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SIMULATING LONG TERM EVOLUTION SELF-OPTIMIZING BASED NETWORKS

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Abstract: With the first 3rd Generation Partnership Project (3GPP) Long Term Evolution (LTE) networks being deployed more complexity is added to current existing cellular mobile networks and more capital (CAPEX) and operational (OPEX) effort will be needed. In addition, the rising demand of users for new services and higher data rates demands more efficiency from operators. For this matter, 3GPP Release 8 as introduced the Self-Organizing Network (SON) concept, a set of self-configuration, self-optimizing and self-healing functions that allow the automation of labor-intensive tasks, reducing operational and capital costs. While requirements on cutting operational expenditure remain, operators still remain skeptical with the efficiency of these functions. In this paper, Physical Cell Identity (PCI) conflict detection and resolution, Automatic Neighbor Relation (ANR) and automatic Handover Parameter Optimization (HPO) functions are proposed as part of a simulator for LTE SON based networks. Based on user defined inputs, these functions allow operators to closely predict and gather optimal policy input values for SON algorithms, while maintaining desirable network performance. Based on a real network scenario, results show simulator's clear benefit when compared with other proposals.

1 INTRODUCTION

With the arrival of the 4th generation standards, especially the 3rd Generation Partnership Project (3GPP) Long Term Evolution (LTE), more complexity is added to the current existing networks. The rising number of parameters from multiple co-existing standards, in most cases from different suppliers, combined with the increasing demand of 3rd party services, demands more management effort from mobile network operators.

Introduced since 3GPP Release 8 specifications, the Self Organizing Networks (SON) concept aims to reduce most of common planning, optimization and operational tasks through automated mechanism such as self-configuration, self-optimization and self-healing mechanisms, reducing operator's operational and capital costs (OPEX/CAPEX).

With first commercial LTE networks being deployed, operators question the performance and reliability of these automated functions in their current networks. For this matter some proposals have been made to evaluate network performance under these circumstances, [1], [2]. Despite the variety of features, these simulators don't allow, in most cases, the recreation of a typical operator network configuration, putting into question the reliability and usefulness of the obtained results in a real life scenario.

In this paper, a new simulation tool is proposed for LTE SON based networks. This simulator aims to evaluate Physical Cell Identity (PCI) conflict detection and resolution, Automatic Neighbor Relation (ANR) and Automatic Handover Parameter Optimization (HPO) functions based on customizable scenarios using user defined network inputs such as geographical positioning of evolved-NodeBs (eNodeBs), antennas orientation or radio propagation environment characterization.

The rest of the paper is organized as follows. Section 2 presents a brief overview of SON current state-of-the-art. The implemented algorithms are presented in Section 3 followed by a brief description of the simulator in Section 4. A simulation scenario and performance results are set in Section 5 and 6, respectively. Finally, Section 7 presents the overall conclusions.

2 Self-Organizing Network Concept

Started by NGMN (Next Generation Mobile Networks) and later included by 3GPP in the

Evolved UMTS Terrestrial Radio Access Network (E-UTRAN) specification process since Release 8, SON is the key driver to improve operators O&M (Operations & Maintenance). By automating most of common planning, optimization and operational tasks, SON aims to reduce Capital and Operational costs by reducing time-consuming manual processes in network management. Reference [3] establish the guidelines needed to create autonomous functions that can be organized essentially in the following groups, in the format of user-cases:

- Self-Configuration;
- Self-Optimization;
- Self-Healing.

Self-Configuration compromises the automation of tasks related to the deployment of new evolved NodeB (eNB). The Self-Configuration process works in a pre-operational state, starting from the moment the eNB is powered on until the RF transmitter is switched on. This process evolves the transport link detection, connection with the core network elements, download and upgrade of software version, setup of initial configuration parameters, including neighbour relations, self-test and finally RF transmitter activation.

Self-Optimization is the process in which User Equipment (UE) and eNB measurements are used to auto-tune the network. This is an operational state process which starts when the RF interface is switched on. This autonomous optimization allows a more fast and accurate resolution of network problems. The optimizations tasks within this function are:

- Neighbor list optimization;
- Coverage and capacity optimization;
- Mobility load balancing optimization;
- Radio Access Channel (RACH) optimization;
- Inter-Cell interference coordination.

