**Application for participation in the competition for grant funding for young scientists**

**on scientific and (or) scientific and technical projects for 2022-2024**

**Annotation**

The development of modern info-communication systems and communication networks opens up many different services for use by subscribers. In modern conditions, the user is not only a person, but also a variety of devices connected to the network. The rapid growth of the generated load at the same time causes congestion in certain sections of the network, which leads to a deterioration in quality.

Along with the problems of data transmission, difficulties arise in the automation and control of greenhouse industrial complexes.

"Intelligent" agriculture is based on the use of automated decision-making systems, integrated automation and robotization of production, as well as technologies for the design and modeling of "green" systems.

With an unbalanced approach to the use of seed potential, plant protection products, the capacity of the machine and tractor fleet, new technologies, up to 40% of the harvest cost is lost.

Many holdings and peasant farms are moving to the creation of electronic maps for more effective field monitoring. Also used are systems of informatization and monitoring, mapping of yield, degree of infestation, etc., as well as differentiated technologies, especially when applying mineral fertilizers when working on maps-tasks. In addition, unmanned aerial vehicles and remote sensing of the earth are used primarily to monitor the state of crops, which makes it possible to more quickly and carefully monitor the development of crops. Drones equipped with cameras and sensitive sensors can inspect fields and monitor crop health. Such devices will be able to collect information for developing maps, schedule fertilization, even guard fields. Some IoT solutions refer to when the crop is already harvested. For example, smart storage for vegetables and fruits that check the temperature, humidity and lighting of the room. If the conditions are violated, the system corrects the situation and notifies about changes in the warehouse owner.

According to forecasts, the number of smart (smart) devices in agriculture in 2-3 years may increase by 1.5-2 times, which will entail a sharp increase in the transmitted information, that is, an increase in teletraffic. The role of telecommunications in ensuring uninterrupted operation and timely response to changes in the environment is significantly increasing. Therefore, the dominant role in the creation of information traffic will be played by the exchange of information of the type "man-machine" and "machine-machine". The noted tendencies make the development of means of optimization and planning of the network infrastructure on the basis of the introduction of more advanced mechanisms of control over the process of information transmission urgent.

At the same time, a simple increase in the radio resources of the network will no longer solve the problem of the quality of the services provided. In some types of access, in particular in cellular networks, the implementation of solutions with excess bandwidth is often simply impossible due to the lack of free radio frequencies or the presence of fundamental restrictions on the information transfer rate.

The fact that most of the information flows will be generated by devices and software systems requires the introduction of more advanced means of managing the information transfer process. This is necessary to eliminate the uncontrolled reallocation of the resource due to repeated requests and other forms of influence of the behavior of the source of traffic generation on the characteristics of the network bandwidth.

Thus, despite the impressive progress achieved in the development of network infrastructure and information transfer technologies, the risk of overloads will also exist in promising communication networks. To eliminate the noted shortcomings, as well as to substantiate the economic relations between the operator and the subscriber, it is necessary to have tools based on models and methods of queuing theory for a preliminary assessment and selection of the optimal scenario for the development of the network from several alternative possibilities.

The project involves the development of hardware and software for data transmission processes in info-communication systems and communication networks of multiple random access, construction and research of mathematical models of Markov and non-Markov queuing systems, including with repeated requests and with random requirements for the volume of the occupied wireless network resource, in including conflicts, reservations, with negative and impatient applications using original analytical methods (the main one is the method of asymptotic analysis, as well as its modification developed by the team of the scientific school to which the applicants belong), allowing to draw general conclusions for the entire class of solved tasks and decision-making in precision farming technologies. Unlike previously known,

In this case, the assumed theoretical results will generalize the previously known, and the proposed methods will expand the class of problems in the queuing theory to be solved. The results obtained will make it possible to find the characteristics of the monitoring data streams and estimate the necessary costs for their processing, which in turn will provide the opportunity to develop the necessary equipment for the semi-automation of the control system and precision farming technologies of the agro-industrial complex in decision-making.

