A Hybrid Neighbor Optimization Algorithm for SON based on Network Topology, Handover Counters and RF Measurements

D. Duarte[1], A. Martins[1,2], P. Vieira[1,3] and A. Rodrigues[1,4]
[1]*Instituto de Telecomunicaçõoes (IT), Lisbon, Portugal*
[2]*CELFINET, Consultoria em Telecomunicações Lda., Lisbon, Portugal*
[3]*Instituto Superior de Engenharia de Lisboa (ISEL), ADEETC, Lisbon, Portugal*
[4]*Instituto Superior Técnico (IST), Lisbon, Portugal*

Keywords: Self-Organizing Networks, Neighbor Cell List, Optimization, Radio Frequency Measurement, Handover Statistics.

Abstract: With the increasing complexity of current wireless networks, it became evident the need for Self-Organizing Networks (SON), which aims to automate most of the associated radio planning and optimization tasks. Within SON, this paper aims to optimize the Neighbor Cell List (NCL) for radio network cells. An algorithm composed by three decision criteria was developed: geographic localization and orientation, according network topology, Radio Frequency (RF) measurements collected by drive-tests or traces and Performance Management (PM) counters from Handover (HO) statistics. The first decision, proposes a new NCL taking into account the Base Station (BS) location and interference tiers, based on the quadrant method. The last two decision criteria consider signal strength and interference level measurements and HO statistics in a time period, respectively. They also define a priority to each cell and added, kept or removed neighbor relation, based on user defined constraints. The algorithms were developed and implemented over new radio network optimization professional tool. Several case studies were produced using real data from a mobile operator.

1 INTRODUCTION

According to a recent traffic report published by Cisco®, global mobile data traffic reached 3.7 exabytes per month at 2015, and up to 2.1 exabytes per month at 2014. 4^{th} Generation (4G) traffic exceeded 3^{rd} Generation (3G) traffic for the first time in 2015. Although 4G connections represented only 14 % of mobile connections in 2015, they already account for 47 % of mobile data traffic, while 3G connections represented 34 % of mobile connections and 43 % of the traffic. In 2015, a 4G connection generated six times more traffic, on average, than a non 4G connection (Cisco, 2016).

With the already existing 3G/4G standards, especially with the Long Term Evolution (LTE) (3GPP, 2010), more complexity is added to current networks. The co-existence of multiple standards, mostly from different suppliers, and the increasing demand of 3^{rd} party services, asks for more management effort from mobile network operators. The main goal for SON implementation is to automate most of the common planning, optimization and operational tasks, reducing operators operational and capital costs. Crossed sectors detection is an example of automatic operational tasks. It is one of the most common implementation errors when deploying base-stations (Duarte et al., 2015).

The increasing network intensification, even with more small cells and more Heterogeneous Networks (HetNets) is also coming rapidly (Ramiro and Hamied, 2012). This ongoing change will bring more multi-standard demands and multi-vendor challenges. Efficient and effective operations must overcome such complexity. Hence, the only way these challenges can be cost-effectively, efficiently and humanely overcome is through the use of more automated and autonomous systems.

The SON use cases can be structured as Self-Planning, Self-Deployment, Self-Optimization and Self-Healing. Network optimization is a continuous closed-loop process encompassing periodic performance evaluation, parameter optimization and redeployment of the optimized parameter values into the network. The optimization decisions can be carried out by human subjects or computerized systems, lead-

Duarte, D., Martins, A., Vieira, P. and Rodrigues, A.
A Hybrid Neighbor Optimization Algorithm for SON based on Network Topology, Handover Counters and RF Measurements.
DOI: 10.5220/0005958201450151
In *Proceedings of the 13th International Joint Conference on e-Business and Telecommunications (ICETE 2016) - Volume 6: WINSYS*, pages 145-151
ISBN: 978-989-758-196-0

ing the last to self-optimization. The optimization algorithms will aim at tuning parameter values in order to achieve a well-defined goal, expressed in terms of coverage, capacity, quality or even a controlled combination of them, taking into consideration that any optimization activity always involves implicit trade-offs between these key variables.

