An Overview of Self-Organizing Networks (SON) in Wireless Networks

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Abstract

The latest trend in technological aspect in the arena of telecommunicationsis the progression of Long TermEvolution(LTE) and LTE-Advance that assures exceptional performance and a promising market in the wireless network (WN) domain. Tofulfill promises, new features have been appended with every new release (Release 8, Release 9). This paper aims to give an outline of the Self-Organizing Network (SON) function that was proposed in LTE and carried further to LTE-Advance. There are many beneficial factors about SON like Automatic Neighbor Relation (ANR), Automatic updates, Automatic recovery, adjustment in parameters as per change in the network environment that have been reviewed. The different kinds of architecture that can be applied depending on SON functions have been explained. There are many questionable aspects of SON which have been introduced as its limitations, along with the scope of SON functions in the future in alliance with the developing network.

Keywords: Self Organizing Networks (SON), 3rd generation partnership project (3GPP), LTE-Advanced

I. Introduction

The augmentation in technology is brought about to make it simpler for humans/users to reach out and communicate. We have advancedfrom Analog Cellular Networks (1G) to Digital Cellular Networks(2G, 2.5G (Enhanced Data rates for Global Evolution, EDGE) and now comes the age of LTEtechnology. LTE is also known as 4G technology. LTE has gained importance due to itshigh-speed data rate and interference reduction [1].

Long Term Evolution is nothing but the merger of 3rd Generation Partnership Project (3GPP), which includes High Speed Packet Access (HSPA) and 3GPP2 including Evolution Data Optimized (EVDO). This implies that LTE is inter-operable and compatible with the older technologies. There are numerous features introduced in LTE (Release8 and Release9) and LTE Advance(Release 10). With LTE networks there is a rise in the number of usersand thereby there is a needfor morebase stations. Also with the upcoming base stations and new features, to make it appealing to the clients and increase the revenue for the companies providing these services, the cost of installation and expenses should be minimized. One feature that can help achieve this is Self-Organizing Networks (SON), a recommendation by Network Generation Mobile Networks (NGMN) along with 3GPP [1] [2] [3][4].

NGMN planned the release of self-organizing networks since 2006 but was able to issue the specifications and standards by 2008. Thus, SON is mostly linked with LTE. There are various requirements and sets of standards laid down by 3GPP and NGMN as SON was being recognized in LTE.SON helps the mobile industry to reduce its Operational Expenditures (OPEX)and Capital Expenditure(CAPEX) [9] by some

amount by converting the vigorous operational and maintenance actions from manual configurations to automatic configurations. SON established their importance in the efficient and profitable functioning of the Wireless Networks[1] [5].

II. What Are Self-Organizing Networks?

As the networks continue to flourish and mobile broadband expands; the incorporation of LTE, LTE advance and Heterogeneous networks(HetNets), handling the operational and maintenance (OAM) task becomes more and more crucial. The change in architecture of LTE to flat architecture which has straightforward communication between the Enhanced Node B (eNB) affects the operational behavior [1] [2]. As per the views of 3G America and 4G America white papers, decentralization and automatic execution of administrative and operational tasks becomes important [3].

Thus, SON comes into the picture, which is connecting networks and does not require human supervision to maintain and configure the networks. These systems usually do not find the need to be dominated by any one omniscient body. In LTE,the eNB's have all functional rights and are decentralized with the removal of Radio Resource Control (RRC) [6]. Similarly, SON can be positioned in these eNB's which help them to arrange, plan and solve their issues independently.Figure 1 shows the functioning of networks with and without SON [1][2] [7].

