Using Self-Organizing Networks in 5G

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***Abstract*—Over the years the number of mobile network users and the generated traffic by them has increased exponentially. To satisfy this growing demand, an efficient way of managing limited network resources is needed. An established way of doing so is using network automation. Currently in 4G, Self-Organizing Networks (SON) is the widely chosen approach for network automation. But as 5G brings new technologies and service requirements, SON has several drawbacks in such an environment as it was developed for 4G first. This paper addresses SON and several introduced advantages like reduced deployment effort and Automated Neighbor Relation (ANR) first. Afterwards, we explore some limiting factors like weak Self-Coordination that are hindering the deployment of SON as a sole network management automation (NMA) mechanism in 5G.**

***Index Terms*—5G, network management, network automation, Self-Organizing Network**

1. Introduction

As described by Hämäläinen et al. in [1] SON was initially introduced with 3G but got a lot more attention in the last two decades as a key factor for deploying 4G. With a growing user base and demand for more traffic, MNOs (Mobile Network Operators) had to constantly upgrade their infrastructure further and use the existing one more efficiently. With no means of network automation at hand, all the planning for and configuration of a new base station was a human operator driven process. The same holds for ongoing optimization and error-solving in mobile networks. But as humans are very error-prone and slow regarding such tasks these areas were and still are very cost-intensive. To avoid high capital expenditures as well as operating expenses, network automation was needed.

SON especially aims to implement a kind of Plug-and-Play functionality for the deployment of new base stations as well as to introduce ways of automatically adapting control parameters of base stations to optimize e.g. Mobility Robustness. But as promised features of 5G as described by El Hattachi and Erfanian in [2] including greater throughput, ultra-high reliability, lower latency as well as higher mobility range and connectivity density require new technologies enabling these features, the bar for efficient network management automation will raise to a level where it remains questionable if SON can reach it.

In Section 2 we will first describe what the initial goals of SON were when it was developed. Afterwards, different architecture schemes for SON are presented as well as a black box model which is used to explain the workings of a SON function. In Section 3 the reader will find a selection of different advantages that SON usage promises, e.g. reduced deployment effort, energy-saving, Automated Neighbor Relation and more. In Section 4 we will discuss several drawbacks that SON usage in 5G has to face. The paper ends with a conclusion in Section 5 where also future developments of NMA are highlighted.

2. Description of SON

As shown by Lehser in [3] there are often named four main categories of SON use cases in general. These are:

- Planning
- Deployment
- Optimization
- Maintenance

While Planning and Deployment mainly focus on the initial deployment of automation in base stations, e.g. initial parameter configuration, Optimization and Maintenance do focus on the operational phase and often make use of SON functions. In the following section we will describe how a SON function works. The model can also be seen in Figure 1.

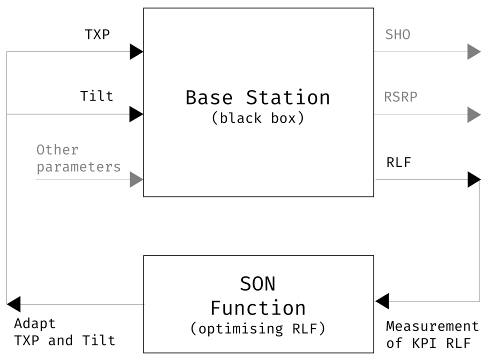

Figure 1: SON Function (optimizing RLF) measures Key Performance Indicator *Radio Link Failure* and adjusts the corresponding influencing control parameters *Antenna Tilt* and *Transmission Power*

2.1. SON Functions

When visualizing a base station one has to distinguish between two kinds of parameter sets. The first ones are the

doi: 10.2313/NET-2020-11-1_18

control parameters of the base station and the other ones are KPIs (Key Performance Indicators) that are somehow influenced by the control parameters. Control parameters may be but are not limited to:

- Transmission Power (TXP)
- Antenna Tilt or Remote Electrical Tilt (RET)

KPIs (Key Performance Indicators) may be but are not limited to:

