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RESEARCH OF SELF – ORGANIZING NETWORKS (SON) ALGORITHMS EFFICIENCY APPLYING ON FOURTH – GENERATION MOBILE NETWORKS

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The application of SON algorithms for automating the processes of operating fourth-generation mobile networks based on the networks of operation, administration and management of OAM (Operation and Maintenance) is considered. The features of the tasks at the stages of self-optimization and self-configuration of the network for the various stages of 4G mobile network life cycle are shown. Criteria and approaches to assessing the effectiveness of solving problems by the SON network are proposed. The technical requirements are also formulated for SON algorithms. The experimentally achieved values of the selected performance exponents depending on the duration of the test cluster self-optimization time of the 4G network are shown.

Keywords: Algorithms of self-optimization, LTE, Self–Organizing Networks, Self–healing, Telecommunications

1. Introduction

The strategy for automating the processes of managing mobile communication networks implemented by the chief developer of Technical specifications for mobile communications of the 3G, 4G and 5G generations - By The 3GPP partnership project in the technological concept for the self-organizing networks (SON) use, which covering all stages of the life cycle of these communication networks.

In accordance with definition, indicated in the technical specifications of the 3GPP Partnership Project, a SON network – is a network used by a Mobile Network Management and Operations (MNO) system to automate network management while minimizing human involvement in network management.

Taking into account that SON algorithms are not standardized by the 3GPP Technical Specifications (TS 32.500, 2014; TR 28.861, 2019), the study of automated management of cellular networks without the participation of a human-operator is becoming an increasingly urgent task.

The technology of 4G mobile communication refers to a technology that has reached market maturity and allowed for the research not in laboratory, but for a real use.

The effectiveness of any activity is usually expressed by using the ratio of result in cost. In this case, the task is to maximize the result of the cost per unit.

Under the effectiveness of the use of the SON network, we will understand the interdependence of the results (exponent) of the SON network working and either financial or resource costs. In this study we will consider changes in the following private exponents of the effectiveness of 4G network functioning:

– LTE user throughput DL (Mb/s) – The average data transfer rate to the end user in the "down" line, Mb/s.

- LTE user throughput UL (Mb/s) – The average data transfer rate to the end user in the "up" line, Mb/s.
- PS_Data_Vol (MB) – The amount of packet data transmitted in communication lines by directions "down" and "up", MB.
- VK_4G_E_RAB_DR (%) – Percentage of disconnection of established connections not at the initiative of the subscriber, %.

The above private exponents will be the constituent elements in the main exponent of the effectiveness of the 4G network.

The results of applying the SON algorithm presented in this article are obtained on a cluster of 4G network, put into commercial operation.

The purpose of the performed study is to assess the effectiveness of the SON algorithm on 4G mobile networks under the conditions of dense urban areas.

2. Research Background

Due to the large number of parameters, the process of automating the planning of networks of mobile operators requires a support. Self-organizing network (SON) presented the network of an automated control with the provided continuous monitoring of the service quality and network, as well as data analysis collected from different network nodes, provides a useful feedback. The SON capabilities put attention on the support business priorities of mobile broadband and intelligently manage of network traffic load. This allows operators to focus on providing an excellent user experience. Figure 1 shows how the SON functioning process is arranged, that is cyclic and includes solving the problems of self-configuration, self-optimization and self-healing, as well as managing network parameters according to the results of current measurements (Gandalf, 2019, TS 32.511, 2018).

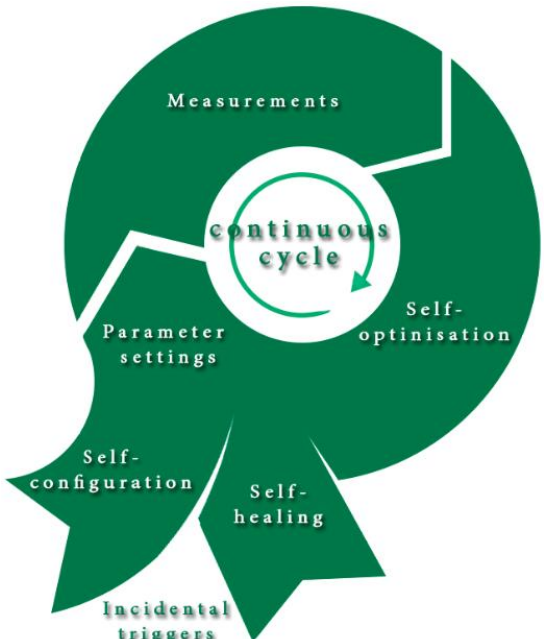


Figure 1. The process of working of Self – Organizing Network (Gandalf, 2019)

2.1. Requirements to Performance and Complexity

Within using SON, it is necessary to maintain a balance between the performance improvement, obtained by adding SON functionality and the total complexity of decision implementation into the operator's network. Implementation complexity can be measured by using, for example, an additional load on transport network, server power capacity, memory space, etc.