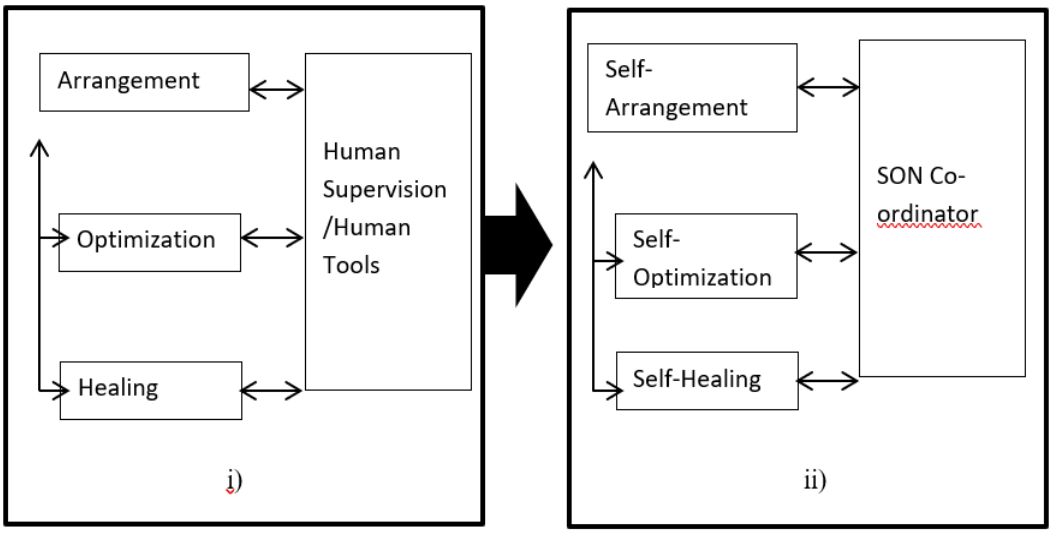

Figure 1.*i) Without SON ii) with SON (When the eNB is switched on)* [7]

III. SON in LTE and Its Features:

As per 3GPP standard, SON could support similar networks which included LTE.InRelease 8 self-configuration feature came into picture which helped in the automatic functioning of neighbor relations, Physical Cell Identity (PCI). Optimization of the network got added as a feature of SON in Release 9. Mobility Load Balancing (MLB) is highly significant in Release 9 [8] [7]. When a cell gets congested quality decreases and UE face interference. To avoid this condition MLB automatically handovers these UE to a neighboring cell. This avoids interference, maintains mobility within the given threshold [6] [10].Energy Saving feature came in with Release 9 but made more impact in LTE Advanced. Release 10 brought in autogenous repair, automatic healing feature of SON. Another aspect is that SON could be used with Heterogeneous Networks (HetNet) as it is a feature of LTE in Release 9. But as mentioned earlier

3GPP standards were applicable to similar networks.LTE Advance focuses on SON for HetNets[1] [2] [8] [13].Key SON features are described as below. Figure 2 gives a view of the main SON functions.

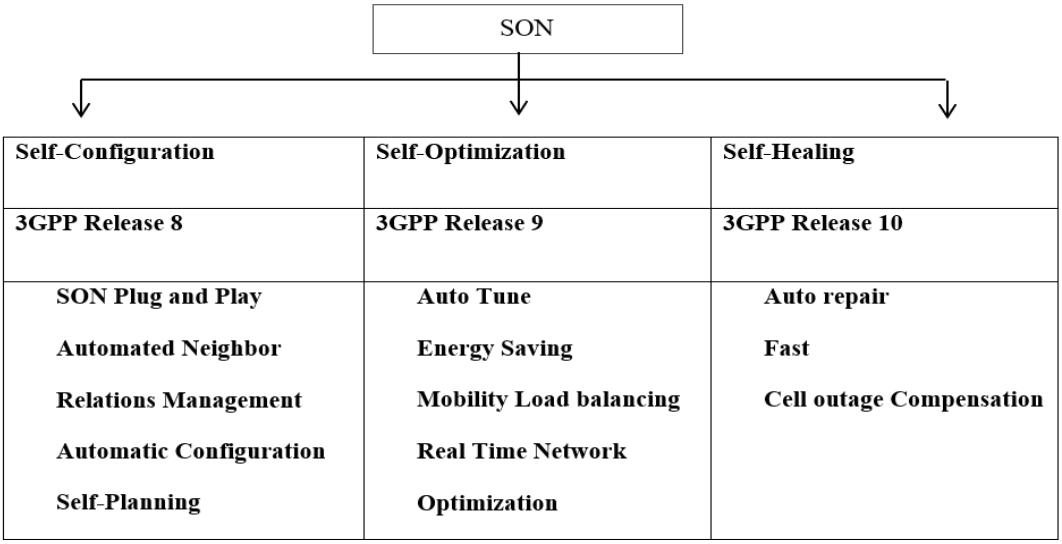

Figure 2. *SON in 3GPP (LTE)* [5] [8].