**2. Explanatory note**

1. General information

1.1. Name of the project topic: Development of mathematical decision-making models based on queuing theory to increase the productivity of Smart-platforms using the example of precision farming

1.2. The name of the priority direction in the development of science: Sustainable development of the agro-industrial complex and the safety of agricultural products.

1.3. The name of the specialized research area: Technical support for the modernization of the agro-industrial complex, type of research - applied.

1.4. Estimated start and end date of the project, its duration in months: 03/01/2022 - 12/31/2024, 34 months.

1.5. The requested amount of grant funding (for the entire duration of the project and by years, in thousand tenge):37390.234; 2021 - 11,613,516 thousand tenge; 2022 - 15857.976 thousand tenge; 2023 - 9,918,742 thousand tenge.

1.6. Key words: precision farming, queuing theory, mathematical model, software, decision making.

**2. General concept of the project**

2.1. Introductory part

The project is aimed at solving the scientific problem of analyzing modern information and communication systems for the transfer of agricultural data of large volumes, in order to increase the efficiency of design, operation and reliability of the functioning of Smart-platforms in conditions of high load, in the form data transmission processes in info-communication systems and communication networks of multiple random access, saving copies of data, unreliability of service devices. As a result of joint work, scientists will create a mathematical model and an info-communication system for decision-making in the implementation of precision farming technologies in the agro-industrial complex and smart technologies based on models of the queuing theory.

2.2. Objective of the project

The goal of the project is to create a mathematical model and a hardware and software complex for the development of a decision-making system by Smart-platforms when processing and transmitting agricultural data in info-communication systems and networks used for precision farming technologies and the Internet of Things.

2.3. Project objectives

Task 1. Development of a web portal for info-communication systems for transferring data from clients of Smart-platforms

Task 2. Testing the developed web portal, analysis and correction when errors are detected

Task 3. Development and adaptation of the system to ensure the collection, processing, decision-making and data transmission of info-communication systems

Task 4. Development of a hardware system for a prototype Smart-platform used in precision farming on the example of managing a machine and tractor fleet

Problem 5. Construction of new probabilistic models of processes of information and communication systems of multiple random access in the form of queuing systems with repeated calls (Retrial Queueing) of various configurations

Task 6. Development of new and improvement of existing methods for studying the created mathematical models, including the method of initial moments, the method of diffusion approximation, modifications of asymptotic analysis in various limiting conditions

Task 7. Determination of the main probabilistic characteristics of the created models, including the assessment of the area of ​​applicability of approximations and the calculation of the characteristics of the reservation of the used resources of the transmitted data in precision farming technologies

Task 8. Development of recommendations for the use of the web portal, obtaining a title of protection for intellectual property

Task 9. Experimental studies of the developed hardware complex for the prototype of the Smart-platform used in precision farming by the example of the management of the machine and tractor fleet. One (1) article or review will be published in a peer-reviewed foreign or domestic edition recommended by COXON. 1 (one) report will be submitted / accepted / published for participation in an international conference indexed by Scopus and / or WoS databases. A study guide based on the results of research work will be developed.

Task 10. Research of Markov resource RQ-systems and determination of the main probabilistic characteristics of the created models in info-communication networks

Task 11. Determination of the exact probabilistic characteristics for the number of claims in the orbit in the considered communication systems with exponential distribution functions of the probabilities of the service time on the server

Task 12. Investigation of non-Markov RQ-systems with non-exponential distribution function of service time on the device, construction of an approximation of the probability distributions of the number of requests in the orbit of data transmission of info-communication systems

Task 13. Testing, verification, approbation and reproduction of the results of the developed mathematical, software and hardware for decision making and data transmission on the example of the management of the machine and tractor fleet

Task 14. Preparation of the final report on research work for 2022-2024.