2.2. Requirements to Stability

The SON algorithms should be able to identify a susceptible to interference or incorrect measurements so that the algorithm can always respond correctly to the situation in the network.

2.3. Requirements to Time

The time interval, during which the SON algorithm operates, varies from seconds to days, depending on the mode of use. For example, for the case of using optimization of coverage and bandwidth, the algorithm responds in months since it analyses the changes in the radio environment and reacts on it. For optimization of mobility load balancing to the base stations the algorithm for compensating of malfunctions in a cell should responds quickly enough, that is, in the order of seconds after a malfunction was detecting in a cell.

2.4. Requirements to changings

The interrelation is necessary between all algorithms that change the same parameters to ensure that the parameters will not be changed in the opposite directions. In this case, a conflict may arise. For example, algorithm of compensation cell failure may adjust the powers of pilot signal for direction traffic to cells without failures, on which the algorithm of load balancing may respond like on the induced unbalances of traffic load by unwanted countermeasures.

2.5. Requirements to Architecture and Scalability

The SON algorithms can be implemented in the central, distributed or combined ways. The centralized implementations require the possibility of centralized monitoring, storage and data analyse. If the algorithms are implemented in a distributed manner – the appropriate computing power, memory, and storage capacity in the servers are required (TR 36.902, 2011, TS 36.300, 2018).

2.6. Financial Requirement

The SON solutions should reduce capital expenditures (CAPEX), since after SON implemented, the network will efficiently use radio resources and therefore will require fewer base stations. However, the introduction of SON functionality will increase the cost of equipment, including terminals, base stations and service systems, due to the necessity of additional hardware and/or software. Therefore, one should take into account the impact of SON on the cost of the entire mobile network (TS 32.541,2018).

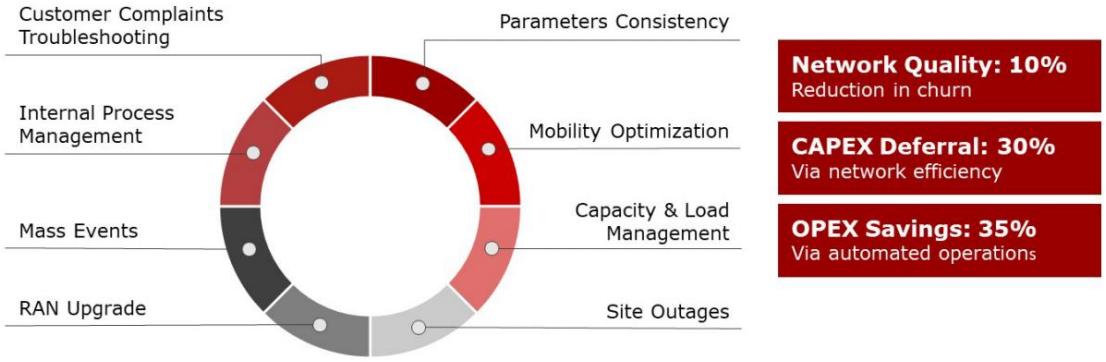


Figure 2. The contribution to operational cost savings and overall business relevance of using SON solution on a radio access network (Gabriel Brown, 2019)

The SON already deployed in RANs mobile networks and has shown that it provides significant benefits in terms of reducing costs and increasing network performance. Processes such as remotely configuring new base station equipment use SON to reduce labour, improve accuracy, and improve the speed of commissioning new network elements. The SON also is used to improve the performance and throughput of the cellular network. Fig. 2 shows the results obtained in operating cost savings and the overall effect from SON application on radio access networks for European operators. In the figure to the left an example of the average operating cost savings achieved with SON using in RAN is shown; the way how they distributed across different optimization processes. Based on this data, it can be concluded that the SON using affects to the overall budget of the business, including deferred of capital expenditures and increased revenue by improving the quality of radio coverage and provided services. These advantages are significant, as long as that most cellular operators now either already using SON algorithms, or are considering options for deploying a SON network and return on investment for its implementation (Gabriel Brown, 2019).

