Survey Report- Wireless Networks
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Self-Organizing Network (SON)

Abstract
With the rapid growth of mobile communications, deployment and maintenance of cellular mobile networks are becoming more and more complex, time consuming, and expensive. In order to meet the requirements of network operators and service providers, the telecommunication industry and international standardization bodies have paid intensive attention to the research and development of self-organizing networks. In this report, we first discuss about when and why SON was introduced. Then we move forward and discuss about the aspects of SON and architecture of SON. Then we learn about the various Cases of SON in which we will discuss about issues and its solutions pertaining to topics like Automatic Neighbor Relation(ANR), Load balancing, Energy saving, Coverage and capacity optimization, RACH optimization and CELL outage compensation.

Introduction:
Radio access elements account for a large share of cellular networks’ installation, deployment, and maintenance costs. The usage of advanced access and transmission techniques, both the transmission bandwidth and quality of service (QoS) of mobile networks, need to be improved since new wireless service models and applications have been developed and also due to the increasing spectrum band and data rate. This is why efforts to introduce SON focus on the network’s radio access assets first. Moreover, the deployment and optimization of mobile networks are very complicated and challenging engineering tasks that require a comprehensive systematic approach. Conventional procedures usually cost a long time, and a lot of resources and manpower to do this. The revenue from a mobile network highly depends on its operational efficiency. Hence, operators need advanced technologies and proper strategies to reduce the OPEX of LTE networks. Thus, introduction of SON has helped reduce the capital expenditures (CAPEX) and operational expenditures (OPEX) through Self-configuration, Self-optimization and Self-healing.

Self-Organizing Network (SON)
The 3GPP standardization body introduced SON in its December 2008 Release 8 while drafting LTE specifications. The main functions of SON are:

1. Self-Configuration
2. Self-Optimization
3. Self-Healing

1. Self-configuration
Self-configuration process is defined as the process where the newly deployed eNBs are configured by automatic installation procedures to get basic parameters and download necessary software for operation. Self-configuration process works in pre-operational state, which starts from when the eNB is powered up and has backbone connectivity until the RF transmitter is switched on.
With respect to the above figure, the procedure of self-configuration is given as follows:
1. An IP address is allocated to the new eNB and the information of the Self-configuration Subsystem of OAM (Operation and Management) is given to the eNB.
2. A GW is configured for the new eNB so that the eNB can exchange IP packets with other internet nodes.
3. The new eNB provides its information, including type, hardware and etc., to the Self-configuration Subsystem for authentication. Necessary software and configuration data are downloaded from the Self-configuration Subsystem.
4. The new eNB is configured based on the transport and radio configuration data.
5. The new eNB connects to the normal OAM subsystems for other management functions.
6. S1 and necessary X2 interfaces are established.

2. Self-optimization
Self-optimization process is defined as the process where UE & eNB measurements and performance measurements are used to auto-tune the network. This process works in operational state, which starts when the RF interface is switched on. The self-optimization process collects measurement information from UE and eNB and then with the help of external optimization tool, it auto-tune the configuration data to optimize the network. A typical example is neighbor list optimization.

3. Self-healing
The self-healing functionality monitors the alarms, and gathers necessary correlated information (e.g. measurements, testing result, etc.) and does deep analysis, and triggers appropriate recovery actions to solve the fault. It also monitors the execution of the recovery actions and decides the next step accordingly. Auto-restart and other automatic alarm features allow the network
operator even more quick-response options.

**SON Architecture:**

![Image of SON Architecture]

According to the location of optimization algorithms, SON can be divided into three classes: Centralized SON, Distributed SON and Hybrid SON.

1. **Centralized SON**

![Image of Centralized SON Example]

In Centralized SON, optimization algorithms are stored and executed from the OAM System. In such solutions SON functionality resides in a small number of locations, at a high level in the architecture. Above figure shows an example of Centralized SON. In Centralized SON, all SON functions are located in OAM systems, so it is easy to deploy them. But since different vendors have their own OAM systems, there is low support for optimization cases among different vendors. And it also does not support those simple and quick optimization cases.

