

Abstract

to the thesis research. A subject of this thesis paper:
«Research of Self-Organizing Networks (SON) algorithms efficiency in different application scenarios in mobile networks»,
submitted for the PhD degree in
specialty 6D071900 – «Radioengineering, electronics and telecommunications»

by

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According to 3GPP documents, a self-organizing network is a network, that used by a mobile network monitoring and control system to facilitate and automate operation without human participation in this process.

In the context of the global pandemic of coronavirus infection (COVID-19), one of the few industries that not only did not suffer, but also financially grew, was the telecommunications industry, and in particular, mobile communications. In connection with the widespread introduction of the quarantine regime, the load has increased dramatically on those parts of the networks where such an increase in traffic was not expected.

What helped mobile operators to cope with the sharply increased load and quickly manage the resources of their networks?

There are several factors here:

- 1) Initially technologically correct radio network planning;
- 2) Timely increase in carrying capacity of traffic networks;
- 3) The use of algorithms for self-organizing networks SON (Self - Organizing Networks) for operational management, administration, and network optimization.

Let's take a closer look at the 3rd factor. The development of SON began during the introduction of 3G networks and continues uninterrupted at this day. Self-Organizing Networks (SON), developed by the 3GPP consortium, provide automation, operational efficiency, and simplified management of mobile wireless networks. Thus, implementing SON ensures optimal network performance with minimal human intervention.

The main drivers for the SON development are:

- number and complexity of networks, nodes, elements, and parameters;
- availability of technological, multiprofile and multi-level operations in the network;
- traffic growth and bandwidth management;
- consistent quality and availability of services;
- necessity in interactive networks.

The ability to successfully manage all of these tasks ultimately results in significant OPEX and CAPEX savings, superior performance, and a positive customer experience.

Currently, in Kazakhstan has formed a duopoly in the telecommunications services market. There are two main players, that provide mobile and fixed

communication services to the population - first one is "Kazakhtelecom" JSC with the Tele2, Altel, Kcell, Activ trademarks and second one is "KaR-Tel" LLP with the Beeline trademark. These are thousands of base stations and tens of thousands of antennas that need to be controlled. The use of self-organizing networking (SON) tools greatly simplifies network management. Active implementation of self-organizing network tools by operators in the territory of Kazakhstan Republic began about 7 years ago. This process is quite time-consuming and not simple, since each region, city, town has its own characteristics. For example, features of the relief, buildings, population density. All these factors effect on planning and management of communication networks.

Vendors who sell SON solutions to telecom operators, being in a market economy, try to sell as many tools as possible and get the maximum profit. In reality, it is not necessary to use numerous SON tools. The most important thing is the choice of SON tools for the tasks of optimizing the mobile operator and the initial settings of key indicators (KPI). In this study has been developed and proposed a modified methodology, the provisions of which can be used to standardize the application and evaluate the effectiveness of SON on mobile operators' networks.

It is critically important for mobile operators to learn how to properly algorithmize the use of self-organizing network (SON) tools and determine the effectiveness of their work on their networks.

Relevance of the research topic:

The complexity of the technical operation of mobile communication networks under dynamically changing operating conditions (network load, meteorological conditions, seasons, global pandemics) are growing up. All this requires the growth of automated network management capabilities without the participation of the network operator. The SON algorithms are not standardized by the 3GPP Technical Specifications, which resulting in an unnecessarily wide variety of control systems and inconsistencies in network operation requirements.

The 4G cellular communication technology refers to a technology that has reached market maturity and makes it possible to conduct research not in laboratory, but in real network operation conditions.

Efficiency involves not only the result of activity, but also the external conditions under which it is achieved.

Under the effectiveness of the SON network accepted the ratio between the results (indicators) of the SON tools works and either financial or resource costs. In this study of the SON algorithms application effectiveness will consider changes in the following basic indicators of the functioning of the 4G network:

- LTE user throughput DL (MB/s) – Average data transfer rate per end user in the downlink, MB/s.
- LTE user throughput UL (MB/s) – Average data transfer rate per end user in the uplink, MB/s.
- PS_Data_Vol (MB) – Amount of packet data sent in communication lines of the directions "down" and "up", MB.
- VK_4G_E_RAB_DR (%) – Percentage of disconnection of established connections which not initiated by the subscriber, %.

- VK_4G_LTE_Mobility_SR – percentage of successful emanate token passing of subscriber terminals service when moving from the service area of one sector to the service area of another sector (Hard handovers).
- DL_PRB_Usage_Rate (%) – percentage of resource blocks utilization in the direction of the downline.
- UL_PRB_Usage_Rate (%) – percentage of resource blocks utilization in the upline direction.

The presented thesis research was carried out on the base of scientific research, methodological and experimental work, with the implementation of experiments and modeling on the network of one of the mobile operators.

The object of research is a mobile network cluster.

The subject of research is the evaluation of the effectiveness of the applied algorithms of self-organizing networks (SON) for various usage scenarios in mobile networks.

The abovementioned conditions form the **target of this thesis research**, which is formulated as follows: Development of a methodology for evaluating the effectiveness of SON algorithms for various application scenarios in mobile networks.