Task 15. Development of recommendations for further application and dissemination of work results, filing an application for a title of protection

**3. Scientific novelty and significance of the project**

1) Project manager B. Isabekova - PhD, candidate of technical sciences, has experience in developing new models of various technical systems, adapting and modifying known approaches, developing original algorithms and research methods for software systems, as well as systems for processing and transmitting data storage in cloud archives and in the networks of info-communication systems.

The group of the declared scientists has the following preliminary results:  
 - calculations using fuzzy logic on the example of determining soil moisture depending on climatic conditions;

- a new dependence of soil temperature on its depth and season was obtained, based on the use of the Fourier theory of thermal conductivity and data from meteorological stations, but without the use of the thermal diffusivity coefficient;

- the dependences of the temperature capacity and thermal diffusivity of the soil on moisture were obtained, on the basis of which the soil temperature is calculated according to the known formulas. Fuzzy logic was used for the first time when developing dependencies;

- basic mathematical models of resource queuing systems with an unlimited number of devices have been proposed, which make it possible to take into account the requirement of an application for the provision of a random amount of resource;

- a method of dynamic sifting has been developed, which makes it possible to build modifications for studying resource queuing systems with an unlimited number of devices, which, in contrast to the classical problem of studying the number of occupied devices, makes it possible to analyze the total volume of the occupied resource in the system;

- developed a method of asymptotic analysis for the study of basic resource systems with an unlimited number of devices, which makes it possible to construct a Gaussian approximation of the total volume of the occupied resource;

- algorithms for lossless compression of hyperspectral images and its modification in ordering and using difference-regression transformations, which make it possible to increase the compression ratio and computational efficiency, respectively;

- algorithmic and software for the lossless and lossless hyperspectral image compression system superior to analogs in terms of compression ratio;

There are also the results of the AP000000223 project, carried out in 2021. Comprehensive study of compression methods and algorithmslossless and lossless hyperspectral images, as well as comparative experiments on various quality criteria of the reconstructed images for the identification of cereal diseases in the agricultural sector.Research work was carried out on the basis of the GIS Center of the NJSC "KATU im. S. Seifullin ". In the course of scientific research,ateven spectral correlation, regression analysis, difference-discrete transformations, evaluation of quality criteria for reconstructed hyperspectral images and statistical methods.

In this project, it is planned to improve the methods and approaches in the study of precision farming technologies and to develop a scientific and technological basis for making decisions when implementing them using queuing systems and theory.

2) The scientific novelty of the project lies in the development of new probabilistic models of data transmission and processing systems in info-communication systems, in particular the greenhouse industrial complex and communication networks of multiple random access, taking into account the random (discrete and continuous) volume of incoming data, impatience, priorities of applications, availability conflicts and displacement, as well as in the development of methods for their research, intended for the analysis, calculation and assessment of key indicators of quality, productivity, reliability and efficiency of systems operation and decision-making in the implementation of precision farming technologies in the agro-industrial complex with the development of SMART technologies.

The theoretical and applied foundations of research in the field of data transmission and processing in info-communication systems are based mainly on the theory of probability, the theory of random processes, the theory of queuing and the theory of teletraffic. To analyze the performance indicators of such systems, various mathematical models and methods can be applied, including queuing systems with repeated calls (Retrial Queueing) [1-3], resource queuing systems [4-6] and stochastic geometry models [7, 8].

In the monographs of Russian and foreign scientists G.P. Basharin, V.M., Vishnevsky, A.N. Dudin, A. Melikova, K.E. Samuilova, E. Gelenbe, W. Whitt, G. Pujolle, D. Gross, C. Harris, L. Kleinrock, JW Roberts, M. Schneps-Schneppe provides a detailed overview of modern applications of queuing models in telecommunications, modern computer networks and information systems [9-12].