2. **Distributed SON**
In Distributed SON, optimization algorithms are executed in eNB. In such solutions, SON functionality resides in many locations at a relatively low level in the architecture. In Distributed SON, all SON functions are located in eNB, so it causes a lot of deployment work. And it is also difficult to support complex optimization schemes, which require the coordination of lots of eNBs. But in Distributed SON it is easy to support those cases, which only concern one or two eNBs and require quick optimization responses. For Distributed SON, X2 interface needs to be extended.

3. Hybrid SON

In Hybrid SON, part of the optimization algorithms are executed in the OAM system, while others are executed in eNB. In Hybrid SON, simple and quick optimization schemes are implemented in eNB and complex optimization schemes are implemented in OAM. So it is very flexible to support different kinds of optimization cases. And it also supports the optimization between different vendors through X2 interface. But on the other hand, it costs lots of deployment effort and interface extension work.

SON major features:

1. Automatic Neighbor Relation (ANR):
   One of the major labor intensive activities for mobile network operators is the updates for neighbor cell relationships to facilitate easy handovers. It is necessary to have the correct neighbor relationships in place otherwise this will result in dropped calls as a result of handovers failing to complete correctly. The manual update of neighbor relationships become even more complicated as the network needs to decide if it can handover to a neighbor cell with a similar radio access technology, or whether it has to change, e.g. from LTE to HSPA, etc.. The UE is provided with a neighbor list by the base station or Node B, and this provides the frequencies the UE should monitor for handover.

   Solution:
   The ANR function resides in the eNB and manages the conceptual Neighbor Relation Table (NRT). Located within ANR, the Neighbor Detection Function finds new neighbors and adds them to the NRT. ANR also contains the Neighbor Removal Function which removes outdated NRs. For example, newly reported cells are added, and cells with very few handover attempts or frequent handover failures are removed from the NRT. The Neighbor Detection Function and the Neighbor Removal Function are implementation specific. The ANR function relies on cells broadcasting their identity on global level, E-UTRAN Cell Global Identifier (ECGI) and allows O&M to manage the NRT. O&M can add and delete NRs. It can also change the attributes of the NRT. The O&M system is informed about changes in the NRT.
2. Load Balancing:
Load Balancing refers to the process whereby similar network elements that are intended to share traffic, share the load. The similar network elements can be anything from packet gateways to MMEs to base stations and sectors. In LTE, MME pools are expected to share user traffic load across different MMEs as load increases, while eNBs may have RRM functions that share/offload traffic to neighboring cells in order to increase system capacity.

Solution:
The objective of Mobility Load Balancing is to intelligently spread user traffic across the system’s radio resources as necessary in order to provide quality end-user experience and performance, while simultaneously optimizing system capacity. Additionally, MLB may be desirable to shape the system load according to operator policy, or to “offload” users from one cell or carrier in order to achieve energy savings. The automating of this minimizes human intervention in the network management and optimization tasks. The term Mobility Load Balancing (MLB) is used to refer specifically to the network cell (eNB) level only, not core entities such as the MME, gateways, etc. The goal of MLB is to spread user traffic across system radio resources in order to provide quality end-user experience and higher system capacity. This can be accomplished by one or a combination of algorithms that perform Idle or Active balancing of users. These SON algorithms for offloading traffic from one element to another can include intra-carrier, inter-carrier, or inter-technology resources, as long as there is software intelligence to ensure radio admission and continuity of service on the target element. The actual transfer of users is accomplished by modification of handover threshold parameters. This can require coordination with competing SON algorithms and standardized messaging with multi-vendor equipment to ensure robustness and stability. The Load Balance are of 2 types.

1. Distributed Load Balance:
Algorithms run locally in the base stations. Load information is exchanged between base stations so that Idle/Active HO (handover) parameters may be adjusted and/or adjustments to RRM functionality can be made.