3.1. Self-Configuration: This feature mainly focuses on the tedious procedures that the complete network requires to go through when a new base station or a new eNB is being set up (Intentional events) [2]. This causes each eNB to change certain configuration which was all done under human supervision. This system is now automated, and all the vital information desired for the system to operate is reconfigured on its own. All of this happens as a part of the preoperational stages. Base stations now have the power to update software and help in attaining Physical Cell Identity and authenticating it[8]. After these initial stages then the base station automatically searches for the respective neighbors. Thus, this self-planning feature helps in reducing the manual labor required and faster implementation of the networks[2] [3][5] [6].

Use cases are nothing but what the actual problem is and what should be expected out of the solutions. There are various Use cases that are described to view real-life problems and try and find a solution to it. They shall be examined as the article progresses[3] [6] [8] [5].

3.1.1 Example of One of the many Use Cases for Self-Configuration:

A)Physical Cell Identity (PCI): We provide the eNb with Cell Identity so that the User equipment can identify its base station that it's being served from. In SON as soon as the eNB is initialized, it acquires a PCI.There can be cases where there are two eNBs have the same ID. To avoid such conflict each eNB should have unique ID's. As per LTE specifications, there are approximately 504 physical cell ID's. [3][10]

B)Automatic Neighbor Relation (ANR):One of the vital tasks ofSelf- Configuration function isdetermining the neighbors and the serving base station when the new eNB is turned on.Thus, it is the first one to be systematized by 3GPP. ANR backed up by the User Equipment (UE), helps in identifying different cells including the cells listed in the neighbor list and the serving station. It also identifies cells that belong to a different technology [4]. The interface between two eNB is connected automatically with ANR. It reduces the number of calls due to handovers. ANR is further categorized into Neighbor Relation Detection Method, Neighbor Removal method and Neighbor Relation Management. These sub-methods are used whenever a

new cell is to be added or to be removed or there is an update from the OAM system [3] [10].Thesteps mentioned belowdescribes how ANR functions:

UE measures the presence of variouscells with the help of Evolved-Universal Terrestrial Radio Access Network (E-UTRAN) Measurement Configuration and informs the serving cell. It uses Physical Cell Identity to get these measurements. Then the UE seeksthe Broadcast Control Channel (BCCH) and reads the Global ID and reports it to the serving base station[3] [10].

Then it updates this ID to the OAM system and obtains the Internet Protocol (IP) address for the new base station TheeNB then update their neighbor list as per the results obtained fromthe cell, and if required establishes the X2 interface amidst the eNB[3] [10].

3.2. Self-Optimization: After the base station has managed to configure and install itself into the network. This is the operational stage where optimization of all the parameters takes place. Here its duty is to automatically adjust the parameters like capacity coverage, power, energy, traffic and load control with the help of the eNB and UE.It tries to achieve maximum efficiency by harmonizing theeNB.This feature helps in reducing the workload for the vendor and reduces the operational cost incurred[1] [3][6] [12].

Self-optimization is a continuous work-cycle where the data is gathered and then checked for optimization; depending upon the result, it performs the steps to accumulate data again and the same circle continues. This happens as the different networks and different service providers use different measurements and technologies [3] [6] [8].

3.2.1 Example of the Use cases for Self-Optimization

A)Mobility Robust Optimization (MRO):There is a need to detect disputes in the parameters and provide an acceptable solution to it, which is done by MRO.Radio Resource Management (RRM) is always present to solve issues like handovers but there are certain obstacles that RRM is incapable of solving, which is automatically adjustable using MRO. One of the issues is quick handover between cells (Ping-Pong situation) that causes wastage of radio resources and reduces optimization. Another issue is failure in radio links (RLF) and access failure[8].MRO performs a study over the cells and determines their relationship with each other.The issues detected wereearly handover and too late handover or handover to a non-prioritized cell. This information is given to the OAM, and it makes the required adjustments [4] [6] [10].

B) Coverage and Capacity Optimization (CCO): The foremost intention is to render continuous coverage and capacity while using minimal resources that can be used withouthuman supervision. The system has to be automated to check on the signal quality and bit rate catered to the UE. These parameters influence the throughput to be obtained. The UE collects information of the signal quality and the data rate that is being dispatched along with the power and traffic load. It also measures the antenna parameters.This information is given to the eNB and certain tools are used to make changes in parameters, and then given to capacity and coverage optimization function.Further, these parameter changes are distributed [10].