Initial research in the field of computer networks, presented in the works of L. Kleinrock, G.P. Basharin, M. Schwartz, V.M. Vishnevsky, as well as in the works of A.K. Erlang, were based on simplified models of the nature of information flows - Poisson flows and exponential distribution of packet transmission time.

One of the most interesting and topical directions in the development of PME(TMO) at the present time is the study of resource Queueing Systems(CMO).

A large number of works are devoted to the study of RQ systems, the most extensive overview of significant results up to 2008 is presented in the monographs by JR Artalejo, A. Gomez-Corral, GI Falin, JGC Templeton [13-15]. Currently available scientific publications in this area offer quite a lot of different models and approaches to their analysis.

E.L. Romm and V.V. Skitovich was the first to formulate a generalization of the Erlang problem, where each incoming request has some information quality, which the authors call the value of the request [16]. Subsequently, O. Tikhonenko, M. Kawecka, WM Kempa, E. Morozov, R. Nekrasova, L. Potakhina made a significant contribution to the development of methods for studying resource QS. K.E. Samuilov [17-18]. In their works, the authors consider service systems for customers of random size, as a class of systems with a certain capacity and dependent or independent service time of customers on their volume

Resource QS with limited resources as models of next-generation wireless communication networks are used in the works of T. Kimura, T. Murase, T. Okuda, T. Czachorski, T. Nycz, F. Pekergin, K.E. Samuilov, V.A. Naumov [19-21]. Several works by A. Pechinkin and S. Shorgin and colleagues are devoted to the study of the total volume of claims in systems operating in discrete time.

Despite the large list of applied problems that can be solved using queuing models with incoming flows of requests of a random size, today accurate analytical results on the study of the total volume of requests in the system exist only for the case of a Poisson incoming flow and classical QS.

However, the results of studies of real flows indicate the presence of a correlation and a large variance between the moments of arrival of requests, which leads to the use of models of correlated flows (Markovian Arrival Process). Therefore, developed in the works of G.P. Basharin, M. Newts, D. Lucantoni, the theory of QS with correlated flows has found wide application in the study of telecommunication systems. An overview of significant results on models with correlated flows and methods of their study can be found in [22-24].

At the same time, it should be noted that for systems with a non-Poissonian input flow (that is, non-Markov systems), there is currently no universal approach to research, most of the results were obtained using simulation modeling, and analytical results were obtained only for some special cases. The complexity of the study of resource systems with repeated calls is due to the fact that currently there is no universal approach to research, therefore, to work on the project, it is proposed to use asymptotic methods for studying QS, developed at the Tomsk Scientific School of Applied Probabilistic Analysis under the guidance of Associate Professor Paul S.V. Such methods make it possible to obtain asymptotic expressions acceptable for practice for the desired characteristics of the system in the cases where when their prelimit research is impossible. Various asymptotic methods and approaches in queuing theory are described in [22-24] and others.

Thus, the project involves the construction and study of mathematical models of queuing systems using the example of a greenhouse industrial complex with random requirements for the volume of the occupied wireless network resource, including with feedback and different types of service requests, with splitting (copying) requests, group service , unreliable devices. Unlike the previously known models, the models under consideration will make it possible to assess the required volumes of reserved resources for Internet of Things traffic and develop a strategy for allocating resources with competing traffic. In this case, the proposed theoretical results will generalize the previously known, and the proposed methods will expand the class of problems to be solved in the theory of queuing in info-communication networks and technologies of precision farming in making decisions on applied problems of the agro-industrial complex. The developed software and hardware for the management of the greenhouse industrial complex will be carried out taking into account all the research carried out using modern programming languages ​​Java / C# / Phyton.

All this determines the relevance of creating a mathematical and info-communication system for providing or implementing smart technologies for making decisions in precision agriculture in the agro-industrial complex, with the aim of building mathematical models that allow you to modify, improve and develop methods for analyzing and calculating service quality indicators in info-communication systems.

3) The research team is selected from specialists in the field of mathematics, telecommunications and information technology.