Within self-optimization, this paper aims to optimize the NCL for radio network cells. The paper contribution is incremental to previous published work (Duarte et al., 2014), incorporating recent research leading to new results.

The paper is organized as follows. Section 2 overviews the NCL issue. Section 3 presents the proposed algorithm, followed by the simulation results and analysis presented in Section 4. Finally, conclusions are drawn in the final section.

2 NEIGHBOR CELL LIST OVERVIEW

NCL optimization pertains to the optimization of the existing neighbor list of a cell plus the neighbor lists that are applied to the neighboring cells. This considers the cells that are already in a production environment, as well as the new cells, for which completely new neighbor lists have to be generated. The target scope covers intra-frequency, inter-frequency and inter-technology neighbors. The HO is one of the most critical issues in cellular networks. It enables connection continuity for mobiles during mobility, while allowing the efficient use of resources, like time and frequency reuse between cells. Most of todays cellular standards use mobile-assisted HO, in which the mobile measures the signal quality of neighbor cells and reports the measurement result to the network. If the signal quality from a neighbor cell is better than the serving cell by a handover margin, the network initiates an HO to that cell (Nguyen and Claussen, 2010). The configuration and NCL management are one of the most important issues to provide seamless mobility for User Equipment (UE)s in the radio network. Between handover candidate cells, each base-station has a connection of direct interface with other base-stations and messages related to the HO procedure are exchanged through the radio interface in order to prepare HO execution. Each cell maintains a list of cells that are the targets for connection.

In LTE without SON mode of operation, a human system operator determines the NCL and uploads it into the evolved NodeB (eNB). On the other hand, in LTE systems under SON mode of operation, also called Autumatic Neighbor Relation (ANR), each eNB is supposed to configure and manage the NCL autonomously. Firstly, the initial NCL has to be configured without any cooperation with the UE when a new eNB has been deployed since, initially, there are not any activated UEs belonging to the new eNB. Secondly, the NCL needs to be constantly updated based on the change of network topology by collecting the information from the UE (Kim et al., 2010). The basic condition of defining a neighbor relation between cells is the coverage overlap with each other, and forming a HO region, as presented in Fig.1. In a sectored cell environment, sector cells belonging to the same eNB are neighbors. The measurements reported by the UE, such as Reference Signal Received Power (RSRP) and Reference Signal Received Quality (RSRQ) are then used by an optimization algorithm implemented in the eNB, in order to continuously update the list of neighboring cells.

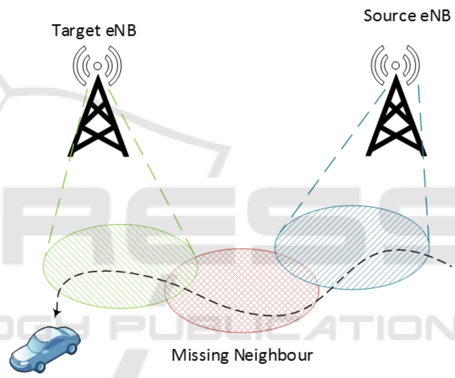

Figure 1: Missing neighbor relation (Duarte et al., 2014).

It is important to note that a delay is introduced when the HO is attempted into a neighbor cell that is not included in the NCL. If the NCL includes any cells which are not supposed to be the neighbor cells, the system overhead is wasted due to unnecessary management and maintenance of direct interface between neighbor cells. Therefore, with or without ANR, accurate NCL configuration is demanded to prevent HO delay and save system overhead (Kim et al., 2010), which motivates the current research issue.

3 THE ENHANCED NCL ALGORITHM

This section presents the proposed algorithm. A description of the algorithm is made along with the used line of thought in NCL optimization.

