An Experimental System for Verifying Topology Changes in Mobile Communication Networks

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***Abstract*—Automatic Configuration Management (CM) parameter change assessment, the so-called Self-Organizing Network (SON) verification, is an important enabler for stable and high-quality modern mobile communication networks. However, it also presents a new set of challenges. While improving network stability and resolving unexpected conflicts caused by parallel configuration changes, SON verification can have trouble coping with very dynamic networks that exhibit frequent topology changes. Such changes can be, for example, due to energy saving features which try to maximize the energy efficiency of a mobile network by adapting the topology to the network traffic.**

The experimental system presented in this paper demonstrates a new paradigm for handling such changes. It extends the currently available SON verification principles by providing a solution for the assessment of the impact of topology changes and for correcting them, in case the changes lead to degraded performance. The system includes a wide variety of visualization capabilities, including the various network states, user behavior, and performance statistics.

I. Introduction

The Self-Organizing Network (SON) concept is a key enabler for managing the complex modern networks. It covers the tasks of self-configuration, self-optimization and self-healing [1]. A SON-enabled network is managed by a set of autonomous SON functions performing specific network management tasks. The functions are designed as control loops, which monitor Performance Management (PM) and Fault Management (FM) data, and based on their goals configure the Configuration Management (CM) parameters. For example, the Coverage and Capacity Optimization (CCO) function has been developed to optimize the coverage of a cell by changing its antenna tilt or the transmission power.

In today's SONs we usually differentiate between closed-loop functions, which have a predefined absolute goal, and functions that form an action plan that achieves a high expected utility. Both function types perform changes to CM parameters, but only the latter may re-adapt the action plan in order to maximize the utility. The SON verification approach [2], [3] is one member of this particular function class. It is seen as a special type of anomaly detection that partitions the network into sets of cells called verification areas, triggers an anomaly detection algorithm for those sets, and finally generates CM undo requests for the abnormally performing cells in order to return them to the last known stable configuration. Unfortunately, one of the challenges verification strategies are facing are dynamic network topology changes. Typically, cells are switched on or off when energy saving features are enabled [4], [5]. However, enabling or disabling cells can negatively influence a verification mechanism, which may create a suboptimal action plan or even blame certain CM changes that actually did not harm the performance. Moreover, it is known that energy saving mechanism may optimize the network only locally, i.e., they might find the best local configuration which may not be necessarily the most suitable global one.

In order to be able to handle dynamic topology changes, we present a verification approach based on Steiner trees [6]. The Steiner tree problem is a combinatorial optimization problem that tries to reduce the length of a Minimum Spanning Tree (MST) by adding extra vertexes and edges to the initial edge weighted graph. Those additional vertexes are referred to as Steiner points whereas the initial nodes are called Steiner terminals. In general, Steiner points represent cells that can be turned on or off during their operation whereas Steiner terminals depict such that always remain on. Based on whether a cell is used as a Steiner point to form the tree, we decide whether and how to consider it while generating the corrective actions.

This topology verification solution has been implemented in a realistic Long Term Evolution (LTE) simulation environment. The experimental system described in this paper presents a visualization of our work in [6] with a clear focus on operability aspects for the mobile network operator.

II. Experimental System Description

In this demonstration, we are visualizing the proposed topology verification solution in a simulation scenario. The simulation environment is called SON Simulation System (S3). It consists of a set of closed-loop SON functions, a verification mechanism, as well as an LTE radio network simulator. The latter one is also part of the SON simulator/emulator suite. The simulated scenario itself covers parts of Helsinki, Finland (cf. Figure 1). The area that is simulated is 50 km^2 and the total number of macro cells is 32. Furthermore, the colors visualize the coverage provided by a cell whereas buildings are represented by gray squares. In addition, 9 small cells are deployed within the coverage of the macro cells. The small cells are allowed to be dynamically switched on or off by the

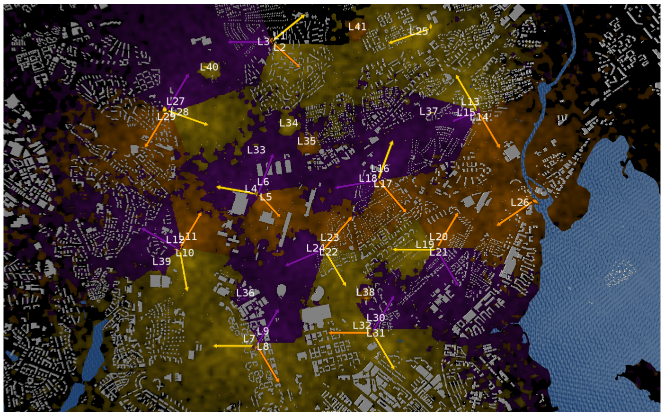

Figure 1. LTE network map: northern parts of the city of Helsinki, Finland. Colors visualize the coverage. Buildings are marked in gray.