- Radio Link Failures (RLF)
- Successful Handovers (SHO)
- Reference Signal Receive Power (RSRP)

RLF refers to some sort of break on the physical layer. SHO is a successful uninterrupted transfer of an ongoing connection from one cell to another. RSRP describes the received power of a special reference signal at an user equipment (UE), e.g. a smartphone. KPIs like RLF and SHO are measured by the base station itself while other KPIs, like e.g. RSRP can be measured by UEs and are reported back to the base station. One KPI gets always measured for fixed values of control parameters that are influencing it. The SON function which is responsible for this KPI regardless of where it resides — maybe in the base station itself — will adapt the control parameters (which are influencing the KPI) and trigger new measurements. From a pool of [Control parameters | KPI] vectors then the control parameters are chosen which optimize the KPI. So, for example a SON function trying to optimize RLF would conduct a variety of measurements of RLF while adapting TXP and Antenna Tilt as those two parameters have an impact on RLF. Out of all the [(TXP, Tilt) | RLF] vectors the (TXP, Tilt) configuration would be chosen for that RLF is minimal. SON functions often follow the structure of a basic Switch-Statement, following pre-defined rules for adjusting the control parameters of the base station. Those pre-defined rules are created by a human operator with a lot of expertise in the field of what the SON function tries to optimize and are not trivial to come up with. In general, another way of describing a SON function would be to call it a closed control loop.

2.2. SON Architectures

When looking at SON on a higher level, the question where to implement the actual SON functionality arises. In regards to Self-Configuration the functionality resides in the OAM (Operations, Administration, Maintenance) module of the MNO but regarding Self-Optimization and the black box model the SON function could be either inside the base station or it could also be somewhere else. In general, there are three possible answers to this question as described by Feng and Seidel in [4].

2.2.1. Centralized. In this approach all SON functionality resides in a dedicated module in the OAM system of the provider. That means that collected data and measurements first have to be passed to this module. On the one hand, it is easier to set up such a system as one only has to implement functionality at a rather high level in the architecture and at few places while on the other hand, this approach also comes with a drawback. As different providers have their different OAM systems, it becomes harder to optimize between them.

2.2.2. Distributed. This approach is very close to the black box model in Figure 1 when making the assumption that the SON function resides in the base station. While it becomes easier now to optimize between few neighboring base stations one has a higher effort to implement this architecture as there are many of them. Also, it gets harder to optimize with the number of base stations involved.

2.2.3. Hybrid. As both previous models suffered from major drawbacks, the solution is to combine the two approaches. So small optimizations are done on the level of the base stations by themselves but bigger optimization algorithms are run in the OAM system. The only drawback this model suffers from is the high effort to implement as especially interfaces have to be further extended.

3. SON Advantages

As seen in Section 2 SON does have a lot of different use cases ranging from the deployment of base stations to the subsequent maintenance as well as automated solving of problems that may occur. In the following some of those use cases are presented.

3.1. Reduced Deployment Effort

The deployment of a base station still mainly consists of manual efforts. Nevertheless, SON can support this deployment process and reduce the overall effort. When looking at the life cycle of the deployment of a base station SON can help with the following steps [3]:

- Authentication of the base station
- Installation of software, e.g. connecting to OAM and downloading configuration data
- Automated Transport and Radio Parameter Setup

3.2. Energy Saving

The basic idea of this use case is to adjust the network capacity to the needed load and not providing unused capacity and therefore wasting energy. The network capacity is reduced by switching off cells that are experiencing low traffic. To do this base stations have to hand over their current connections to neighboring or overlying cells first before being able to shut down. This deactivation function is triggered by the base station experiencing low traffic itself. The activation of a cell when the load on the network is increasing again however has to be performed by a neighboring cell. As shown by Roth-Mandutz and Mitschele-Thiel in [5] for example fingerprinting techniques can be used to identify the best fitting cell to be activated.

