Optimising Handovers in Enterprise Small Cell LTE Networks with Decentralised Mobility Robustness Optimisation (MRO)

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Executive summary

The number of LTE cells deployed is growing rapidly, and will climb much higher as indoor enterprise small cells are deployed in offices, shops and large campuses. A big challenge to successful deployment is for these small cells to form a seamless network. It used to require radio frequency engineers to configure each cell individually, but the number of low-cost small cells to be deployed means that this is no longer practical. There is no alternative but for the cells to self-organize. Node-H is addressing the need for Self-Organising Networks (SON) by building a high degree of automation into its LTE software solution. Among the functions offered by the Node-H SON suite, Mobility Robustness Optimisation (MRO) is an essential building block of enterprise small-cell networks. MRO improves the management of handovers to increase their success rate, prevent losses of connectivity and reduce the signalling load due to mobility-related Radio Link Failures (RLFs). This is done in a decentralized fashion that eliminates the need for costly central servers. Furthermore, the Node-H MRO solution is 3GPP compliant and inter-operable with other 3GPP Rel-9 and later Home eNodeBs (HeNBs) and User Equipments (UEs).

Introduction

The ability to perform handovers between cells is a requirement of any cellular network. Mobility removes location-based anchors, improves the user experience and reduces hardware installation constraints. However, providing a quality mobility service has traditionally relied on the calibration and configuration of mobility parameters by the network operator. In order to reduce network configuration efforts and to allow the network to adapt to changing environments, the concept of Self Organising Networks (SON) has been introduced in the suite of 3GPP protocols.

In the context of SON, Mobility Robustness Optimisation (MRO) refers to a category of procedures that allow cellular networks to select their own set of optimal mobility parameters. Such procedures are to be run autonomously and without human intervention in either a centralized or de-centralized manner across the network. Their objective is to rectify failures due to poorly managed handovers. In other words, they make sure that handovers are triggered when needed, and only if needed.

The figures below show the coverage maps of three cells in an office environment. The coverage area where HeNB 1 is strongest is shown in blue, HeNB 2 is shown in red, and HeNB 3 is shown in yellow. The same network is shown across all figures, and it shows that in different locations a UE with a particular trajectory can experience different issues.

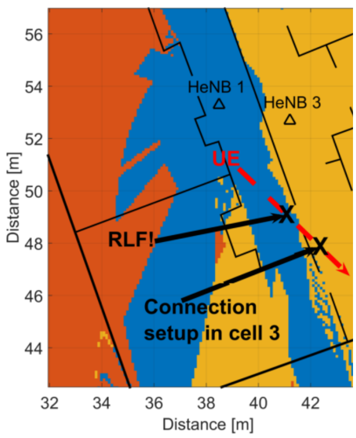

Figure 1: Handover Too Late.

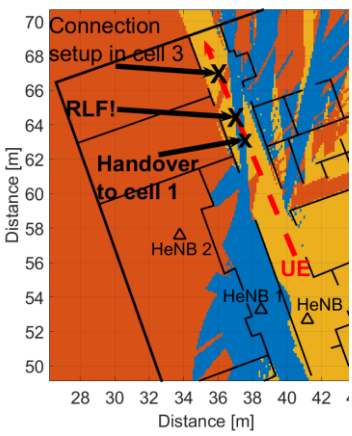

Figure 2: Handover Too Early

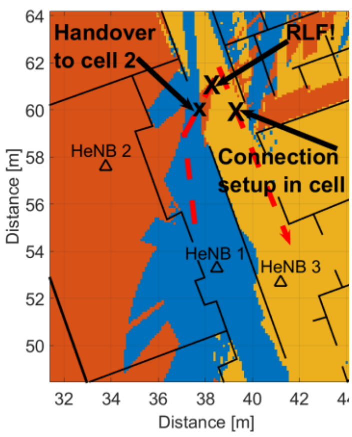

Figure 3: Handover to Wrong Cell.