3. Experiment method and description

In this study a cluster of base stations in one of the districts of Almaty city is examined (Figure 3).

The cluster consisted of 25 base stations of 4G (LTE) standard.

The time interval of observations was 52 days.

Statistical data collected in 26 days before the optimization of the base stations in this cluster and 26 days after the application of the developed algorithm of using the SON tools.

The fundamental difference between the applied algorithm and the existing SON algorithms is the presence of amendments to some values of the target network indicators, as well as the difference in operating conditions of the tools for step-by-step optimization of the antenna tilt angle and in balancing of the traffic load at base stations on cellular communication.

The changes were made to the threshold values of key performance exponents of cellular networks for the base stations under study:

– The total received broadband power or interference level in the Received Total Wideband Power (RTWP) sector was increased from -105 dBm to -103 dBm.

– In the LTE_Mobility_SR parameter or the percentage of successful outgoing handovers of the subscriber equipment, the threshold was changed from ≥ 95% to ≥ 98%, thereby tightening the requirements for the quality of the subscriber's service transfer from one base station to another and minimizing the likelihood of the abonents connection fault or Internet session fault;

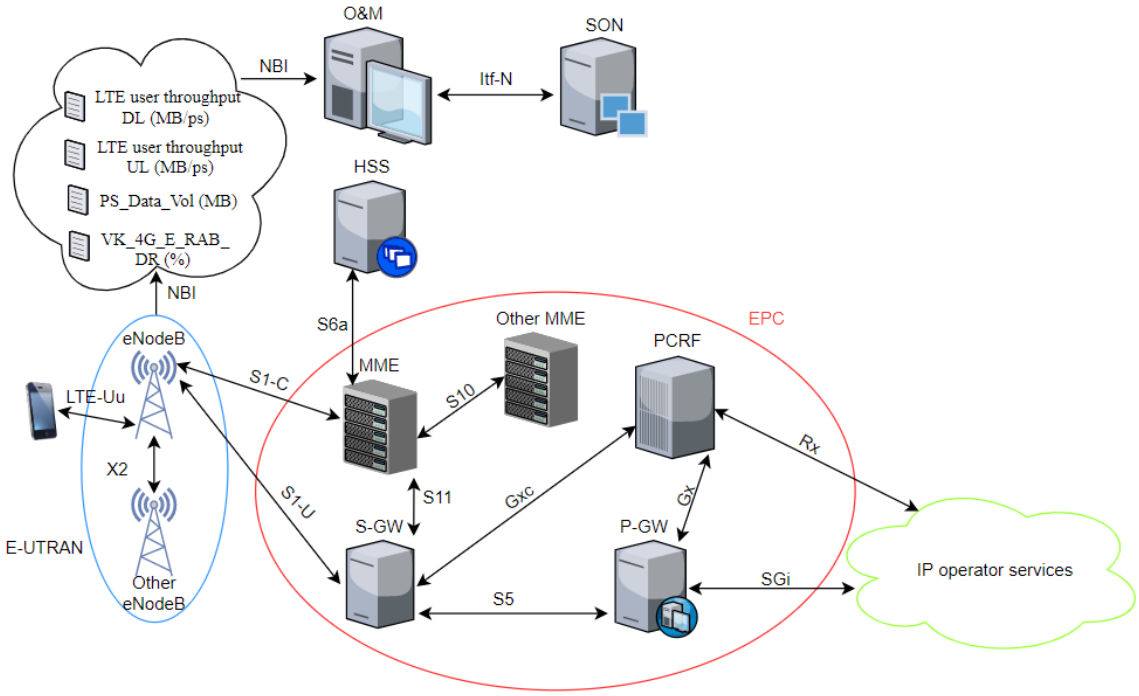


Figure 3. Block diagram of the experiment

Also, for the tool of step-by-step optimization of the angle of inclination of the antennas, the maximum permissible step of changing the electrical angle of inclination (electrical tilt) of the antennas for base stations was adjusted. The allowable step was changed from 1 degree to 2 degrees as a part of this experiment to increase the speed of response and improve the situation at the LTE base stations.

