ABSTRACT

for dissertation for the PhD degree specialty 6D071900 – «Radio engineering, electronics and telecommunications» of

MUKHAMEJANOVA ALMIRA DALELKHANKYZY

Modeling and analysis traffic of Machine to Machine and Internet of Things (M2M/IoT) technologies

Relevance of the dissertation research.

Communication networks of the XXI century are not only the result of the development of those that existed before them but represent fundamentally new communication networks. New requirements for communication networks arise in connection with the advent of the concept of the Internet of things.

The concept of the Internet of Things (IoT) is based on the basic principles of the M2M machine-to-Machine technology. IoT and M2M devices currently cover many use cases. M2M/IoT applications include intelligent transportation systems, logistics and supply chain management, intelligent measurement, e-health, video surveillance and security, smart cities, and home automation. It is expected that many smart devices will be widely used in the fields of automotive, security, e-health, and logistics.

When designing and operating telecommunication networks, one of the main problems is the problem of ensuring the quality of data transmission. The solution of this problem for such information distribution systems as telephone networks, built on the principle of channel switching, provided the provisions of the theory of teletraphy, in which the Poisson flow is the model of the call flow. The current period of rapid development of high technologies has led to the emergence and widespread distribution of packet data networks in which the data flow model is not Poisson and the provisions of the classical theory of teletraphy do not provide a solution to the problem.

The emergence of the Internet of Things (IoT) concept, based on the principles laid down in the M2M (Machine to Machine) machine-to-Machine interaction technology, has presented new requirements for communication networks. Applications used in the M2M/IoT network require higher data transmission quality reducing time delays and reducing the likelihood of packet loss.

To solve these problems, mathematical modeling of network traffic is necessary. Since the M2M/IoT network is a network with packet data transmission, when modeling network traffic, it must be considered that it is not Poisson.

In connection with the above, the topic of the work aimed at solving the problems of modeling, analyzing, and predicting packet traffic of machine-to-machine interaction technologies and the Internet of Things (M2M/IoT) is relevant.

The research purposes. Development and research of packet traffic models of machine-to-machine interaction and the Internet of Things (M2M/IoT).

The research objectives. To achieve this goal and in accordance with the subject of the research, the following tasks are solved within the framework of the dissertation work:

- development of a computer model of packet traffic arriving at the LoRaWAN network server, based on statistical processing and analysis of real traffic, and establishing the degree of its self-similarity
- development of a model for predicting network packet traffic arriving at the LoRaWAN network server;
- evaluation of the quality of service of M2M/IoT packet traffic by a network server using the developed computer model;
- determination of the dependence of the buffer size of the network server on the volume of incoming packet traffic and the degree of its self-similarity using the developed computer model.

The object of research: They are machine-to-machine communication networks and the Internet of Things (M2M/IoT) using packet data transmission.

The subject of the research: are the packet traffic of machine-to-machine interaction and the Internet of Things (M2M/IoT).

The research methods. The research methods used are methods of queuing system theory, probability theory and mathematical statistics, theory of teletraffic. The software package Statistica, Simulink (a package in the Matlab environment) was used as computer modeling tools, as well as programming in Matlab was used to process the computer results.

Scientific novelty:

1. A computer model of self-similar packet traffic with a given degree of self-similarity arriving at the LoRaWAN network server with a limited buffer capacity in the Matlab environment has been developed.
2. A model is proposed that provides satisfactory accuracy of the forecast of network traffic forecasting, in the construction of which the Brown method is used.
3. An assessment of the quality of traffic service in the LoRaWAN network was performed, taking into account the time delay of the packet and the probability of packet loss.
4. The resulting 3D model was obtained to determine the amount of buffer memory and the probability of losses depending on the volume and degree of self-similarity of incoming traffic.

The theoretical value of the research results is that they can be used for:

- development of models and algorithms for determining the quality of service of M2M/IoT network traffic in new generation 4G and 5G communication networks;
- analysis and design of network technologies designed to improve the quality of service;
- assessment of the impact of the rapid growth of M2M/IoT network traffic on the quality of service of other traffic flows in communication networks.

The practical significance of the research.

1. The developed computer model of M2M/IoT network traffic can be applied at the design stage of inter-machine communication networks and the Internet of Things.

2. The prediction of traffic values for the upcoming time periods will enable telecommunications operators to make timely management decisions on the allocation of resources necessary to service incoming traffic.

3. The results of experimental studies of network traffic can be used to:

a) evaluate traffic quality indicators;

b) estimates of the required bandwidth and buffer sizes of network devices serving traffic.

The main provisions for defense:

- computer model of aggregated M2M/IoT traffic coming to a network server, presented as self-similar using Pareto distribution, developed in the Matlab system;
- M2M/IoT traffic forecasting model, using which the most accurate forecast was obtained;
- methodology for calculating the characteristics of M2M/IoT traffic service in a network server, presented as a queuing system with a limited queue length, using a computer model;
- a technique for determining the buffer size of a network server that receives M2M/IoT traffic, depending on the volume and degree of self-similarity of incoming traffic, using a computer model.