Finally, Self-Healing functions aim to automatically detect and localize failures in network elements, and take the appropriate decisions, e.g. load balance traffic in case of high traffic element failure, reduce cell power in case of high temperature failure or fallback to previous software version in case of errors during network software update.

3 SON Functions

3.1 PCI Conflict Detection and Resolution

The PCI is the physical identification of a cell contained in SCH (Synchronization Channel). There are totally 504 unique PCIs defined in the Evolved UMTS Terrestrial Radio Access Network (E-UTRAN) spread over 168 designated Physical Cell Identity Groups, where each one contains three unique identifiers. Each PCI plays an important role in that each allows synchronization signals (including Primary Synchronization Signal (PSS) and Secondary Synchronization Signal (SSS)) and the reference signals (including Cell-specific Reference Signal (CRS) and UE-specific Reference Signal (URS)) to be generated and distinguish by UEs. In addition, is also from the PCI that scrambling sequences of most of the physical channel such as PBCH, PCFICH, PHICH, PDCCH, PDSCH, and PUCCH are generated, [4].

As earlier stated, one of the main goals of SON is to automate most of common planning, optimization and operational tasks. As in UTRAN, with the allocation of SC (Scrambling Codes), in E-UTRAN, PCI assignment is a task that requires great care. Bad PCI allocation may lead to interference that can reduce network performance due to call drop rise. Replacing manual PCI planning methods by automatic functions may pose some risks. Depending on propagation environment or terrain morphology, algorithm may fail to correctly predict interference. For that matter, advanced PCI conflict detection and resolution mechanisms are needed to maximize network availability and reduce interference probability.

To provide PCI conflict detection and resolution mechanism two algorithms were implemented, respectively. The first algorithm is based on the one proposed in [5] witch, through joint collaboration with the ANR function (later explained) and using UE measurements reports, detects PCI conflicts. In addition to the algorithm presented in [5], periodic measurements reports are also considered to increase PCI conflict detection probability. The work presented in [5] also presents a mechanism based on transmission gaps where UEs can measure surrounding neighbours while serving cell is not transmitting and thus increase PCI conflict detection probability. This latter mechanism was not considered because it is not clear as to how the UE can distinguish serving cell signal from others when a near cell contains the same PCI as the serving cell. Anytime a cell receives a measurement report the algorithm presented in Figure 1 is set. In Figure 1, if local cell NRT (Neighbour Relation Table) is not empty, the algorithm checks if reported ECGI exists.

If exists, the algorithm checks if the corresponding NR (Neighbour Relation) PCI is different from reported cell PCI. If different the algorithm proceeds to the PCI resolution process.

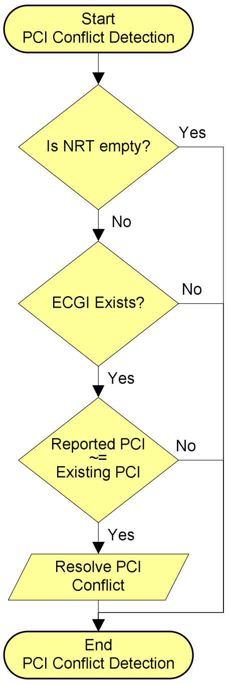

Figure 1: PCI conflict detection algorithm.

Once a PCI conflict is detected, a designated resolution algorithm takes place. In this algorithm, a new PCI is assigned to the conflicting cell. As also described in [5], to avoid new conflicts, a compilation of a set of locally conflicting PCIs is made by retrieving the PCIs of the neighbours and neighbours of neighbours to the selected conflicting cell. In Figure 2, if a cell has detected a PCI conflict, the resolution algorithm starts by contacting the conflicting cell. Once the conflicting cells are notified about the PCI conflict, a new PCI generation process begins. This process starts by gathering all neighbour cells PCI. For each neighbouring cell, PCIs are gathered from their neighbouring cells. Once all neighbouring PCI are gathered, a new PCI is generated excluding the ones previously detected. This new PCI may be generated taking into account a pre-defined list of available PCI, provided during configuration download, or can be locally generated as follows:

$$PCI = 3N_{ID}^{(1)} + N_{ID}^{(2)} \qquad (1)$$

where $3N_{ID}^{(1)}$ is the Physical Cell Identity Group raging from 0 to 167 and $N_{ID}^{(2)}$ the Physical Layer Identity raging from 0 to 2.