3.1 Algorithm Overview

The NCL optimization flowchart is presented in Figure 2. The network topology is one of the inputs. It contains the BS geographic location, antenna configuration and orientation, as well as the cell identifiers and Primary Scrambling Code (PSC) or Physical Cell Identity (PCI). Another considered input is the initial NCL configuration of each cell, with all the defined neighbor relations. Finally, geo-positioned traces (Vieira et al., 2014) and drive-test data are available, along with PM statistics, focusing on the number of HO for each defined neighbor relation.

The initial NCL is the starting point, if it exists. In order to optimize the NCL, three distinct criteria were developed in the algorithm, which will be described in the following: planning, through network topology, HO statistics and RF measurements. They also define a priority to each cell considering several calculation constraints, introduced by the operating radio engineer.

Thus, the final goal is to prepare a global prioritized list for each cell considering the three criteria, simultaneously. The output will be an optimized NCL that maximizes the HO target, based on several aspects of the implemented network, and user constrains (Duarte et al., 2014). Finally, cells of higher priority are added, according to Table 1, only limited by the maximum NCL size. With this approach, the co-located cells are always added to new NCL and neighbor relations with good HO performance are kept. Nearby cells must be on the NCL. It's also possible to identify missing neighbors in overlap conditions, through the use of drive-test measurements (Sousa et al., 2015). These candidate cells will be added to the NCL. If the list is yet not full, then low priority candidate cells will be added or kept, by planning criteria, the last with HO performance below thresholds.

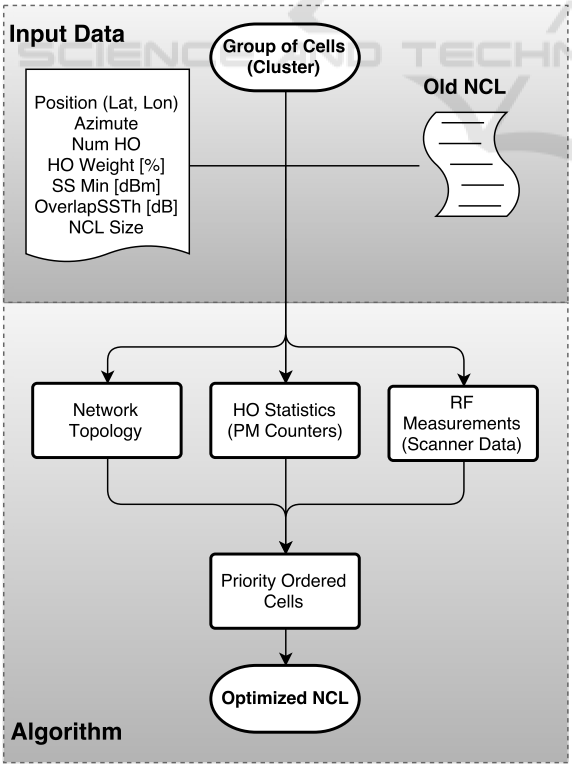

Figure 2: Proposed algorithm flowchart.

Table 1: Priority ordered cells.

Criteria	Priority
Co-Loc	1
HO	2
Distance	3
DT	4
Plan	5
HObellowTh	6

3.2 Network Topology Decision

It is based on the distance from the source cell to the target cell and antenna orientation. After processing the network topology, the base-station's cell information is available. Hence, the distance between cells is calculated and one proximity ranking is defined for each target cell. Thereafter, the several tiers are defined, using classical hexagonal radio planning theory, where the six closer sites are considered as the first tier. The first tier and adjacent cells are mandatory, and must appear in the new NCL. These cells are classified with priority 3. This calculation is based in the source/target cell location and orientation. The addition of the target cells to the NCL should follow the scheme illustrated in Figure 3 as the rules in Table 2. Firstly, the source cell orientation is verified by its azimuth. Assuming a source cell, represented in orange, belonging to the first quadrant (1°Q), *i.e.*, between 0° and 90°, every target cells directed there, must be added to the NCL. For the remaining quadrants, only those sectors directed to the source cell area service (in this case, the 1°Q), are added to NCL with priority 5. In order to know the position of each target cell, *i.e.*, its quadrant, it is calculated the angle between cells, by own location and using its geographic coordinates (Duarte et al., 2014).