The three types of mobility problems that MRO attempts to solve are:

- Handover Too Late: “An RLF occurs after the UE has stayed for a long period of time in the cell; the UE attempts to re-establish the radio link connection in a different cell.” Quoted from 22.4.2.2 in TS 36.300 [1]. See Figure 1. As the UE moves from HeNB 1 into the coverage area of HeNB 3 a Radio Link Failure occurs due to rapid deterioration of the signal from cell 1 before a handover can be prepared. This could be due to the UE turning a corner, a heavy door closing fast, etc.

- Handover Too Early: “An RLF occurs shortly after a successful handover from a source cell to a target cell or a handover failure occurs during the handover procedure; the UE attempts to re-establish the radio link connection in the source cell." Quoted from 22.4.2.2 in TS 36.300 [1]. See Figure 2. A UE has moved from the HeNB 3 coverage briefly into an area of HeNB 1 coverage and then out of that coverage again, and a Radio Link Failure occurs due to the signal from cell 1 vanishing in less than the configured time to trigger handovers.

- Handover to Wrong cell: "An RLF occurs shortly after a successful handover from a source cell to a target cell or a handover failure occurs during the handover procedure; the UE attempts to re-establish the radio link connection in a cell other than the source and the target cell." Quoted from 22.4.2.2 in TS 36.300 [1]. See Figure 3. A UE is moving from the coverage of HeNB 1 into the coverage of HeNB 3, but briefly passes through an area where HeNB 2 coverage is strongest. The handover occurs to HeNB 2, instead of HeNB 3, and shortly after the UE is out of coverage of HeNB 2 and an RLF occurs.

Small cell networks in enterprise scenarios usually involve large numbers of HeNBs to guarantee coverage. Unlike in rural or residential deployments, it is precisely in dense multi-cell scenarios such as enterprise that MRO functions can play an important role in improving the network performance. This is because enterprise scenarios typically experience larger numbers of mobility events than, for instance, residential scenarios. This, in addition to their open-access (i.e. non-CSG) nature has motivated varying lines of research into how MRO techniques should be designed. These vary from fuzzy-logic [1] to Q-learning [2] approaches, passing through varying degrees of cooperativeness between the cells. Node-H's decentralized approach to MRO is interoperable with other cells, eliminates the dependency on costly C-SON infrastructure and is highly scalable to larger networks. The following section explains how it works using the "Handover Too Early" scenario as an example.

Practical example of *Handover Too Early*

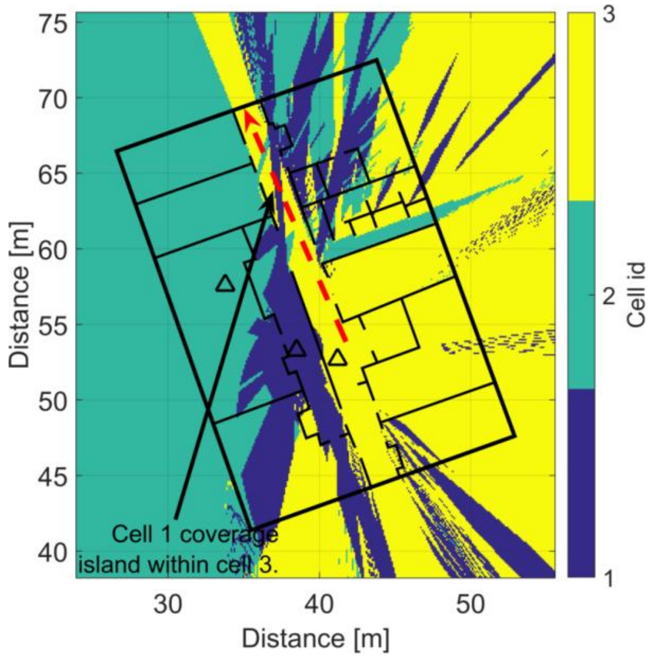

Figure 4: Office building coverage map.