In the process of performing the thesis research to achieve the target were carried out the following research tasks:

- Analysis of the evaluation of the effectiveness of the application of SON algorithms in mobile networks.
- Explore the possibility of calculating a comprehensive, multifactorial assessment of the effectiveness of the application of SON algorithms in the form of an integral indicator.
 - Determine factor groups and a set of parametric indicators.
 - Assign the weighting coefficients to factor groups.
 - To conduct an experimental study of the effectiveness of applying the modified SON algorithm on a cluster of a mobile communication network in Almaty city.
 - Estimate changes in the radio coverage area in a selected mobile network cluster using dedicated radio coverage simulation and calculation software, Mentum Planet.
 - On the base of the results of the performed research, to issue a calculation module of the methodology for evaluating the effectiveness of SON algorithms for various application scenarios in mobile networks in the form of software.

The scientific novelty of the thesis research is as follows:

1. A methodology to evaluate the effectiveness of the use of SON algorithms for various scenarios of application in mobile networks has been developed.
2. For the first time, a comprehensive assessment of the effectiveness of using SON algorithms for various application scenarios in mobile networks is given.
3. On the base of the proposed methodology has been developed the software to calculate the effectiveness of the SON algorithms use for various application scenarios in mobile networks.

4. An amendment to the standard operating procedure of the SON tool has been proposed, which help to significantly reduce the time required to optimize the network.

5 A patent of the Republic of Kazakhstan was received: "A system for evaluating the effectiveness of the use of self-organizing networks (SON) algorithms on mobile networks" No. 6455 dated 09/24/2021.

According to the results of the research, the **following provisions are put forward for defense**:

1. Methodology for evaluating the effectiveness of the SON algorithms use for various application scenarios in mobile networks, which allows us to evaluate the effectiveness in the form of an integral indicator.

2. A comprehensive assessment of the effectiveness of using SON algorithms for various application scenarios in mobile networks is presented.

3. An amendment to the standard operating procedure of the SON tool has been proposed, which can significantly reduce the time required to optimize the network.

Approbation of the obtained results was carried out when forming a technical strategy for the implementation of SON on the network of a mobile operator. The results of the work are recorded by the act of implementation from the mobile operator "KaR-Tel" LLP.

The main provisions and results of research are reflected in **scientific publications**: 8 scientific papers and reports in international scientific-technical conferences and scientific journals, including: 3 scientific articles in domestic publications from the recommended by COXON MES RK list; 3 scientific reports in collected articles of international scientific-technical conferences, including a face-to-face presentation at an international scientific conference; 1 article in the journal of the Higher Attestation Commission of the Russian Federation; 1 scientific article in the "Transport and Telecommunication" journal that indexed in the Scopus database, with a percentile at the time of publication of 64% in the section "General Engineering". As the main author the results of research activities were recorded in the patent of the Kazakhstan Republic: "A system for evaluating the effectiveness of the use of self-organizing networks (SON) algorithms on mobile networks" No. 6455 dated 09/24/2021.

The author personal contribution to the solution of the issue under study is determined by:

1. In substantiating, formulating and choosing a methodology for studying the results of applying algorithms for self-organizing networks (SON) on mobile networks.

2. Development of a methodology for evaluating the effectiveness of the application SON algorithms for various application scenarios in mobile communication networks, which made it possible to evaluate the effectiveness in the form of an integral indicator.

3. Arrangement and implementation of experimental studies on the mobile communication network, as well as the formulation and implementation of modeling with using the specialized software package "Mentum Planet".

The thesis research was completed by the dissertation student in accordance with the current requirements for design, structure, and content. The work consists of 3 main chapters, normative references, designations and definitions, designations and abbreviations, introduction, conclusion, list of references and applications.

The first chapter provides an overview of the state-of-the-art in evaluating the effectiveness of the application of self-organizing network (SON) algorithms in mobile networks. The features of the functions of self-organizing networks (SON) and the concept of self-optimizing cellular networks are considered. The analysis of approaches for evaluating the effectiveness of the use of SON algorithms on the networks of mobile operators is carried out.

The second chapter is consecrated to the development of a methodology for evaluating the effectiveness of the functioning of algorithms for self-organizing SON networks. In this chapter, a factor analysis of indicators for the model for evaluating the effectiveness of the use of SON algorithms was carried out. A detailed description of the modules of the modified system for evaluating the effectiveness of algorithms for self-organizing networks (SON) is given. Weighting coefficients were assigned to each module in the overall assessment of the system using the method of expert assessments. The software designed on the base of the developed methodology for evaluating the effectiveness of the functioning of algorithms for self-organizing SON networks is presented.

The third chapter contains an analysis of the results of an experimental study and modeling of the application of self-organizing networks (SON) algorithms on a mobile operator's network. As well, in the third chapter, the calculation of signal losses in the radio link before and after the operation of the upgraded SON algorithm on a cellular network cluster is given. The simulation of the situation with radio coverage using the "Mentum Planet" software showed that the proposed upgraded SON algorithm during its work significantly amended the problem with exceeding the planned radio coverage area of base stations in the cluster under study. Checking the results when calculating the Pearson coefficient showed that the results of modeling and experiment have high convergence and low error.

The conclusion summarizes the results of the research and the main conclusions of the dissertation work.

The appendices contain the following key data from the research results:

1. Listing of developed software.
2. Block diagram of factor groups and indicators for evaluating the effectiveness of the network.
3. Graphical form of the modified system for evaluating the effectiveness of the application of SON algorithms.
4. Developed recommendations for decision-making by the operator connections.
5. Figure of simulation results of a radio network cluster before and after operation of the modified SON algorithm.
6. A copy of the act of implementing the main results of research on the network mobile operator.

7. A copy of the received patent of the Kazakhstan Republic for useful model "System for evaluating the effectiveness of the application of algorithms for self-organizing networks (SON) on mobile networks" No. 6455 of 09/24/2021.