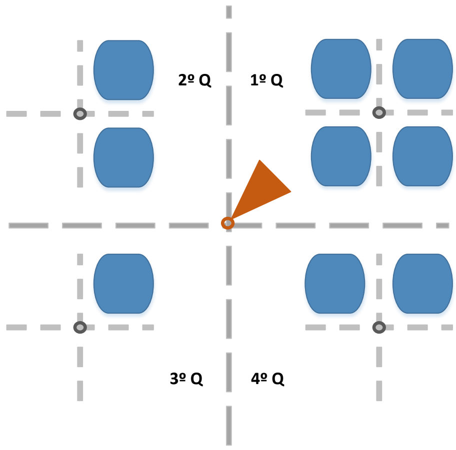

Figure 3: The quadrant theory.

Table 2: The quadrant theory bounds.

Target Quadrant Location	Eligible Target Sector
[0°; 90°]	[0°; 360°]
[90°; 180°]	[0°; 90°] & [270° ; 360°]
[180°; 270°]	[0°; 90°]
[270°; 360°]	[0°; 180°]

3.3 Handover Statistics Decision

The HO statistics decision criteria aims to keep cells belonging to the initial NCL. The PM counters are collected to each cell for a large period, e.g. one month. If the existing HO number, $NumHO$, or the HO ratio, $HoWeight$, in the neighbor relation is above a certain thresholds introduced by the user, the cell is marked with priority 2 to be kept, see Figure 4. This is useful, since it allows to remove cells with low HO count from the source cell. These criteria does not allow to add new cells.

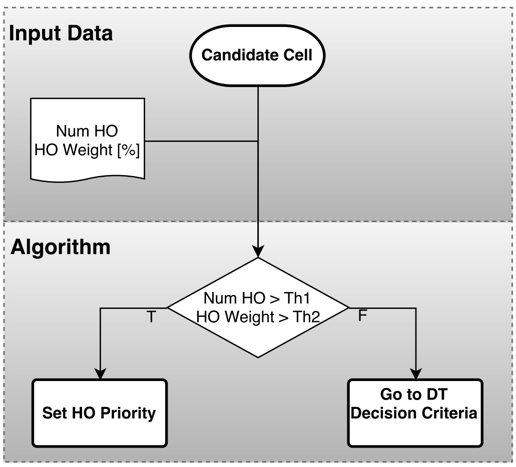

Figure 4: Handover statistics decision flowchart.

3.4 RF Measurements Decision

The RF measurement decision criteria adds or keeps target cells to the new NCL, if its signal strength level is above a certain threshold, minimum signal strength $SSMin$, collected by drive-test or network traces (Carvalho and Vieira, 2011). Additionally, it has to satisfy all overlap conditions, see Equation 1 and Equation 2 for 3G networks:

$$|RSCP_s - RSCP_t| < OverlapSS_{Th} \quad (1)$$

$$|Ec/Io_s - Ec/Io_t| < OverlapQual_{Th} \quad (2)$$

where $RSCP_s$ and $RSCP_t$ are the source and target cell received signal strength, respectively, in each sample. Ec/Io is the quality level.

The algorithm uses the source cell corresponding measurements and, for each sample, checks the signal and quality levels for the target cells. The target cell is marked with priority 4 if it satisfies Equation 1 and Equation 2, for a minimum number of samples $NumSamples$. This approach can also be made for quality measurements. The RF Measurement decision flowchart is presented in Figure 5.

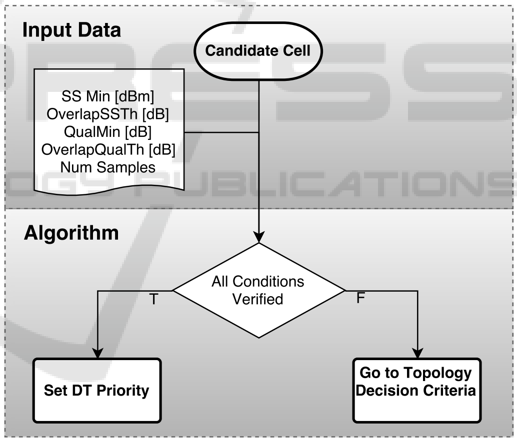

Figure 5: RF Measurements decision flowchart.