A technique gaining popularity is the Active Antenna System that is used to measure the antenna parameters and change them to provide CCO. There can be a drawback to this system as well. A minor change in the antenna positioning and tilts can cause increased interference and degrade the network performance as well [3] [8] [10].

3.3Self-Healing: This feature was introduced in SON as the need to solve and overcome the occurrence of unintentional events like failure or malfunctioning of the networks,UE,eNB's.This can also help in adjusting

the boundsto avoid certain failures or provide measures to recover faster from a failure. It follows certain Self-healing Mechanism or strategies that provide feasible solutions. It reduces the labor of changing the software and hardware manually.[3] [6] [11].

3.3.1 Example of Use Cases for Self-Healing

A)Cell outage Detection and Compensation: When a failure occurs or a defect in equipment is found, SON usually analyses the cause of the breakdown and tries to solve it using certain algorithms. Cell outage detects the flaws and creates a report. The detection of these flaws is crucial to understand the decline in the efficiency of the system.

The cell outage compensation tries to solve the issues and bring back the system to the normal mode. COC takes precautionary measures and is always alert for any such kind of random failure. It keeps a backup /temporary solution in case there is less time to fix a given problem. All the solutions need to be authenticated and verified before the implementation [4] [8] [12].

IV. Basic Components/Framework design for SON:

The different SON functions examinedabove have a great impact on the designs to be implemented. It changes as per the requisite of the functions. They were deployed in different releases of LTE. The self-configuration feature was included in Release 8 of LTE while, Self-optimization and self-healing came in the later Release of Rel 9 and Rel 10 and then into LTE-Advanced. Each one of these features useddistinct set of rules and methods to help make optimum use of network resources. Thus, due to this there are different elements, components in the architecture of SON [3] [6].

The features mentioned earlier of SON can prove beneficial to mobile operators whoswitch between different technologies or provide more than one technology like Code Division Multiple Access (CDMA), HSPA evolved from Wideband Code division Multiple Access (WCDMA) and LTE. Thus, another target of SON implementation is to allow co-ordination among service providers and coexistence of various technologies. These different architectural designs influence thecordial functioning of the network [6] [8] [11].

4.1.Centralized SON(C-SON): As the name proposes, all the tasks are carried out at one location, that is the Operational and Maintenance (OAM) system. It is not present at every location, but in few locations at a higher administrative level[11].It collects data and measurements from various networks it is working on or the different technologies it is using. This data that arecollected over a period of time is used for examining each functional aspect of the network, estimating the flaws and correcting them [3] [11] [9].

4.1.1 Benefits of C-SON:

As the data is being taken from different networks and cells, there has to be a link or some form of parameters that correlate these cells. Thus a centralized system is a global system which will include all parameters and changing any of these parameters for a peculiar cell will depend on parameters of other cells as well [6].

With a centralizedarrangement, it is obvious that certain resources will be shared, and this results in concurrent optimization of the different cell parameters. This inter-mutual optimization is required in cases like mobile traffic and load balancing [6].

The main feature of a centralized design is that SON can be capable of managing service providers that support different technologies.Since it's a centralized system, it is easy to set up SON functions and elevate them whenever required [6].

As it is the point of communication for all the other cells and all the information exchanged is through this central system, it has all the database of every cell it is correlated to. This makes it easy to change the approach to optimization and use different methodologies to get the best optimization. In short, the system is flexible [6].

4.1.2. Drawbacks of C-SON:

The most well-known disadvantage of a centralized system is the old Single Point failure. If the System fails, all other connected systems stop functioning. This causes a lapse in the network. Then the time taken to reboot the network can cause losses [6].

It's slow processing, as it has to collect data from every cell it's related to and analyze that data. This causes delays and makes the whole system slow.Also the bandwidth requirement is large as it has to comprehend a huge database [6].

4.2.Distributed SON: In the distributed system SON functions are decentralized unlike the centralized system. It is the eNB's that carry out SON functions which take less time for adjusting the required parameters as the eNB has the permit to make decisions. Thus, it subjugates the drawbacks of the centralized system. SON functionalities are distributed within the eNB's that form the lower administrative level [6] [11].

4.2.1 Benefits of D-SON:

Most Significantly, there is no occurrence of single point failure Since all the data is not being sent onto one location and decision making occurs on an individual basis in separate eNB's, it essentially does not demand for large bandwidth. Its acts fast and make the transitions in case of changes in parameters and failure. Does not wait for the response from higher management(faster)[6].