2. Centralized LB:
Algorithms run in a core network element. Base stations report load information to a central entity which then responds with appropriate modifications to idle/active HO parameters.

In either case (distributed or centralized), it is assumed there will be centralized Operations, Administration and Management (OA&M) control for an operator to enable/disable and configure relevant algorithm settings.

3. Energy Saving:
Mobile network operators are increasingly aiming at decreasing power consumption in telecom networks to lower their OPEX and reduce greenhouse emissions with network energy saving solutions for long term sustainable development. With the expected deployment of large numbers of mobile network radio equipment, in the form of Home NB/eNBs, OPEX reduction
becomes even more crucial. Energy consumption is a significant part of an operator’s OPEX. OPEX reduction can be accomplished by designing network elements with lower power consumption and temporarily shutting down unused capacity when not needed. Power amplifiers consume a significant portion of the total energy consumption in a wireless network.

**Solution:**
Sustainable development is a key criterion for telecom operators, to address the problems of resource shortage and environmental deterioration due to greenhouse emissions. Energy saving mechanisms allow operators to reduce OPEX and provide the quality of experience to end users with minimal impact on the environment. The possibility to temporarily switch-off some parts of radio access network nodes, such as a given Radio Access Technology (GSM, UMTS), will reduce the operational costs related to power consumption. Energy savings by switching off/on cells can be initiated in several different ways as follows:

- By the operator, from the OAM manager;
- Setting policies and conditions that result in autonomous switching off/on cells when the conditions are met;
- Completely autonomous by the eNB with information exchanged on the X2, S1 interfaces.

When a cell is switched off, there may be a need for the neighboring cells to pick up the load. However, switching off a cell should not cause coverage holes or create undue load on the surrounding cells. A switched off cell is not considered a cell outage or a fault condition. All traffic on that cell is expected to be moved to the underlying umbrella cells before any switch off occurs. When a NE is "switched off" for energy savings purposes, no alarms should be raised to the OAM manager for a condition that is a consequence of a "switched off" NE. The operator should have the capability to prevent the network from automatically compensating based on the cell that is in energy savings mode in order to prevent unnecessary disruption in the network.

4. **Coverage and Capacity Optimization:**
A typical operational task is to optimize the network according to coverage and capacity. The traditional way is to find the problems by drive tests and use planning tools to find possible solutions. Incorrect testing can negatively affect user experience and waste network resources. Furthermore, running such tools is a cumbersome task that requires a significant preparation on the operator side to compile all necessary data inputs, create optimization clusters, and then implement the changes in the network.

**Solution:**
Coverage and Capacity Optimization (CCO) has been identified as a key area in 3GPP as a self-optimization use case for SON, which will complement traditional planning methods by
adjusting the key RF parameters (antenna configuration and power) once the cells have been deployed. This method will permit the system to periodically adjust to modifications in traffic (load and location) in addition to any changes in the environment, such as new construction, or new cells being put on air.

There are a number of ways in which it can be achieved:

1. Adjustment of antenna parameters:
   In order to provide CCO using an adjustment of the antenna parameters, a Remote Electrical Tilt, RET antenna is required. Previous generations of base stations only enabled manual adjustment of the antennas. Now it has become viable for them to be electrically steered. The adjustment is generally the angle if tilt. Moving it upwards increases the boundaries of the cell, although care has to be taken to ensure that coverage is maintained close to the antenna tower. The adjustment can be made either mechanically or electrically. However when a system is installed with electrical tilt, sometimes mechanical tilt is also needed to give a wider range because the electrical tilt is limited. The antenna tilt needs to be carefully adjusted. If it is lowered too much, then the cell boundaries will be brought inwards and coverage holes may appear causing issues with handover. If it is adjusted too high, then the coverage will be extended and it may result in interference levels rising at the cell borders where signals from the adjacent cell will also be received if they use the same channel. Accordingly the self-optimization and adjustment needs to take in these requirements.