Personal contribution of the author. The main experimental and theoretical results obtained during the dissertation research were obtained by the author independently.

Approbation of dissertation results. The main results of the dissertation research were reported and discussed at: V International Scientific Conference: "Digital Technologies in Science and Industry – 2019 (dtsi-2019)", dedicated to the 10th anniversary of the International University of Information Technologies (Almaty, 2019); IV International Scientific and Practical Conference "Informatics and Applied Mathematics" (Almaty, 2019); International Scientific Internet Conference "Trends and prospects for the development of science and education in the context of globalization" (Ukraine, 2020); V International Scientific and Practical Conference "Europe and the Turkic world: Science, Technology and Technology", (Turkey, 2020); XI International Scientific and Technical Conference "Energy, Information and Communication Technologies and Higher Education" (Almaty, 2020), XII International Scientific and Technical Conference "Energy, Information and Communication Technologies and Higher Education" (Almaty, Kazan, 2022).

The practical significance of the work. The results of the research of the dissertation work were carried out at The results of the research of the dissertation work: a certificate of entering information into the state register of rights to objects protected by copyright, "Determining the optimal amount of buffer memory for a network server" was obtained. No. 31349 of 12/22/2022., conducted at the Almaty

University of Energy and Communications named after G.Daukeev, in "Uni Grand Engineering" LLP.

The practical significance of the dissertation work lies in the use in the educational process and the results of the introduction into production.

The mathematical model proposed in the dissertation was used in the calculations of construction and installation design works, to assess the quality of service parameters, which allowed to increase the reliability of the results obtained and was introduced into production (Uni Grand Engineering LLP). Implemented in the educational process during lectures, practical, laboratory classes for undergraduates of the educational program "Radio Engineering, Electronics and Telecommunications" in the discipline: «Networks and services of the Internet of things and M2M» of the Almaty University of Power Engineering and Telecommunications named after Gumarbek Daukeyev.

Publications. The main results of the dissertation research were reflected in 16 scientific papers, including 7 publications in the journals of the Committee for Quality Assurance in the Field of Science and Higher Education of the Ministry of Science and Higher Education of the Republic of Kazakhstan in 3 works reflected in the works of foreign (indexed in the Scopus database), 6 publications in the materials of international conferences. The author's certificate of the Republic of Kazakhstan «Determination of the optimal amount of buffer memory for the network server» No. 31349 dated 12/22/2022 was received.

The volume and structure of the dissertation. The dissertation consists of an introduction, definitions, notations, and abbreviations, 4 sections, conclusions, appendices. The work is presented on 119 pages, contains 51 figures, 14 tables and 113 titles of bibliographic sources.

The introduction. The introduction reveals the relevance of the scientific work, describes the problem under study. The main idea, scientific novelty, personal contribution of the author, as well as research results and approbation of the publication are presented.

The first the studies necessary for modeling, network planning, and analysis of the impact of M2M/IoT traffic on the quality of service of the mobile communication network (QoS) were carried out. This section analyzes the methods of statistical analysis of network traffic.

The analysis of real traffic in the LoRaWAN network was carried out. The incoming aggregated traffic coming from all devices to the network server was considered. In addition to determining statistical characteristics for modeling M2M/IoT packet traffic, its self-similarity was evaluated. To determine the self-similar traffic properties, Hurst parameters were calculated. Based on the Statistica software package, a statistical analysis was carried out and a short-term prediction of real M2M/IoT traffic was performed by exponential smoothing.

In the second section, the analysis of methods of mathematical modeling of M2M traffic is carried out. In it, the increasing complexity of telecommunication systems and networks requires the development of appropriate computational methods to obtain a reliable assessment of their characteristics. An effective tool for solving these problems is mathematical modeling.

The choice of a Pareto distribution model for modeling self-similar traffic is justified, other types of distribution for self-similar traffic are considered, and an analysis of modern traffic models in mobile networks (M2M/IoT) is carried out.

In the third section, the studies necessary for modeling, network planning, and analysis of the impact of M2M/IoT traffic on the quality of service of the mobile communication network (QoS) were carried out. This section analyzes the methods of statistical analysis of network traffic.

The analysis of real traffic in the LoRaWAN network was carried out. The incoming aggregated traffic coming from all devices to the network server was considered. In addition to determining statistical characteristics for modeling M2M/IoT packet traffic, its self-similarity was evaluated. To determine the self-similar traffic properties, Hurst parameters were calculated. Based on the STATISTICA software package, a statistical analysis was carried out and a short-term prediction of real M2M/IoT traffic was performed by exponential smoothing.

In the fourth section, It is proposed to use the Simulink environment with SimEvents blocking from the MatLab software package to simulate network traffic in the LoRaWAN network. Network traffic arriving at a network server, which is self-similar, is considered as an object of modeling. In the Simulink environment, subsystems have been developed that generate self-similar traffic with a given Hurst parameter. The network server model is presented in Simulink in the form of a queuing System of the PM/1/K type.

A 3D model was obtained to determine the amount of buffer memory and the probability of losses depending on the amount of traffic received and the degree of self-similarity.

The conclusion reflects the main results and conclusions of the dissertation work.