For this study, we used the following Self Organizing Networking (SON) tools:

1) The Tool of step-by-step optimization of Antenna tilt (Antenna tilt optimization Iterative).

2) The Tool for balancing traffic load on mobile network base stations (Mobile load balancing).

3) The Tool for automatic configuration and signal messages exchanging between neighbouring sectors of cellular base stations (Automatic neighbour relation).

4) The Tool for optimizing handoff of maintains (Soft Handovers) for subscriber devices when changing from a service area of one base station to a service area of another cellular network base station (Mobility robustness) (Smarter, 2012).

From the diagram of experiment shows:

1) The SON has communicated with the O&M control module using the N interface, also in the transmission of service information Diameter protocol participates.

2) O&M, in turn, connected with the eNodeB network via the NBI interface and collects service/signalled data from all network elements (Penttinen, 2016).

Every hour, SON receives relevant reports of network status from O&M, which, in turn, collects this service data via NBI interface from all network elements. Based on these data SON decides what actions should be taken to improve the quality of radio-coverage and stable working of radio-access network. Interfaces and network nodes that are involved in the transfer of service and control data are known, and do not need a detailed description.

Node MME primarily supports the implementation of Mobility Management protocol procedures: ensuring security of working on network within UE connecting and choosing of S-GW, P-GW. MME connected with HSS by its network via S6a interface. The S10 interface, connecting various MMEs, allows serving the UE when the subscriber moves, as well as subscriber being in roaming.

The NBI interface or "Northern" interface using in carrier-class networks and in telecommunication network elements. Normally used languages and protocols include SNMP and TL1.

The N interface using by network management systems and by services for control messages sending, notifications and management requests.

DIAMETER is a session protocol that provides interaction between clients for authentication, authorization and accounting of various services (AAA, English Authentication, Authorization, Accounting).

The RX Interface - main purpose of this interface is transferring information of session from AF to PCRF. RX also using by AF to sign up for notifications of traffic plan events. For example, that the IP session has been closed or that the UE has been transferred to another access technology (Magnus Olsson *et al*., 2009).

4. Results and Discussion

The following network parameters were selected as the indicators of the 4G network performance:

- LTE user throughput DL (Mb/s) – The average data transfer rate to the end user in the "down" line, Mb/s.
- LTE user throughput UL (Mb/s) – The average data transfer rate to the end user in the "up" line, Mb/s.
- PS_Data_Vol (MB) – The amount of packet data transmitted in communication lines by directions "down" and "up", MB.
- VK_4G_E_RAB_DR (%) – Percentage of disconnection of established connections not at the initiative of the subscriber, %.

Hereafter, we consider the main parameters of the network that were selected to compare; how the network worked before the inclusion of self-organizing networks (SON) optimization tools; and how it began to work after the tools (SON) turning on. Disable of SON modules is not possible - they work 24/7 365 days a year because various changes constantly happening on the network. Consider the features of each of the selected network parameters.

4.1. Change in the private exponent (LTE_User_Throughput_DL) of the efficiency of the 4G network according to the results of the experiment

This parameter is very important for the end user, since the faster the user downloads data, the less he would think about changing the mobile operator and remain a loyal customer of the company. Another important criterion is the fact, that the more traffic the base station processed for a certain billing period, the more profit the mobile operator will get in terms of money. Respectively, the higher speed the end user has, the more information he downloads and spends his internet package. It is calculating at the sector level and above.

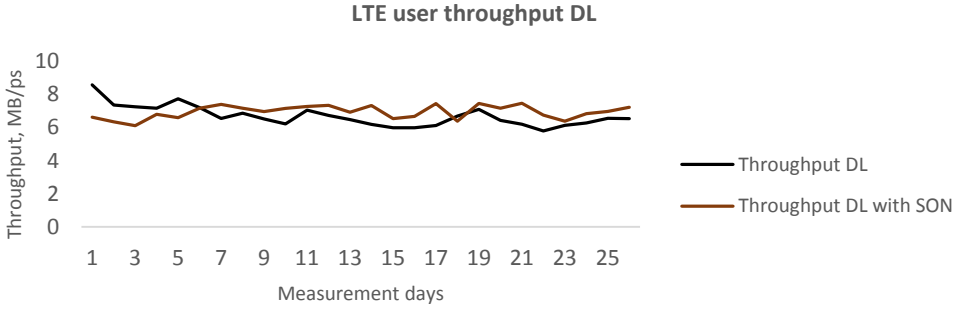


Figure 4. Graph of LTE_User_Throughput_DL parameter before and after enabling self-organizing network (SON) tools