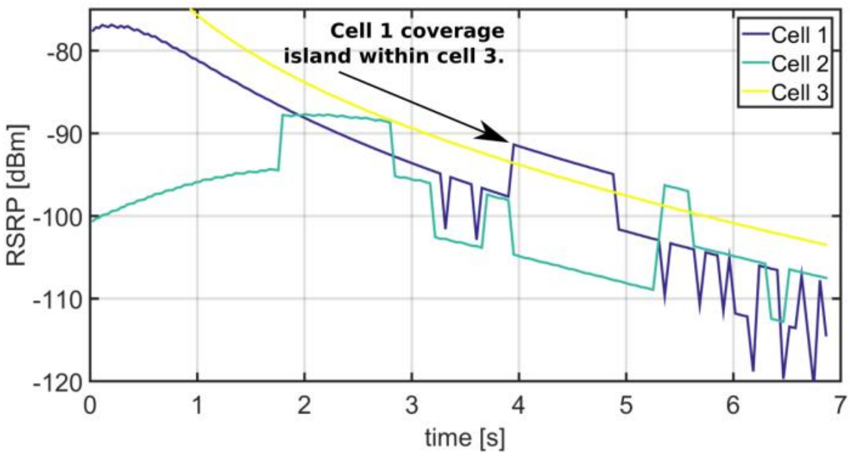

Figure 5: RSRP measurements taken by the UE.

To achieve proper mobility where handovers are successful and the signalling load is reduced, LTE small cells need mobility parameters tailored to the scenario in which they are deployed. Each location has its own distinctive features such as RF cluttering, RF obstacles, neighbouring small-cells, varying user densities, etc. There is no default set of mobility parameters which can perform optimally in all practical deployment scenarios. Real life failures are inevitable, but self organization techniques allow the cell to learn from the failures and adapt its parameters to improve its performance.

Mobility problems can arise, for example, when a UE crosses a coverage island of one cell within the coverage area of its own serving cell. Consider, for instance, the small cell deployment depicted in Figure 4, where three HeNBs have been installed in an office building. The nature of this scenario gives rise to multiple coverage islands. As UEs cross them, they experience rapid variations of the Reference Signal Received Power (RSRP) from neighbour cells. Consider a UE connected to cell 3, moving along the red dashed line in Figure 4 and performing RSRP measurements as shown in Figure 5. When the UE reaches coordinates *(x, y) = (38, 64)* at around time *t=4* s, the RSRP of cell 1 rises quickly. If the serving cell 3 then decides to handout the UE towards cell 1, the UE could later suffer a Radio Link Failure (RLF) when it exits the cell 1 coverage island (approximately at *t=4.9* s). This is an example of a *Handover Too Early*, which could have been avoided if the source cell had used a higher RSRP-based handover triggering threshold for that neighbour. Every cell in the network keeps a Neighbour Relationship Table (NRT), wherein multiple details about their neighbouring cells are stored. In particular, the *cellIndividualOffset* (CIO) is a neighbour-specific parameter that can be tuned to control, on a per-neighbour cell basis, when handouts shall be triggered.

If the problem illustrated above is not solved, the network must deal with numerous RRC connection setups and re-establishments. These may not always succeed, thus disrupting the users' connectivity, worsening the overall customer experience and increasing the network signalling load.

Node-H MRO solution

The SON layer of Node-H's LTE software includes a dynamic MRO algorithm to fine-tune the triggering thresholds based on the specific events that are happening in that particular deployment. The optimal threshold values drift over time and depend on stochastic variables such as spectrum occupation, UE and traffic density, clutter variations, etc. A common way to tackle this in enterprise deployments is to **calculate a static set of thresholds during network planning**. However, this does not address the time-varying nature of the problem so it fails to guarantee continuous control over long periods of time**. Drive-tests** can also be used as a means of mobility problem detection, but are costly, incapable of reacting quickly to spontaneous RF variations and impractical for indoor small cell networks. **Centralized MRO**, in which a central server monitors neighbour relations network-wide, tracks mobility problems and adapts the thresholds accordingly, has also been proposed [3]. But a centralized server is not always an option, and may be expensive for small and medium enterprise deployments, and its scalability to large deployments with many thousands of small-cells and possibly millions of neighbour relations is questionable. Furthermore, the current lack of C-SON standards will lead to integration issues among multiple suppliers.