The final results of the project imply a developed set of problem-oriented programs that calculate the main probabilistic and temporal characteristics of the studied models (systems) with the ability to enter any initial data, as well as recommendations for the design of communication networks based on the mathematical analysis of these models.The developed algorithms and software can be used to calculate the most important service quality indicators for network planning and user perception quality indicators, which will determine a wide range of application of the results obtained in research, design organizations and telecommunications organizations in the field of agriculture, based on theoretical research. and developed hardware and software for the management of precision agriculture in the agro-industrial complex.

4) The results of research on queuing systems and developed software will be duly registered as intellectual property with the receipt of a patent and copyright certificates. The research carried out draws on the experience of previous work in the relevant industry.

In the course of the project, new mathematical models of telecommunication networks will be proposed in the form of resource queuing systems with repeated calls (Retrial Queueing systems) of various configurations, including multi-line ones, with negative and impatient orders, with and without conflicts, with priority service and preemption. The study of these models is supposed to be carried out using original analytical methods, namely, modifications of the asymptotic analysis method under various conditions, the diffusion approximation method, the sifted flow method, etc. During the project, methods and models will be obtained for the main probabilistic-temporal characteristics of the studied models,

**4. Research methods and ethical issues**

1) In the course of the project, the methods of mathematical modeling, the mathematical apparatus of the theory of probability, the theory of random processes, the theory of queuing, the theory of differential equations, optimization methods, numerical methods, simulation methods and information technologies will be applied and used.

However, these approaches are not enough due to the limited scope of their applicability and the complexity of the systems under study (for example, the analytical form of the solution can be obtained in quite rare cases, and the performance of the simulation model is limited by the performance of computer technology). In this regard, it is proposed to use original research methods: the diffusion approximation method, the method of initial moments, modifications of the asymptotic analysis method.

2) The main method for studying the proposed models is assumed to be the method of asymptotic analysis, which is actively developing by the performers of the scientific group and allows obtaining analytical results in those cases when they cannot be obtained using classical approaches of the queuing theory.

3) Integration of the listed methods and approaches will make it possible to conduct an exhaustive analysis of the systems under study and determine the characteristics of their functioning, such as the probability distribution of the number of applications in the system, the number of occupied resources and their joint distributions in the models under consideration.

4) To perform numerical calculations of the characteristics of the functioning of systems and assess the area of ​​applicability of asymptotic results, simulation modeling and methods of mathematical statistics will be used.

ЗДЕСЬ НАДО ДОБАВИТЬ МЕТОДЫ ОСНОВНЫХ ИСПОЛНИТЕЛЕЙ!!

Про Smart, автомаизацию, коплесы программ и сельское хозяйство

Как они могут быть реализованы

Технологии автоматизации управления машино тракторного парка (точное земледилеие)

The results obtained in the study will have both theoretical and applied significance.

5) Each participant is familiar with the standards of scientific ethics and intellectual honesty. The results of research and developed software will be duly registered as intellectual property with the receipt of a patent and copyright certificates.