It is calculated as the ratio of the total amount of data to the values sum of the data time transmission for all user terminals (UE). The formula for calculating of the parameter is below:

$$\text{DL_Avg_Thr_CEU} = \frac{\sum_{i=1}^{25} \text{L.Thrp.bits.DL.CEU}}{\sum_{i=1}^{25} \text{L.Thrp.Time.DL.CEU}}. \quad (1)$$

The result of the use of self-organizing networking (SON) tools with the developed algorithm, described in Section 3, is an increase in the average download speed of packet data in Mbps downlink by 4.23% (Figure 4), which is rather serious result within the whole cluster of basic 4G stations.

4.2. Change in the private exponent (LTE_user_throughput_UL) of the efficiency of the 4G network according to the results of the experiment

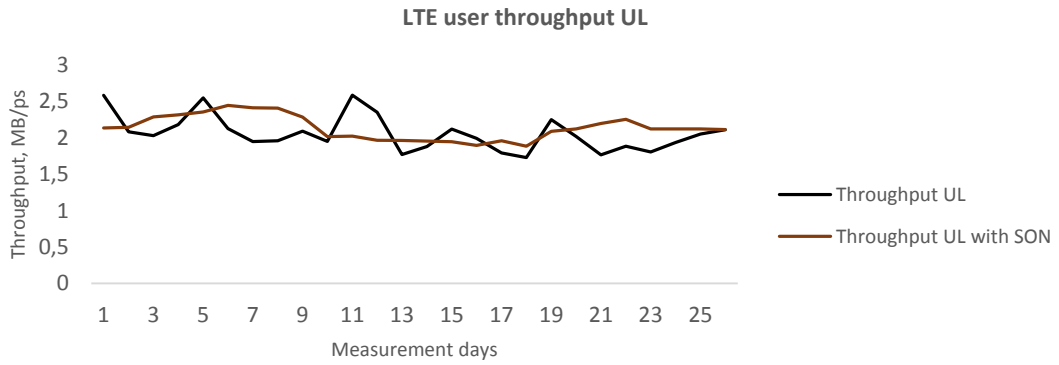


Figure 5. Graph of LTE_User_Throughput_UL parameter before and after enabling self-organizing network (SON) tools

According to this parameter, all the main factors are the same like for the previous one, except that this parameter shows us the speed at which a subscriber can transfer information from his smartphone to the Internet (file hosting services and various instant messengers). It calculated at the sector level and above. It calculated as the ratio of the totally amount of data to the sum of the data transmission time values for all user terminals (UE).

The result of using of Self-organizing networking (SON) tools with the developed algorithm described in Section 3 is an increase in the average download speed of packet data in Mbps uplink by 2.9% (Figure 5), which is not a significant increase in the speed in terms of the base stations cluster of 4G standard.

$$\text{UL}_{\text{Avg}_{\text{Thr}}} = \frac{\sum_{i=1}^{25} (\text{L.Thrp.bits.UL} - \text{L.Thrp.bits.UE.UL.LastTTI})}{\sum_{i=1}^{25} \text{L.Thrp.Time.UE.UL.RmvLastTTI}}. \quad (2)$$

4.3. Change in the private exponent (PS_Data_Vol_MB) of the efficiency of the 4G network according to the results of the experiment

The amount of packet data transmitted in communication lines by directions "down" and "up", MB. It is calculating at the sector level and above and calculated as the sum of the amount of packet data. This parameter directly related to the exponent of base station performance, since the more traffic the base station passes through itself, the more money it brings.

$$\text{PS_Data_Vol} = \sum_{i=1}^{25} (\text{PS}_{\text{Data}_{\text{Vol}_{\text{DL}}}} + \text{PS}_{\text{Data}_{\text{Vol}_{\text{UL}}}}) \text{ [MB]}. \quad (3)$$

in its turn:

$$\text{PS_Data_Vol_DL} = \frac{\text{L.Thrp.bit s.DL}}{8 \cdot 1000000} \text{[MB]}. \quad (4)$$

$$\mathbf{PS_Data_Vol_UL} = \frac{\mathbf{L.Thrp.bit\ s.UL}}{\mathbf{8 \cdot 1000000}} \mathbf{[MB]}. \quad (5)$$