3.3. Automated Neighbor Relation

Base Stations take use of an intern NRT (Neighbor Relation Table) to perform certain actions, e.g. handovers. Such a table can be seen in Table 1 where entries are identified via the target cell id. Before the introduction of SON, NRTs of a base station were manually filled before the deployment by utilizing coverage predictions. But as those predictions were often error-prone and also

TABLE 1: Neighbour Relation Table (NRT) [4]

Neighbour	Local Cell ID	Target Cell ID	No Remove	No HO	No X2
1	L1	T1		x	
2	L1	T2	x		
3	L1	T3			x
4	L1	T4		x	x

network topologies tend to change over time a manual approach seems tedious. SON introduces an ANR module to automatically manage (delete and add) entries from the NRT in a way that in the end a base station can be deployed with an empty NRT without problems. The module consists of [4]:

- Neighbor Detection Function
- Neighbor Removal Function
- Neighbor Relation Table Management Function

The Neighbor Detection Function utilizes RRC (Radio Resource Control) signalling to detect new neighbors and decides whether to update the NRT or not by instructing the NRT Management Function to do so. After adding the new relation the NRT Management Function tells OAM about the change of the NRT and might get instructed to change some attributes (No Remove, No HO, No X2) or default values are used. The Neighbor Removal function is triggered whenever an entry in the NRT is used for a handover and starts a timer. When the entry is not used in a certain time frame again, it gets deleted. For further reading refer to [6] by Dahlén et al. and [4].

3.4. Optimization Algorithms in General

SON also introduced a huge variety of optimization algorithms [4]. These may be but are not limited to:

- Coverage Optimization
- Capacity Optimization
- Mobility Robust Optimization
- Mobility Load Balancing Optimization

Coverage and Capacity Optimization focus on maximizing the coverage (covered area of cell) and capacity of a cell. Mobility Robust Optimization attempts to detect and solve errors occurring due to too late or early handovers. Mobility Load Balancing Optimization handles the handing over from connections from cells facing high congestion to neighboring cells with free resources. In general, all these Optimization Algorithms follow the workings of a SON function as described in Section 2.1.

4. SON in 5G

While SON is still used in 5G there are several drawbacks that hinder the usage of SON the way it was introduced as the sole network management mechanism. SON advantages out of the Self-Configuration category mostly stay valid but primarily Self-Optimization use cases do not. Keshavamurthy and Ashraf state that even in 4G, Self-Optimization and Self-Healing functionality is not as widely deployed as it was initially planned [7]. In this section we will take a look at a selection of some of those drawbacks.

4.1. Reactive Character of SON

As already described in Section 2.1, SON functions themselves are working in a very reactive way. When using the same example with Radio Link Failures as in Section 2.1 those Radio Link Failures did already happen before SON attempts to combat those failures. SON only reacts to a problem after it already occurred. The simplified workflow basically can be reduced as described by Imran et al. in [8] to observing, diagnosing and reacting. As all those actions, especially observing, require a not to be neglected amount of time, the principle of SON functions automatically comes with an inherited delay. This was already an issue in 4G but now more then ever collides strongly with one of the goals of 5G, namely low latency. Therefore, in order to meet the requirements a much more preemptive SON would be needed.

4.2. No E2E (End-to-End) Network Visibility

As described by Mwanje, existing SON solutions primarily “considered automation for specific access network problems” [9]. But to guarantee the wanted quality of service, a complete overview of the performance of the system is strongly needed, especially when considering different network slices with different requirements. Another problem is that SON depends on the full availability of related data to the problem it should solve [7]. Data first has to be gathered through drive tests, OAM reports or customer complaints as seen in Figure 2. This approach also is not capable of predicting future behavior as it is not capable of generating a dynamic model of the system [8].