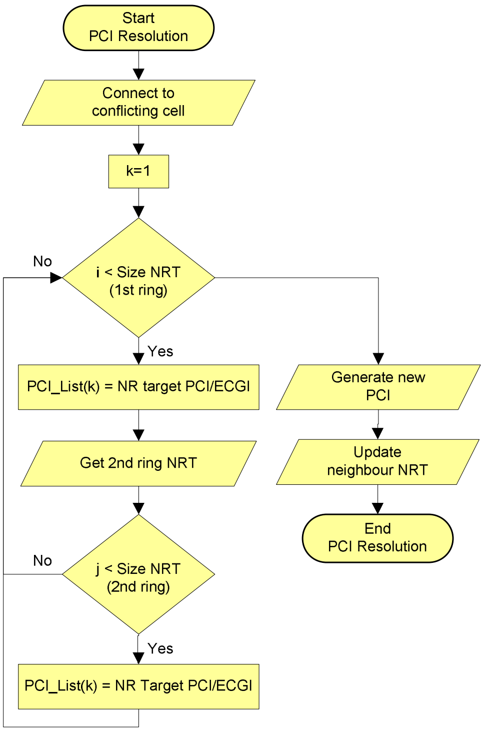

Figure 2: PCI resolution algorithm.

3.2 ANR

Neighbour relation creation is one of the most intensive and important tasks during network planning. Typically neighbour planning is based on tools that, using drive test and networks information can predict signal level and thus help in neighbour's definition. By automatically define neighbours based on UE reports, better mobility can be achieved since missing neighbour situations will be avoided and thus post-integration optimization is no longer needed.

Implemented at cell level, the ANR function aims to automatically create neighbor relations based on UE triggered or periodic measurements reports. Based on [3] an ANR algorithm was implemented to provide automatic neighbour creation. In Figure 3, once a measurement report event condition is fulfilled, most likely A3 or A5 as stated in [3], an intra-frequency handover is triggered. Once the eNodeB receives UE measurement report, a coverage evaluation takes places and a handover decision is made. This handover decision is based on RSRP (Reference Signal Received Power) and RSRQ (Reference Signal Received Quality) measurements from UE neighbouring cells. If eNodeB can identify a candidate neighbouring cell from whose coverage conditions are better, the handover proceeds. In case handover is started, the ANR function request the UE to get the candidate cell ECGI (E-UTRAN Cell Global Identifier). Having received the candidate cell ECGI, if this already exists in NRT, a PCI conflict detection procedure, as stated in section 3.1, takes place. Once the PCI conflict detection procedure is made an X2 connection to the target eNodeB is made in order to exchange NRTs. During NRT exchange, beyond the resource reservation, PCI conflict detection is also made. Finally, local NRT is updated and handover procedure is terminated by sending a connection reconfiguration message to the UE.

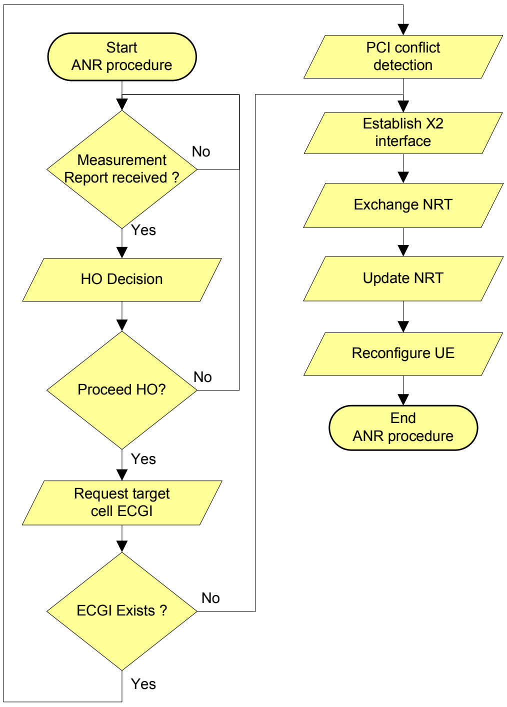

Figure 3: ANR algorithm.