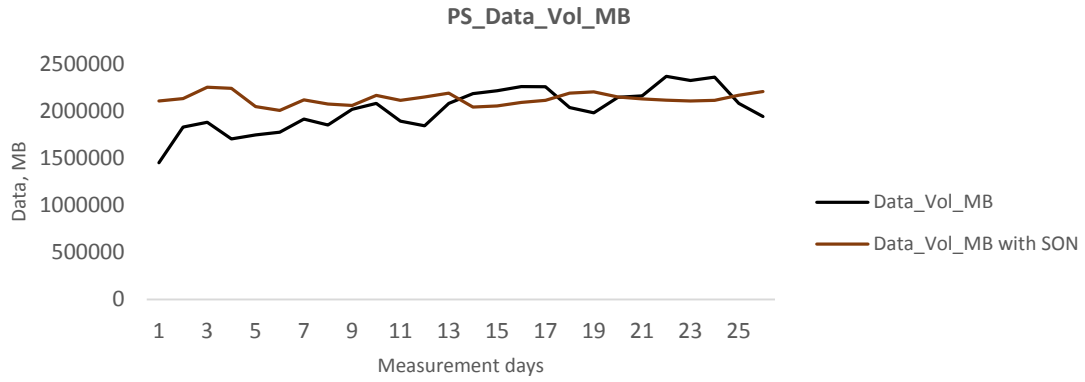


Figure 6. Graph of PS_Data_Vol_MB parameter before and after enabling self-organizing network (SON) tools

The result of Self-Organizing Networking (SON) tools using with the developed algorithm described in Section 3 is an increase for 4.3% of total 4G packet traffic per MB (Figure 6). This is a significant achievement in terms of the base stations cluster of 4G standard.

4.4. Change in the private exponent (VK_4G_E_RAB_DR (%)) of the efficiency of the 4G network according to the results of the experiment

It is calculated as the ratio of the number of established connections, which disconnected not on the initiative of the subscriber, to the total number of established connections, multiplied on 100 (to go to percentage). This indicator is very important for mobile operators, and should be kept to an absolute minimum. Since the interruption of a conversation or Internet session has a very negative effect on the customer experience of a telecommunications company.

$$\text{E_RAB_DR} = 100 \cdot \left(\frac{\sum_{i=1}^{25} (<L.E-Rab.AbnormRel>)}{\sum_{i=1}^{25} (<L.E-Rab.AbnormRel>+<L.E-Rab.NormRel>)} \right) [\%]. \quad (6)$$

The result of Self-organizing network (SON) tools using with the developed algorithm described in Section 3 is an improvement in the percentage of disconnection of established connections not initiated by the subscriber for 1.1% (Figure 7). This is a good result in improving the customer experience for 4G subscribers.

For convenience of analysis, the experimental results shown in Table 1.

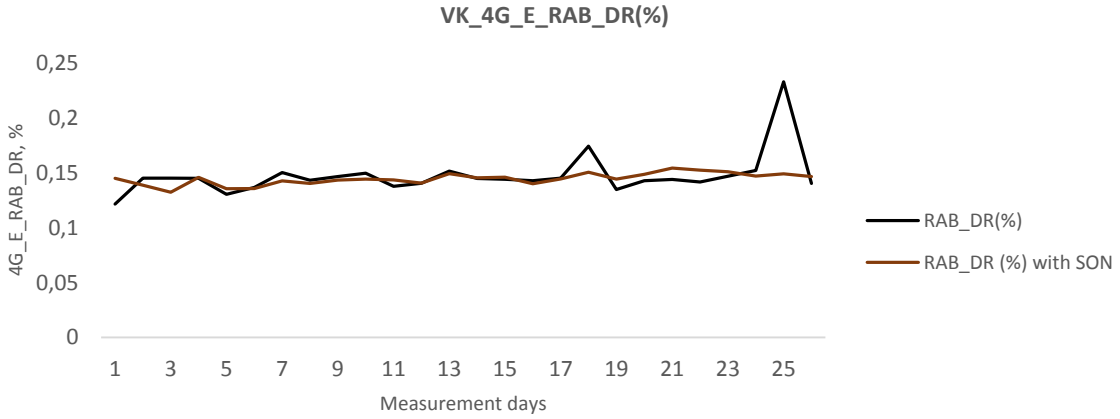


Figure 7. Graph of VK_4G_E_RAB_DR (%) parameter before and after enabling self-organizing network (SON) tools

