

[4] M. Fei and P. Fan, "Position-assisted fast handover schemes for LTE-advanced network under high mobility scenarios," *Journal of Modern Transportation*, vol. 20, no. 4, pp. 268–273, 2012.

[5] C. Papathanasiou, N. Dimitriou, and L. Tassiulas, "On the applicability of steerable beams in LTE-advanced networks with high user mobility," *EURASIP Journal on Wireless Communications and Networking*, vol. 2012, no. 1, p. 234, 2012.

[6] M. Cheng and X. Fang, "Location information-assisted opportunistic beamforming in LTE system for high-speed railway," *EURASIP Journal on Wireless Communications and Networking*, vol. 2012, no. 1, p. 210, 2012.

[7] "Evolved universal terrestrial radio access (E-UTRA) and evolved universal terrestrial radio access network (E-UTRAN); overall description; stage 2 (release 11)," 3rd Generation Partnership Project, Tech. Rep. 3GPP TS 36.300 v11.3.0, September 2012.

[8] "Evolved universal terrestrial radio access (E-UTRA) and evolved universal terrestrial radio access network (E-UTRAN); radio frequency (rf) system scenarios (release 12)," 3rd Generation Partnership Project, Tech. Rep. 3GPP TR 36.942 v12.0.0, September 2014.

[9] "NGMN radio access performance evaluation methodology," Next Generation Mobile Networks Alliance, Tech. Rep., January 2008.

[10] F. Bai and A. Helmy, "A survey of mobility models in wireless adhoc networks," in *Wireless Ad Hoc and Sensor Networks*. Springer, October 2006.