4 APPLYING THE ALGORITHM TO LIVE NETWORKS

This section presents the main results considering the neighbor cell list optimization. The algorithm has been tested in several cities for large cell clusters. For one of the clusters, 1238 cells were optimized, approximately 152 sites with three 3G carriers (F1, F2 and F3), for an intra-frequency analysis. This iteration, as mentioned before, was performed using scanner data information collected by drive test, see Figure 6, and Soft-HO statistics. In this test case, the following thresholds in Table 3 were used. These thresholds are empirical values estimated from several simulations. By changing the thresholds, more or less cells are added to the new list. If we increase the HO parameter, more cells will be removed. On the other hand, increasing the *SSMin* and *NumMinSamples*, fewer cells are added by drive test.

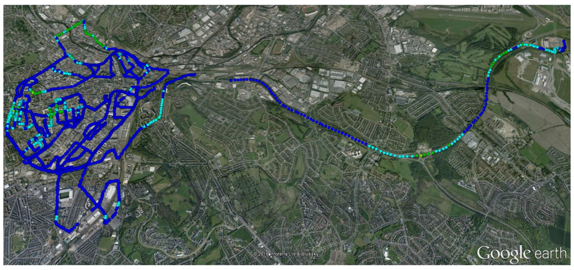

Figure 6: Drive test in cluster analysis.

Table 3: Input parameters.

Parameter	Value
NCL Size	28
NumMinHO	1000
HO Weight [%]	0.1
SS Min [dBm]	-95
OverlapSSTh [dB]	6
OverlapQualTh [dB]	8
NumMinSamples	5

Table 4 shows all the algorithm suggestions.

Table 4: Cluster results.

Action / Frequency	F1	F2	F3
Add	3410	3674	2446
Co-Loc	-	-	-
DT	30	27	22
Distance	274	303	231
Plan	3106	3344	2193
Keep	5653	5306	5697
Co-Loc	646	646	572
HO	2927	2788	3783
DT	83	77	48
Distance	351	344	207
Plan	1492	13339	994
HOBelowTh	154	112	93
Remove	1957	1652	1917

Directly from the results, we can find that there isn't any intra-frequency co-located neighbor relation missing. 9498 neighbor relations are being kept due to HO statistics thresholds, representing 30% of all the suggestions. Scanner data samples provided 287 suggestions, both existent neighbor relations, to keep, and new neighbor relations to be added. With the HO statistics information, RF measurements and network topology, the algorithm suggests 5526 neighbors to be removed, since they are below the thresholds defined for input. In total, there are 30% suggestions of additions, 52.6% to keep and 17.4% of removals. This means that most of neighbor relations are well defined, but there are a large percentage of missing neighbors.

4.1 Case Study - Network Topology (Planning)

Using only the network topology, site location, distance to the source and orientation, it is possible to get a new neighbor cell list. This generated list, to the source cell (blue), does not take into account the old list, only suggests adding neighbor relations. This criteria, used individually, allows to plan the neighbor list for a new site, when neither statistics nor scanner data exists. Applying the quadrant theory described above, the algorithm added (green) 26 neighbor relations, as seen in Figure 7.

Figure 7: Neighbor cell list planning.

4.2 Case Study - HO Statistics (PM Counters)

With only HO statistics, the algorithm proposes to remove all neighbor relations which aren't verifying the conditions, according to user input thresholds. In this test case, the cells with less than 1000 HOs and neighbor relations ration below 0.1% in one month, are removed. The remaining relations are kept, see Figure 8 and Table 5.

Table 5: Test Case - HO Statistics actions.

Action	Number Cells	Color
Kept	18	Yellow
Removed	9	Red

Figure 8: Neighbor cell list based in HO statistics.