Table 1. Experiment Results for SON Algorithm Evaluation

Time interval of the algorithm working / Performance exponents	1 day	1 week	1 month
LTE user throughput DL (The average data transfer rate to the end user in the "down" line, Mb/s.)	Average packet data download speed (Mb/s) *in* DL increase on **0.09%**	Average packet data download speed (Mb/s) *in* DL increase on **0.88%**	Average packet data download speed (Mb/s) *in* DL increase on **4.23%**
LTE user throughput UL (The average data transfer rate to the end user in the "up" line, Mb/s)	Average packet data download speed (Mb/s) *in* UL increase on **0.03%**	Average packet data download speed (Mb/s) *in* UL increase on **0.58%**	Average packet data download speed (Mb/s) *in* UL increase on **2.9%**
PS_Data_Vol_MB (The amount of packet data transmitted in communication lines by directions "down" and "up", MB.)	Packet traffic of 4G (MB) increase on **0.08%**	Packet traffic of 4G (MB) increase on **1.84%**	Packet traffic of 4G (MB) increase on **4.3%**
VK_4G_E_RAB_DR(%) (Percentage of disconnection of established connections not at the initiative of the subscriber, %.)	Exponent of established connections disconnection not initiated by the subscriber **remained unchanged**	Exponent of established connections disconnection not initiated by the subscriber improve on **0.34%**	Exponent of established connections disconnection not initiated by the subscriber improve on **1.1%**

5. Conclusion

The SON networks provide the self-optimizing mobile communications to provide data service availability with a good customer experience, as well as optimized coverage and higher capacity.

The implementation of SON solutions in the 3GPP radio access network has proven its effective and financially attractive character for the mobile operators due to the savings in operating costs and the postponement of additional capital costs associated with the necessity to optimize the network.

The results of the experiment in the use of the developed SON algorithm in the 4G radio-access network made it possible to evaluate the effect of self-optimization on the 4G network segment, which provided a significant increase in the volume of processed traffic and the quality of service for the subscribers. At the same time, the physical expansion of the number of base stations (adding universal frequency processing boards) is not performed.

– According to the results of the experiment (Table 1), we can conclude that the SON algorithm needs time to optimize and improve the quality of the network segment; in this case, we considered a time interval of 26 days.

– As a result of the SON algorithm, the percentage of disconnection of established connections not initiated by the subscriber decreased by 1.1%. During the study period, the number of disconnections of established connections is not initiated by subscribers in the cluster under consideration decreased by 12,173 cases.

– The work of the SON algorithm balanced the load on the base stations in the cluster under study, resulted in the reducing of the load on the overloaded base stations and distribute it among other base stations, which ultimately contributed to increase in the data transfer rate to the end user in the "down" and "up" lines by 4.23% and 2.9%, respectively. The data download speed increased by 0.5 Mb/s, that significantly improved the customer experience and feedback on the telecom operator in this area of the city. The information transfer rate from the user to the base station increased by 0.1 Mb/s, which can also be considered as success, but not significant.

– The result of working SON algorithm on the network cluster is a 4.3% increase in packet traffic per MB. In quantitative terms, in 26 days, taking into account the effect from working of SON algorithm, the collected packet traffic from the investigated network section increased by 900 Gb. This is a very good indicator of improving the quality and speed of mobile Internet.

– A negative result was also received. It expressed in the excess of the planned percentage level of resource blocks utilization in the direction of "down" and "up" lines (PRB DL, PRB UL) by 0.87% and 2.2% respectively, in the studied sectors in the base stations cluster. This excess of the utilization level of resource blocks is not critical. With this level of excess of PRB exponents, the network functions without failures, but it is necessary to plan the expansion of base stations capacity in case of further growth of these indicators.

In according to the results of the study and experiment, we can conclude that adjusting the maximum permissible step of changing the electrical angle of inclination of antennas for base stations by 1 degree helped to speed up the operation of the SON algorithm. It results in faster adjust of the load at base stations in the studied network cluster. Increasing the sensitivity threshold of the RTWP exponent allows to avoid an unnecessarily response of the system (appearance of emergency on the monitoring system, excessive signalling and overload of control channels) to a change in the level of interference in the sectors of base stations. Based on the results of the study and experiment, the effectiveness of the proposed SON algorithm on a cluster of a 4G mobile communication network in a dense urban development confirmed.

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