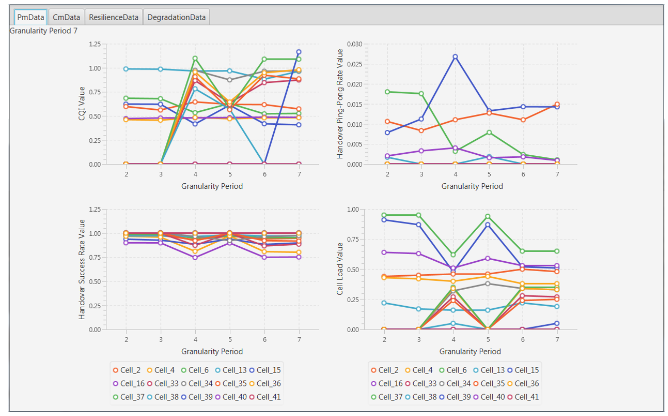

Figure 3. The PM panel showing the KPI statistics of the cells of interest. There are three other tabs between which the operator can switch.

energy saving functions, while the macro cells are responsible for the network coverage.

During the demonstration, 1500 uniformly distributed simulated users follow a random walk mobility model and actively use the mobile network. As shown in Figure 2, users receive the color of the cell their are connected to. They also show their satisfaction with the offered network services. In addition, during the demonstration up to four additional User Equipment (UE) groups will be added to or removed from the network. They consists of 150 UEs, 75 UEs, 85 UEs, and 120 UEs, respectively. The insertion of those additional UE groups leads to a higher load in the deployed macro cells, which causes the cell energy saving features to become active and activate some of the small cells. Thereby, the topology verification approach is triggered and will analyze cell Key Performance Indicators (KPIs) and suggest corrective actions in case it detects a suboptimal network configuration.

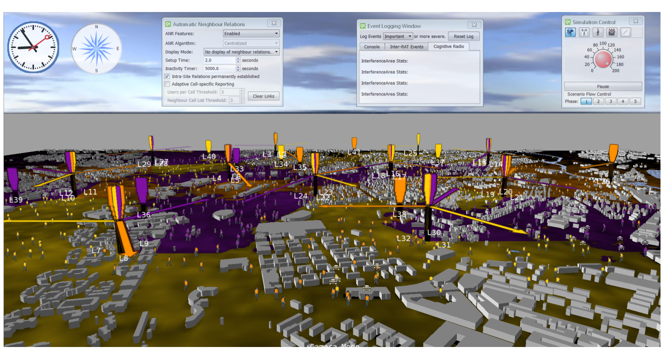

Figure 2. Users actively using the LTE network. They receive the color of the cell they are currently connected to.

Furthermore, the statistics that are generated by the network are shown in the operator's panel. Figure 3 shows a screenshot of the PM panel that represents the KPIs of interest for the topology verification approach. The charts show the performance statistics of the monitored cells. The impact of the topology verification process is shown in a separate tab.

All components of the experimental system can be projected on separate screens, hence, allowing the concurrent visualization of the network and the impact of the topology verification process on the cells' performance.

III. Potential Impact on the Audience

The presented showcase is a big step forward in the operation and maintenance of SON-enabled mobile communication networks. It extends the already available SON verification approaches by allowing them to handle, assess and correct not only CM changes, but also dynamic changes in the network topology. Such dynamic changes are often induced by energy saving mechanisms that enable and disable cells based on the network service demand. With the presented topology verification approach we are able to correct inappropriate topology changes and overwrite changes trigged, for instance, by energy saving algorithms.

Furthermore, the presented experimental system provides some insight into the hidden complexity of heterogeneous Radio Access Networks (RANs) and the corresponding SON environment.

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