3.3 Handover Optimization

As mentioned, one of the SON main goals relies on the automatic optimization of radio parameters. One of these functions is the automatic handover (HO) parameter optimization. Based on performance indicators, this function allows each cell to readjust the Hysteresis and Time-To-Trigger (TTT) parameters, avoiding failed handovers, dropped calls or ping-pong effect.

In order to keep continuity of communication, enhanced capacity and good user perceived QoS, evaluation methodologies are needed. Therefore, Handover Performance Indicators (HPI) must be calculated. In this simulator the implemented optimization algorithm is based on the one described at [6] which takes into account the Ping-Pong Handover Performance Indicator ($\mathrm{HPI_{HPP}}$) to optimize Hysteresis and TTT values. The $\mathrm{HPI_{HPP}}$ measures the event rate where a call is handed over from cell A to cell B and is handed back to cell A in period of time that is less than a designated critical time ($\mathrm{T_{crit}}$). It is calculated as the number of ping-pong handovers ($\mathrm{N_{HOpp}}$) divided by itself plus the number of non-ping-pong handovers ($\mathrm{N_{HOnpp}}$) and the number of failed handovers ($\mathrm{N_{HOfail}}$),

$$HPI_{HPP} = \frac{N_{HOpp}}{N_{HOpp}+N_{HOnpp}+N_{HOfail}}. \quad (2)$$

Using cell measured $\mathrm{HPI_{HPP}}$, this algorithm continuously search for the best values at any time. Additionally, the UE type of traffic and speed is taken into account for a more accurate handover decision.

4 SYSTEM-LEVEL SIMULATOR OVERVIEW

4.1 Simulator Overview

The System-Level Simulator provided by [1] is a non-commercial open source simulator available for academic research. This simulator allows the study of various aspects related to cell planning, scheduling and interference. Developed in Matlab®, this Object-Oriented Programming (OOP) simulator is well organized, presenting a good understandable and maintainable structure that suits for development and testing of new algorithm and functions. For this matter, it was decided to adopt this simulator as the basic foundation for the developed LTE SON simulator.

4.2 Additional Features

By implementing additional functions together with a graphical user interface (GUI), the System-Level Simulator is able to simulate a user customized LTE SON network. Among others parameters, the proposed simulator allows the specification of the following parameters:

- eNodeB geographic location, and height.
- Antenna orientation, radiation pattern, Mechanical Down Tilt (MDT) and Electrical Down Tilt (EDT).
- Pathloss model including Modified COST 231 [7] and 3GPP TR36.942 [8].

Figure 4 shows a simulator network scenario example. In this scenario, a georeferenced topographic map is loaded. Each eNodeB is manually placed and configured. UEs are pseudo randomly placed, and their direction of movement is also defined in a pseudo-randomly matter.

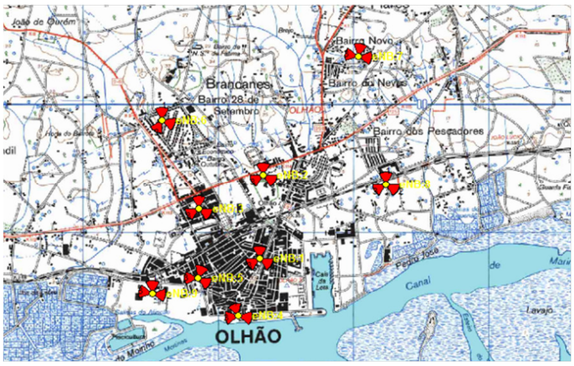

Figure 4: Simulation scenario example (Olhão, Portugal).

5 SIMULATION

5.1 Simulation Parameter

To evaluate the simulator performance, a real network scenario is configured. Table 1 presents the general parameters taken into account in each simulation.

Parameter	***Value***
Propagation Enviroment	Urban Area
Frequency	2,6 GHz
Cellular Layout	9 cell sites, 3 sectors per site
Propagation Model	Urban Macro, [7] (TS 36.942)
Shadow Fading	Log-normal, μ=0; σ=10 (dB)
Multipath Fading	3GPP VehA
Minimum Coupling Losses (BS↔UE)	70 dB (TS 36.942)
Number of Users	270 (10 users per cell)
Total BS TX power	43 dBm – 5 MHz carrier

Table 1: Simulation Parameter

The specific parameters of each algorithm are presented in the following sections. The type of traffic remains the same along each system-level simulation. There is no transmission delay between UE and eNB communication. Due to computational requirements, time values (expressed in TTI (Transmission Time Interval)) are normalized. All algorithms take into account the signalling sequence order proposed in [3].