For the above reasons the SON layer of Node-H's LTE stack includes a **dynamic** MRO algorithm that allows independent HeNBs to adapt **autonomously** to changes in the deployment scenario. Node-H's MRO operates in two stages: first *data collection & problem analysis*, followed by *problem solution* through CIO adaptation. During the data collection stage, the **distributed** MRO algorithm collects the following information:

- RLF reports from UEs using the RRC UE Information procedure.
- Mobility problem logs from neighbour cells over X2 [4] using the RLF INDICATION and HANDOVER REPORT messages.
- Additional internal performance metrics.

This information allows each HeNB to learn about any ongoing mobility issues. With the collected information, it then calculates the *cellIndividualOffset* parameter that solves mobility problems towards a given neighbour. Finally, to prevent race conditions [5] and ping-pongs [6], it negotiates the new thresholds with the relevant neighbour cell.

The MRO algorithm from Node-H runs in a distributed manner on small-cells with the Node-H LTE software solution and it is fully **inter-operable** with Rel-9 and later small cells from other manufacturers. It does not need additional centralized equipment, or costly drive tests. For the sake of security, the MRO algorithm from Node-H also includes stability filters to prevent occasional RLFs from triggering network-wide reconfigurations of the mobility parameters.

Node-H's MRO algorithm's capability to detect and correct mobility problems works best in deployments with high UE densities. For example, consider a scenario with two cells *A* and *B*. Let cell *A* be a high-capacity cell with a large *A3-offset* parameter (e.g. 15 dB) to keep UEs connected to cell A as long as possible before handing them out to other lower-capacity cells. Such a large *A3-offset* would work well only with neighbour cells with a large coverage overlap with cell *A*. Assume that the coverage area of a cell *B* overlaps only slightly with cell *A* (e.g. the HeNB hosting cell B is in a separate room, behind a corner in the corridor, etc). If UEs moving from cell *A* to cell *B* are slow enough, relative to the *time-to-trigger* parameter, then *A*-to-*B* handovers will succeed despite the large A3-offset. However, fast-moving UEs (e.g. company executives in a rush, someone who's late for a meeting, etc) may not enjoy sufficient time for the handover to be triggered, so they suffer a RLF on cell *A* and attempt to re-establish the RRC connection on cell *B*. This is an example of *Handover Too Late* for the *A*-to-*B* neighbour relationship. Fortunately, cell *A* can correct this problem by increasing the *cellIndividualOffset* it holds for cell *B*. Note that this problem affects only the relationship of cell *A* with cell *B*, but not other relationships that cell *A* may have with other cells.

The above scenario has been set up in an office environment with LTE small cells from Node-H. As a result of several rapidly moving UEs, cell *B* received multiple re-establishment requests from unknown UEs in a short period of time (see Figure 6). These events have then been analyzed by the MRO function of both cells *A* and *B*. In about 10 minutes they decided to augment their *cellIndividualOffset* values to solve the problem. This decision has resulted in an earlier triggering of A-to-B handouts, as well as in a substantial decrease in the number of RLFs experienced by the UEs. The reduction in the rate of re-establishment requests is illustrated in Figure 6.