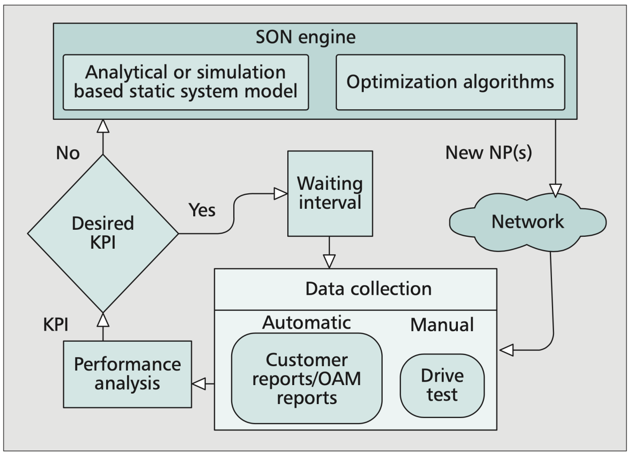

Figure 2: SON Engine: a data collection framework and a system model [8]

4.3. Missing Agreement on Common KPIs

As to the point of writing this paper, there is no unified agreement on specific key performance indicators (KPIs) across different mobile network operators to the best knowledge of the author. But especially with 5G multi-tenancy around the corner, a unified framework for performance evaluation is more important than ever. The usefulness of SON is very dependent on the chosen KPIs that SON functions are trying to optimize [8]. Shared use of infrastructure by different network operators (Multi-Tenancy) only seems possible when some common KPIs are established.

4.4. Weak Self-Coordination Functionality

When keeping in mind the model of a SON function as presented in Figure 1 it becomes clear that there are some SON functions trying to optimize different KPIs that do have common control parameters they are influenced by. This inevitably will lead to conflicts at some point. For example, imagine one SON function optimizing energy efficiency and therefore lowering the base station's transmission power. Another SON function however, may optimize the capacity of the cell and will raise the transmission power again. This will lead to a periodic oscillation of adapting the control parameter transmission power when not being managed by some instance in a higher layer. Unfortunately, even in 4G this still is only partially solved. A reason for that lies in the very foundation of the design of SON itself where SON functions have been developed rather independently of each other and only in hindsight coordination between functions has been added [8].

However, for 5G this Self-Coordination functionality has to be taken into account from the very beginning of development. With a trend towards network densification and network function virtualization (NFV) the amount of network components that have to be managed and coordinated will only grow further as described by Bhushan et al. in [10]. Multi-Tenancy on the one hand will introduce SON functions that only handle the performance of a specific slice but on the other hand also SON functions that perform optimization in between network slices. The RAN (Radio Access Network) Fronthaul Split will generate the additional need to also integrate new functionality to consider latency in the fronthaul [9]. So SON Self-Coordination will face serious challenges in 5G and is "an area of major concern" [7].

4.5. No Focus on Longtime Optimization

Current SON solutions mostly focus only on small-time-scale optimization but not on longtime optimization. This is problematic as there are not any more capacity gains to be expected on lower layers but rather in high network layers. Those higher layers often tend to work on a longer timescale and are important to be considered in order to adapt the network as well as possible to slow changes of user density and movement over time due to certain weekdays, months, seasons or even specific repeating events [8]. That way short time reactions to occurring problems could be avoided as a whole because they may not even occur at all in the first place.

5. Conclusion and Future Work

This paper first explained the reason for the invention of SON, which was the urgent need of mobile network operators to reduce their operating expenses. It then examined the different objectives of SON, namely Self-Configuration, Self-Optimization and Self-Healing and gave a detailed insight in an integral part of SON, the SON functions. Also, different SON architectures as well as use cases were discussed. We then proceeded to present different disadvantages that the deployment of SON would face in 5G and came to the result that while SON is still used in 5G there mainly only are Self-Configuration use cases that remain relevant. However, SON is not prepared to provide Self-Optimization and Self-Healing functionality in 5G. Future work outside the scope of this paper would be a discussion of key technologies that enable a shift from the reactive SON as presented here to a more proactive SON leveraging advancements in the fields of

- Machine Learning
- Big Data Analytics
- Knowledge Sharing

as seen in [9]. These technologies also mark an expected transition from Network Management Automation (NMA) towards Cognitive Network Management (CNM).

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doi: 10.2313/NET-2020-11-1_18