6 SIMULATION RESULTS

6.1 PCI Detection and Resolution

To evaluate the PCI conflict detection and resolution algorithm performance, a new eNodeB commissioning was simulated. To new eNodeB, already in use PCIs will be assigned. The percentage of blocked users due to interference caused by conflicting cells is used as metric to evaluate network stability during integration. Figure 5 presents the initial scenario. In this scenario, "eNB 5" represents the new BTS. As can be seen, the PCI assigned to "eNB 5" will interfere with the ones assigned to already existing "eNB 4". The main goal here is to the algorithm discover the conflicting PCI and assign new ones to avoid interference.

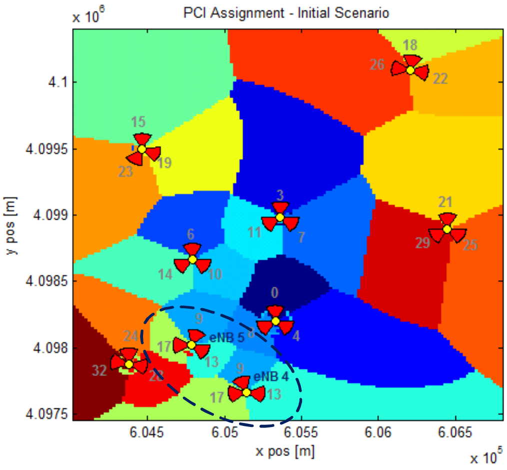

Figure 5: Initial scenario for PCI conflict detection and resolution

Figure 6 presents the final scenario after simulation using the developed algorithm. It can be seen that eNodeB 4 and 5 have now different assigned PCI and that there isn't any near cell with the same PCI.

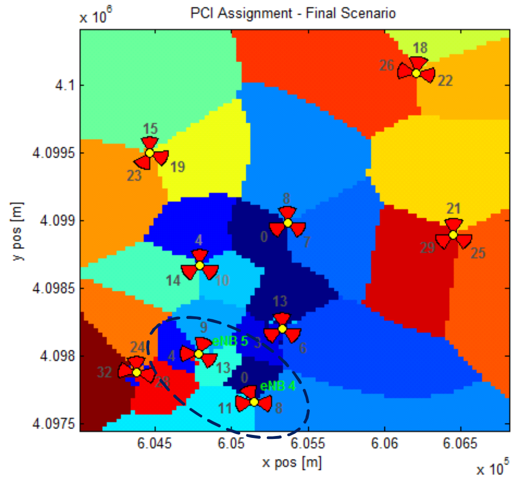

Figure 6: Final scenario for PCI conflict detection and resolution

Figure 7 presents the number and percentage of blocked users during a 500 TTI simulation. As can be seen, blocked users are progressively eliminated and so, it can be concluded that network stability is achieved at the end.

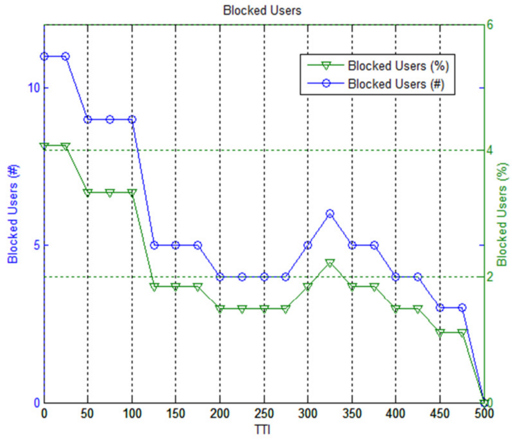

Figure 7: Blocked users do to PCI interference between cells close to each other

The results presented in [5] are not clear as to the effectiveness achieved by the algorithm since it is considered that the network stability is achieved when all expected neighbor relationships are created which may not be entirely true. So it was not possible to establish a term of comparison between our results and those presented in [5].