4.2.2 Drawbacks of D-SON:

As SON functions are distributed, the interchange of information goes onbetween the nodes. This makes it tough to gather data from each node.Thus making changes in the standard procedures for upgrading the system becomes difficult [6].

Optimization is another strenuous task as it requires assimilation of all the data from the different nodes that support SON functions [6].

4.3.Hybrid SON (H-SON): As the name goes, it is the unification of the above two forms of architecturaldesign. It combines the benefits of the prior two systems and reduces the drawbacksfor the betterment of the network. Here partial functionalities are given to the OAM system and partial to the eNB's [6] [10].

4.3.1 Benefits of H-SON:

SON functions get divided; the simpler ones are carried out at the lower levels i.e.eNB's while the complex SON functions that are time consuming are accomplished by the OAM system.

Changes in the pattern of tasks performed can be managed between the higher and lower levels. Real time response is faster in H-SON[6].

4.3.2 Drawbacks of H-SON:

There exists fewdrawback of H-SON, as it proves to benefitthe network system and an intermediary link that fights the differences in the other architectures.However, the cost is a major factor as the expenditure for design of such a system is huge.Although we talk about merging the two models discussed above, systematic co-ordination between the centralized and distributed system is hard to obtain [6].

The design of SON discussed above is mainly for the deployment in LTE networks, but this can be added to the legacy systems of GSM and UMTS.Though limited SON functions would be accomplished in these legacy systems. Hybrid and Distributed SON is possible in the LTEnetworks while the centralized SON can be offered in 2G and 3G networks. Radio resources Management (RRM) and SON can be collaborated in the legacy radio technologies where RRM allocates resources like power, traffic control, coverage capacity and SON adjusts there parameters on an automated basis to familiarize with the alteration in the network environment [6] [11].

V. Limitations in Application of SON

Throughoutthis article, there has been mentioning of data measurement and collection of information for analyzing the condition for performing self-configuration and optimization functions.How do we measure data?What quantity of data is required?What should be the quality of data received? At what interval do we require the data?This data analysis can be taken from the feedback method from operators and User equipment. Now the next issue is how to process this data that has been collected, we alsohave to keep in mind to not exceed cost while designing these processors[1] [2] [9].

Next is formulating algorithms, which requires considering theparameters set for SON functions. These algorithms have to be structured in such a manner that the parameters are satisfied as there can be conflicts. Like we require continuous handover measurements to improve the signal quality while these fluctuations in handover measurements can cause a miscalculation in Mobility Robust Optimization. Methods that we develop need to prioritize the User Equipment. It can help in resolving problems.Also these algorithms need to use the old logistics and tools that could support the LTE system [1] [2] [9].

Thirdly, another question arises that whether the data attained from the UE's is dependable or not. Also we have a decentralized system being used in LTE, so the information is accumulatedin bits and parts from distinct service providers. This database that is being created can be faulty or misread at times causing optimization issues. The tools created for the purpose of optimization should be reliable [1][2][3][9].

SON is implemented in LTE and will be carried further as the technology advances. Thus, the tools should be formulated such that it can be easily altered with minimal expenses. Creating a completely new system for SON in LTE would further intricate the existing network. This would require a huge budget and the working of the system in the real network can be risky. The easiest way to implement SON would be to incorporate changes in the actual system [1][2][3].

VI.Future Prospective

As LTE advances into the future, the network grows wider, as HetNets, pico cells, femto cells get added. These are smaller in size and can be implemented easily anywhere.SON features can be used along with these to obtain parameter measurements that would help in Reconfiguration. The inclusion of these small

cells causes chaos and interference problems.To overcome the interference among these cells a major lookout is for frequency assignment and maintaining the power control so as to have self-organizing functional.SON can be made functional along with other features like Co-ordinated Multi Point(CoMP). It has been beneficial in reducing the interference on the cell edges. Although SON has limitations, it is developing to prove a boon to the ever-growing complex network [1] [9] [11].

VII.Conclusion

Self-organizing networks and its features were discussed on a major ground. It can be seen that SON can help make the network sustainable and manageable while fulfilling the purpose of cost reduction. SON application can be brought into actuality by overcoming the challenges of reliability, calibration of data and other limiting factors. A few of the SON use cases have been discussed for each function that holds prime importance. There can be no ideal solution for deploying SON functions into the network; it requires co-ordination, adaptability of the network to ensure harmony between technologies.

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