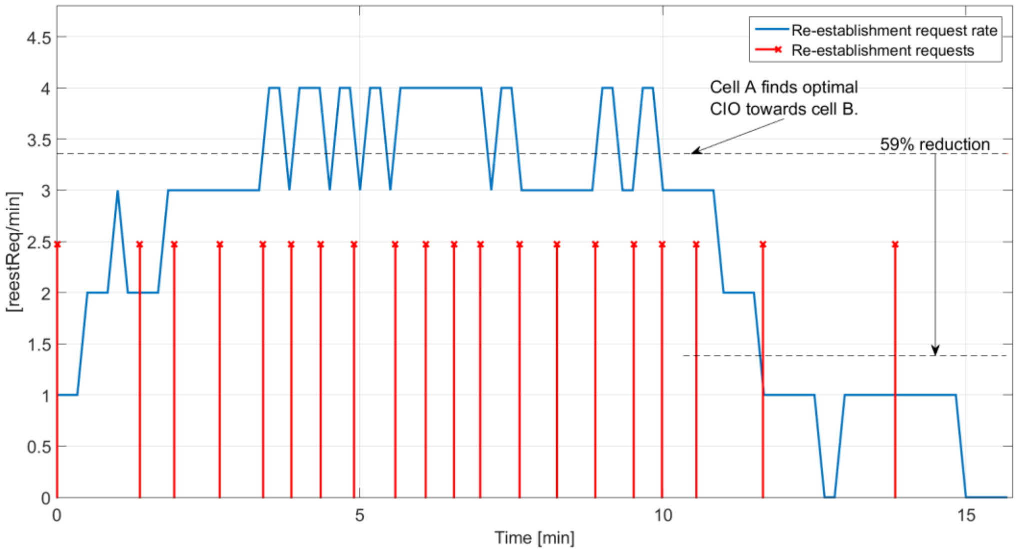

Figure 6: Rate of RRC connection re-establishment requests with a ue-Identity whose PCI is cell *A*'s, received by cell *B*.

Conclusion

This paper has presented Node-H's approach to MRO, which is based on direct HeNB-to-HeNB collaboration over the **X2 interface** and on a **smart management of the Cell Individual Offset (CIO)** towards neighbour cells. A learning approach adapts the cell behaviour so that failures become a stimulus to improving the performance of the cell. For example, over-the-air tests in a small network have shown that **the MRO function from Node-H can eliminate nearly 60% of all *handover too late* events.** This becomes a more significant improvement in larger networks. The fact that this approach uses only standard X2 messages makes it **inter-operable** with HeNBs from other manufacturers, thus empowering the operator in its supplier decisions, as well as enabling smoother transitions between solutions. Finally, the decentralized approach from Node-H eliminates the need for costly centralized servers and enhances the autonomy with which the network can operate.

Feel free to contact Node-H at info@node-h.com to learn more about this and other Node-H SON solutions for LTE small-cells.

Works Cited

[1] V. Buenestado, J. Ruiz-Aviles, M. Toril and S. Luna-Ramirez, "Mobility Robustness Optimization in Enterprise LTE Femtocells," in *77th IEEE Conference on Vehicular Technology (VTC)*, Dresden, 2013.

[2] S. Mwanje and A. Mitschele-Thiel, "Distributed cooperative Q-learning for mobility-sensitive handover optimization in LTE SON," in *IEEE Symposium on Computers and Communication (ISCC)*, Funchal, 2014.

[3] Small Cell Forum, "SON API for small cells," 2015.

[4] 3GPP, "TS 36.423 X2 Application Protocol (X2AP) v11.6.0," 2013.

[5] C. Weaver and P. Monogioudis, "Self-Organizing Mobility Robustness Optimization in {LTE} Networks," 2013.

[6] Y. Watanabe, H. Sugahara, Y. Matsunaga and K. Hamabe, "Inter-eNB Coordination-Free Algorithm for Mobility Robustness Optimization in LTE HetNet," in *77th IEEE Vehicular Technology Conference (VTC)*, Dresden, 2013.

[7] ETSI, "TS 36.300; E-UTRA and E-UTRAN; Overall description; Stage 2; version 9.10.0 Release 9," 2013.