6.2 ANR

As stated in [1], to reduce run-time computational complexity, the measured link quality is abstracted using SINR (Signal to Interference and Noise Ratio) as metric. Each UE has a sensibility of about -133 dBm (link-budget). When accessing a new cell, during handover process, if measured RSRP is lower than UE sensibility the handover will fail. In the same way, if UE received SINR drops below a certain value, when accessing a new cell, the handover will also fail. Figure 8 show the 50 TTI average handover count and fail percentage for a required SINR of -10 dB for a 1 Mbps dual-antenna receiver terminal according to the link-budget presented in [9].

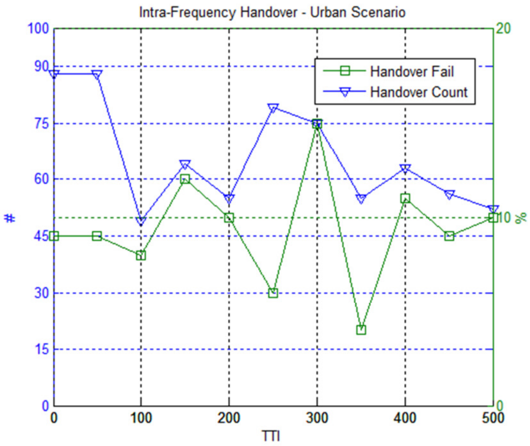

Figure 8: Intra-frequency handover count and fail percentage for a minimal required SINR of -10 dB and a dual antenna receiver.

As can be seen there is an average handover failure of about 10 % mainly due to poor signal coverage areas. These areas exist because considered simulation area is larger than predicted coverage area due to polygon draw limitations. It can also be seen a large number of performed handovers. These results allow us to conclude that the implemented algorithm is properly working.

6.3 Handover Optimization

As previously mentioned handover optimization algorithm takes into account the speed and type of service of the UE. To properly evaluate the performance of Algorithm, different UE types of service and speeds are simulated. Table 2 presents the initial simulation parameters taken into account for handover optimization as described in [7]

Parameter	***Value***
Initial {Hysteresis,Time-To-Trigger)	{3 dB ,3 TTI}
Critical Time (TCrit)	15 TTI
Delta Hysteresis Increment/Decrement	1 %
Delta TTT Increment/Decrement	50 %
Initial Good Performance Counter	5 TTI
Initial Bad Performance Counter	5 TTI
Simulation Time	500 TTI
TTI Length	1 ms

Table 2: Handover Optimization parameters, [7]

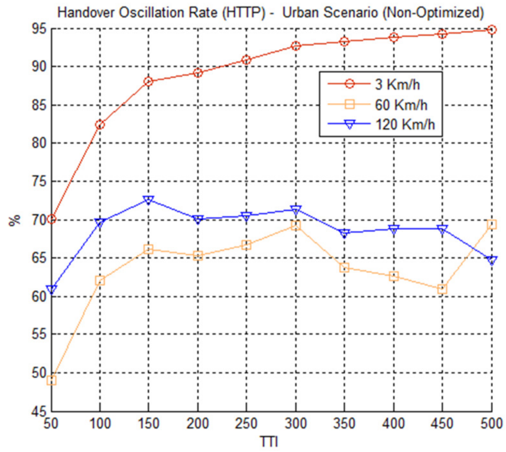

Figure 9: Handover Oscillation Rate for HTTP service without handover optimization.

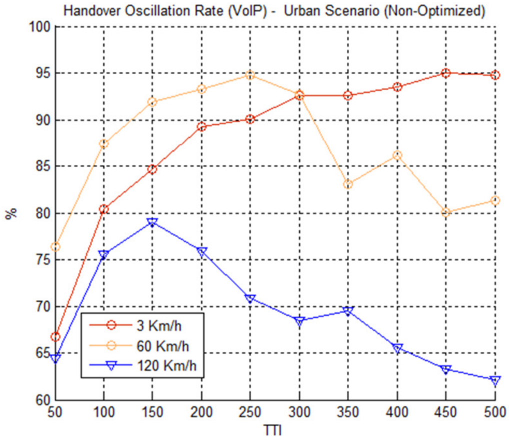

Figure 10: Handover Oscillation Rate for VoIP service without handover optimization.

Figures 9 and 10 show the results for a non-optimized scenario where Hysteresis and TTT are fixed and for HTTP and VoIP traffic, respectively. The results are expressed in HPI_{HPP} rate during 500 TTIs for the case where the UE maximum speed is 3, 60 and 120 Km/h.