2. Adjustment of power level parameters:
   While antenna adjustments may be the most obvious solution, self-optimization and adjustment may also be applied to the power levels. In many respects, base station transmitter power optimization is more challenging than using antenna tilt and control. There are issues with amplifier behavior and also issues with reciprocity with the handsets. It is possible to increase the transmitted power so that the handset receiver can receive the base station further away, but it may not be possible for the handset to increase its power sufficiently to match any improvements especially at the cell edge where it may already be operating close to its maximum level.

5. RACH (Random Access Channel) optimization:
   The configuration of the random access procedure has a critical impact on end-user experience and overall network performance. A poorly configured Random Access Channel (RACH) may increase access setup time and accesses failures, impacting both call setup and handover performance. With optimal random access parameter setting, maximum end-user experience can be obtained.

**Solution:**
If the number of RACH slots allocated is too small then the probability to get a successful access is reduced by collisions. On the other hand, allocating too many RACH slots is a waste of physical resources, as these slots cannot be used by other traffic. Therefore, selecting the optimal
number of access slots is of strong importance to the system. The optimal number depends on the number of users and on the network configuration. With SON these values are varying in time, so the selection of optimal values is time dependent, too. Apart from the delays, also the UL interference is a critical point. The UE starts its RACH transmission with a preamble. If there is no response, the UE again sends a preamble, this time with an increased power. The purpose of this procedure is to access the system with a minimum of power in order to minimize interference. However, if the preamble rejection is not caused by a weak power but due to congestion, another preamble with a further increased power is transmitted. This obviously enhances the UL interference for the PUSCH, but also for RACH attempts of UEs to a different cell, respectively.

There are 3 classes of parameters which can be optimized:

1. **RACH configuration:**
   Selection of number and location of the RACH access slots. This is further optimized by a smart choice of the pRACH Configuration Index and the Root Sequence Index.

2. **RACH preamble splitting and back off parameter values to avoid congestion.**

3. **RACH transmission power control parameters:**
   The power of the initial preamble and the power ramping on each step. Depending on this choice, different scenario can be managed in an optimal way. For example, if the range of a cell contains regions with a very large fading difference, a small initial power with a large power ramping may be optimal, whereas in small cells with a more uniform fading a larger initial power together with a smaller power ramping might be the best solution.

The SON entity for the RACH optimization is in the eNB, with the main signaling using either RRC or MAC control. So the main impact is on the air interface protocol stack. However, also the X2 interface will be concerned in order to be able to exchange access slot configuration between adjacent eNBs for avoiding RACH interferences.

### 6. Cell Outage Compensation:

Cell outage happens due to software and hardware failures (radio unit, antenna etc) or due to external failures such as power supply or network connectivity. One of the key requirements for any cell outage compensation is that the overall network should respond quickly so that immediately the fault is detected and the impact quantified, compensation is introduced. As this needs to be implemented quickly this cannot be adjusted manually and therefore automated means are required.

**Solution:**
One of the key elements of the self-healing network is the compensation when a cell outage occurs. In the first instance any means within the base station itself will be sought to alleviate the situation whatever the fault may be. However if this is not possible because of a complete cell outage, then the compensation must come from other neighboring cells. Neighboring cell compensation is achieved increasing the size of the neighboring cells to try to cover the area of the failed one. The same routines that are used for the coverage and capacity optimization are used. Techniques include titling the antenna and also increasing the power of the base station.
Cellular self-healing network technology can be used to mitigate the effects of a complete cell outage or other failure. However there is likely to be an impact on performance and therefore a fast response once the fault is diagnosed is required to ensure that the network can return to its pre-fault condition.

**Conclusion:**
The evolving mobile business demands broadband mobile networks with high operability as well as high performance. A promising solution is LTE/SON as it allows operators to implement objectives such as robustness, better performance, and energy efficiency at a lower cost than that of traditional management approaches. LTE/SON solution will enhance robustness, scalability and response of the self-X functions and enable effective integration into the existing operations. Furthermore, the self-optimization with a radio planning tool will powerfully enhance the user’s experience.

**References**