4.3 Case Study - RF Measurements (Scanner Data)

With this criteria, the algorithm only finds possible missing neighbor relations. The Figure 9 shows that were added 12 neighbors in overlap conditions. It means that at least five samples, the Received Signal Code Power (RSCP) level between source and each target cell is bellow to 6 dB. The difference between Ec/Io is less than 8 dB. All samples (blue circles) are -95 dBm of minimum RSCP level.

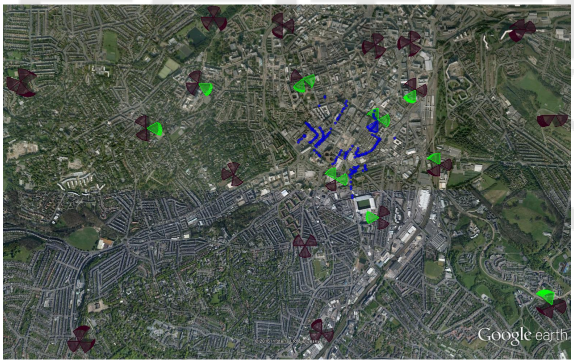

Figure 9: Neighbor cell list based in scanner data.

4.4 Case Study - All Decision Criteria

Finally, all criteria are joint. Thus, it is possible to keep neighbor relations with a large HO number and add missing neighbors with overlap, serving in the same area, through scanner data. It is also allowed to add or keep cells from network topology. The quadrant method, planning algorithm based on azimuth and site location, is important to complete the new neighbor list. Table 6 shows all the actions proposed for the new neighbor cell list.

With high priority, co-located cells were kept . After this, HO priority allows keeping the neighbor relations with good HO performance (16 cells). Only one

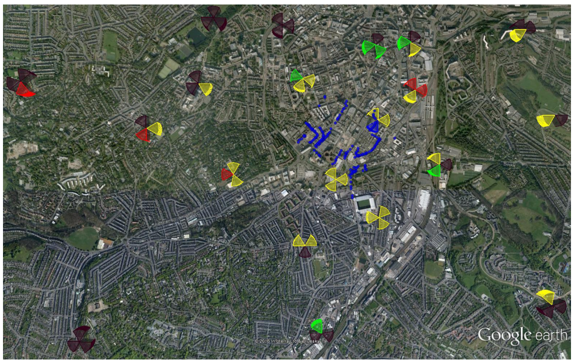

Figure 10: Neighbor cell list optimized.

Table 6: Neighbor Cell List actions.

Action	Number of Cells	Color
Add	6	Green
Co-Loc	-	
DT	-	
Plan	6	
Keep	22	Yellow
Co-Loc	2	
HO	16	
DT	1	
Plan	3	
Remove	5	Red

Neighbor Relation (NR) was kept through RF measurement, priority 4. As seen, there are more cells in overlap conditions, but HO statistics are more prioritized. Finally, 9 NRs were added/kept due to planning priority. Five neighbors were removed from the old list. These last cells fail the input thresholds or the NCL size is full and own priority is below other candidates. Table 7, in appendix, shows the optimized cell list generated by the algorithm and the final action to apply to each NR.

5 CONCLUSIONS

In this paper, a neighbor cell list optimization algorithm for radio access networks is proposed. Three distinct criteria were developed: network topology, HO statistics and RF measurements. The first criteria, proposes a new NCL taking account the site location, azimuths and interference tiers, based on the quadrant method. The last two consider signal strength measurements and HO statistics, respectively. They also define a priority to each cell enabling neighbor relation addition/removal based on user defined constraints. The algorithms were implemented over an already existing radio network optimization professional tool. Several case studies were produced using real data from a mobile operator. These algorithms should be combined, in order to produce a globally optimized NCL that maximizes the HO performance, based on network specifics, and user constrains.

ACKNOWLEDGEMENTS

This work was supported by the Instituto de Telecomunicações and the Portuguese Foundation for the Science and Technology (FCT) under GOLD (PEst-OE/EEI/LA0008/2013).