As can be seen, in both UE traffic type and speed scenarios, a high percentage of handovers are classified as ping-pong handovers and, as expected, at high speed, the HPI_{HPP} percentage is smaller, reaching 64 and 62% for HTTP and VoIP service types, respectively.

In the sequence, Figures 11 and 12 present the equivalent results but now considering the handover optimization function.

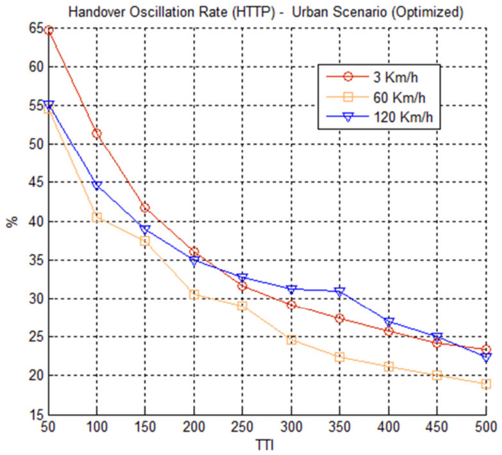

Figure 11: Handover Oscillation Rate for HTTP service type using handover optimization.

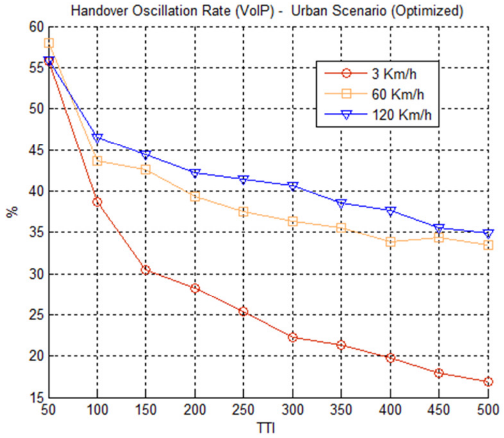

Figure 12: Handover Oscillation Rate for VoIP service type using handover optimization.

As can be seen, in both types of service, and for overall UE speeds, there is a significant HPI_{HPP} reduction especially at low speeds. When using HTTP, there is a reduction of about 71% on HPI_{HPP} when UEs are moving at 3 Km/h. As the speed increases, the HPI_{HPP} reduction decreases. When using VoIP, there is also a significant reduction of about 70% on HPI_{HPP} when UEs are moving at 3 Km/h. Similar to the HTTP service, as the speed increases, the HPI_{HPP} reduction also decreases. Finally, it can also be seen a larger reduction in HPI_{HPP} when using HTTP service type.

When comparing to the results presented in [7], where an empirical scenario is used, the obtained results show that a greater HPI_{HPP} reduction is indeed achieved when using a real scenario. Table 3 presents the final optimized averaged Hysteresis and TTT for HTTP and VoIP services and for each simulated UE speed.

	3 Km/h	60 Km/h	120 Km/h
HTTP	{2,4;10}	{2,01;11}	{2,8;12}
VoIP	{2;8}	{2,0;10,8}	{2,5;10}

Table 3: Handover Optimization parameters, [6]

As presented in [7], in overall, Hysteresis is smaller when service type is VoIP when compared with HTTP. However, at low speed scenarios, Hysteresis is higher when compared to the high speed scenarios.

7 CONCLUSION

In this paper, we propose a LTE SON capable simulator through which self-configuration and self-optimization functions can be visualized and evaluated over user defined scenarios. In this simulator, PCI conflict detection and resolution, ANR and Handover Optimization functions are implemented and evaluated using a real network scenario. The obtained results show an overall benefit of the developed simulator in predicting and gathering the best configuration parameters for SON based networks. When compared to [2], the developed simulator reveals himself more practical and useful thanks to greater detail that can be achieved in each scenario and to added handover optimization function that can estimate optimal Hysteresis and TTT values. Due to the simulation conditions considered in [5] a proper comparison in the PCI detection and resolution functions was not possible. Still, the developed algorithm is able to eliminate conflicts of PCI using only UEs measurement reports. With regard to the handover optimization function the achieved results reveal themselves better when using a real scenario compared to the ones obtained with the empirical scenario used in [6].

8 ACKNOWLEDGEMENTS

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