REFERENCES

3GPP (2010). LTE; Evolved Universal Terrestrial Radio Access (E-UTRA) and Evolved Universal Terrestrial Radio Access Network (E-UTRAN); Overall description; Stage 2. TR 36.300, 3rd Generation Partnership Project (3GPP).

Carvalho, M. and Vieira, P. (2011). Simulating long term evolution self-optimizing based networks. In *Conf. on Electronics, Telecommunications and Computers - CETC*, volume 1, pages 1–1.

Cisco (2016). Cisco Visual Networking Index: Global Mobile Data Traffic Forecast Update, 2015-2020. Technical report, Cisco.

Duarte, D., Vieira, P., Rodrigues, A., Martins, A., Silva, N., and Varela, L. (2014). Neighbour List Optimization for Real LTE Radio Networks. In *Wireless and Mobile, 2014 IEEE Asia Pacific Conference on*, pages 183–187.

Duarte, D., Vieira, P., Rodrigues, A. J., and Silva, N. (2015). A New Approach for Crossed Sector Detection in Live Mobile Networks based on Radio Measurements. In *Wireless Personal Multimedia Communications Symp. - WPMC*, volume 1.

Kim, D., Shin, B., Hong, D., and Lim, J. (2010). Self-configuration of neighbor cell list utilizing e-utran nodeb scanning in lte systems. In *Consumer Communications and Networking Conference (CCNC), 2010 7th IEEE*.

Nguyen, V. M. and Claussen, H. (2010). Efficient Self-Optimization of Neighbour Cell Lists in Macrocellular Networks. In *Personal Indoor and Mobile Radio Communications (PIMRC), 2010 IEEE 21st International Symposium on*, pages 1923–1928.

Ramiro, J. and Hamied, K. (2012). *Self-Organizing Networks (SON): Self-Planning, Self-Optimization and Self-Healing for GSM, UMTS and LTE*. Wiley Publishing, 1st edition.

Sousa, M., Martins, A., Vieira, P., Oliveira, N., and Rodrigues, A. (2015). Caracterizacao da Fiabilidade de Medidas Rádio em Larga Escala para Redes Auto-Otimizadas. In *9. Congresso do Comité Português da URSI - "5G e a Internet do futuro"*.

Vieira, P., Silva, N., Fernandes, N., Rodrigues, A. J., and Varela, L. (2014). Improving Accuracy for OTD Based 3G Geolocation in Real Urban/Suburban Environments. In *Wireless Personal Multimedia Communications Symp. - WPMC*, volume 1.

APPENDIX

In this appendix, a optimized neighbor cell list is show for the test case present above. The Table 7 indicates all NR proposals ordered by algorithm priorities.

Table 7: Optimized neighbor cell list.

Cell	HO SUCC	Overlap Samples	Priority	Action
A	90485	18	CoLoc	Keep
B	23785	8	CoLoc	Keep
C	65735	54	HO	Keep
D	55432	15	HO	Keep
E	48584	25	HO	Keep
F	41501	50	HO	Keep
G	41259	51	HO	Keep
H	33856	30	HO	Keep
I	18061	8	HO	Keep
J	17138	8	HO	Keep
K	16601	0	HO	Keep
L	11078	5	HO	Keep
M	10924	2	HO	Keep
N	8682	3	HO	Keep
O	2864	0	HO	Keep
P	1950	0	HO	Keep
Q	949	0	HO	Keep
R	724	0	HO	Keep
S	0	16	DT	Keep
T	0	1	Plan	Add
U	0	0	Plan	Add
V	85	0	Plan	Keep
W	182	0	Plan	Keep
X	87	0	Plan	Keep
Y	0	0	Plan	Add
Z	0	0	Plan	Add
AA	0	0	Plan	Add
AB	0	0	Plan	Add
AC	331	0	HObelowTh	Remove
AD	185	0	HObelowTh	Remove
AE	58	0	HObelowTh	Remove
AF	42	0	HObelowTh	Remove
AG	0	0	HObelowTh	Remove