**5. Research team and project management**

The composition of the research group is according to Table 1.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| No. | FULL NAME. (if any), education, degree, academic title | Main place of work, position | Hirsch Index, ResearcherID, ORCID, Scopus Author ID (if available) | Role in the project or program, and the nature of the work performed | Brief justification for participation |
| 1 | Isabekova Bibigul Beisembaevna, systems engineer with a degree in Computer Information Processing and Control Systems, PhD in Power Engineering | Non-profit joint-stock company "Toraigyrov University", associate professor | Hirsch index in the Scopus-1 database,  ScopusAuthor ID56826203500.  ResearcherID - ABF-5705-2020,  ORCID - 0000-0001-5044-3211, | Supervisor,  Leadership and monitoring and the performed tasks of the project. Participation in the preparation of articles, patents, interim and final reports. | Project coordination and management.  Research interests: methodological foundations of teaching computer science, power engineering, automation |
| 2 | Sarinova Asiya Zhumabaevna, systems engineer with a degree in Computer Information Processing and Control Systems, PhD in Computer Science and Software | Non-profit joint-stock company Kazakh Agrotechnical University named after Seifullin ", senior lecturer | Hirsch index in the Scopus-3 database,  ScopusAuthor ID - 56662216400  ORCID:0000-0003-4254-376X | Executor, Chief Researcher.  Development of software for calculating and visualizing the main characteristics of info-communication data transmission systems on the portal / Desktop / mobile application for monitoring the transmitted information in the used technologies of precision farming in real time and making decisions. Experimental research and preparation of publications based on the results of the project. Compilation of reports on research and development (2022-2024). | Development of software and hardware for the implementation of precision farming technologies. |
| 3 | Dunaev Pavel Alexandrovich, telecommunication engineer, specialty "Automatic telecommunication",  PhD Doctor in Radio Engineering, Electronics and Telecommunications | Non-profit joint-stock company Kazakh Agrotechnical University named after Seifullin ", senior lecturer | Hirsch index in the Scopus-1 database,  Scopus Author ID: 57208718183, ORCID: 0000-0003-0379-315X, | Performer, leading researcher, implementation of project tasks in the creation of innovative technologically scientifically grounded solutions to increase the efficiency of data transmission of info-communication systems / Experimental research and preparation of publications based on the results of the project. Compilation of reports on research and development (2022-2024). | Development of an info-communication system for decision-making and implementation of precision farming technologies |
| 4 | Paul Svetlana Vladimirovna, economist-mathematician, specializing in "Mathematical methods in economics", candidate of physical and mathematical sciences, specializing in "Mathematical modeling, numerical methods and program complexes" | National Research Tomsk State University,  assistant professor | Hirsch index in the Scopus-4 database,  ScopusAuthor ID - 57031144200 ORCID: 0000-0002-3681-0676 | Performer, leading researcher.  Development of new and development of existing methods for studying these mathematical models, including the method of initial moments, the method of diffusion approximation, modifications of asymptotic analysis under various limiting conditions.  Experimental research and preparation of publications based on the project results | Development of mathematical models and methods of data transmission in communication networks of multiple random access, taking into account a random amount of incoming data from the hardware complex |
| 5 | Amir Yerlan Kamalievich, bachelor in the specialty "Agricultural engineering and technology", master in the specialty "Automation and control" | Non-profit joint-stock company Kazakh Agrotechnical University named after Seifullin ",  1st year doctoral student in the specialty "Automation and Control" | - | Junior Researcher,  theoretical and experimental research, database formation, analysis of information sources | The topic of the doctoral dissertation corresponds to the topic of the project |
| 6 | Job vacancy | Non-profit joint-stock company Kazakh Agrotechnical University named after Seifullin ",  Master's student in the specialty "Power supply and automation of agriculture" | - | Junior Researcher,  theoretical and experimental research, database formation, analysis of information sources | The topic of the doctoral dissertation corresponds to the topic of the project |

A complete list of works for each member of the team can be obtained from a personal card in AIS. The most significant publications of the scientific adviser:

1. [Zaitseva, NM](https://www.scopus.com/authid/detail.uri?authorId=56727729400), Issabekova BB, [Kletsel ', MY](https://www.scopus.com/authid/detail.uri?authorId=6603237321) Determination of soil parameters to calculate soil resistivity Russian Electrical Engineering May 2015, Volume 86, Issue 5, pp 275-281. <https://doi.org/10.3103/S1068371215050119>
2. BB Issabekova, DA Nosovskii A Zhantlesova The control system of a steady short-circuit current measurement using the expert estimation method // 2015 International Siberian Conference on Control and Communications (SIBCON 2015) Omsk, Russia 21-23 May 2015. DOI: 10.1109 / SIBCON.2015.7147056
3. [Issabekov, ZB](https://www.scopus.com/authid/detail.uri?authorId=57194215799), [Novozhilov, AN](https://www.scopus.com/authid/detail.uri?authorId=7003623335), [Novozhilov, TA](https://www.scopus.com/authid/detail.uri?authorId=55772690900) Issabekova BB Protection of a two-cable line from single phase-to-earth fault with absolute selectivity NEWS of the Academy of Sciences of the Republic of Kazakhstan, Series of geology and technical sciences ISSN 2224-5278, Volume 5, Number 431 (2018), 128 - 132, https://doi.org/10.32014/2018.2518-170X.18
4. Issabekova BB, Tokombayev, MT, Zhantlessova, AB Methods for attaching magneto sensitive elements to build protections // AIP Conference Proceedings 2337, 030005 (2021); 6 P. https://doi.org/10.1063/5.0047156.
5. Issabekov, ZB, Novozhilov, AN, Anarbayev, AY, Issabekova BB Configurations of 6-10 kV cable lines and types of cable damages Cite as: AIP Conference Proceedings 2337, 030002 (2021); 4 P. https://doi.org/10.1063/5.0047154.
6. Isabekova B. B., Nogai A. S., Zabylbekova O. M., Uskenbaev D. E., Ainagulov E. B., Nogay A. A., Zhaksybaeva D. K. Search for optimal operating modes of hybrid energy storage units "Bulletin of PGU", power series. Pavlodar –2017. – № 3. - С.119-128.
7. Isabekova B. B., Uskenbaev D. Ye., Nogay A. S., Ainakulov E.B., Uskenbaev A. D Bismut Uramdy asқyn өtkizgishshti birikpelerge қospalardyk әseri “Bulletin of PSU”, energetic series. Pavlodar - 2017. – № 3. - С.148-156.
8. Isabekova B. B., Uskenbaev D.E., Nogai A.S., Alimkulova E.Zh., Alkozha E., Mukhamedrakhimova G.I. Production of metal phosphates for use in electric energy storage Vestnik PSU. energy series, No. 3, pp. 198-205.
9. Isabekova B. B., Uskenbaev D.E., Nogay A.S., Ainakulov E.B. Satpayev, ISSN 1680-9211, No. 2 (132), 2019 - p. 377-381.
10. Isabekov Zh. B., Zhantlesova A.B., Zhumadilova A.Z., Isabekova B. B. Creation of a digital system for calculating greenhouse gases at electric power enterprises in the Republic of Kazakhstan. PSU Bulletin. Energy series. - 2020. - No. 3 - C 110-118.
11. B. B. Isabekova, Zh.B. Isabekov, A.B. Zhantlesova, B. Zharmakin. Designing products on FPGA // Bulletin of PSU. Energy series. - 2020. - No. 4 - C 178-184.
12. B. B. Isabekova,A.B. Zhantlesova, Zh.B. Isabekov, D.I. Kabenov Fundamentals of digital signal processing. Tutorial. - Pavlodar: PSPU, 2020 .-- 199p. ISBN 978-601-267-605-1
13. B. B. Isabekova Aykyn emes logikany qoldanudyk negizinde topyraktyk salystyrmaly elektrlі kedergisin anyktau Pavlodar: PSPU, 2019 .-- 104b Monograph

The most significant publications of the members of the research group:

1. Saule Abimuldina, Assiya Sarinova, Liman Sarlybayeva, Nursulu Akhmetova & Marina Pouch. Development of domestic nutrition additives. Abimuldina et al / Revista DYNA, 84 (202), pp. 289-294, September, 2017. ISSN 0012-7353. DOI: http://dx.doi.org/10.15446/dyna.v84n202.67057
2. The use of correlation analysis in the algorithm of dynamic gestures recognition in video sequence. The International Conference on Engineering & MIS 2019. LNGumilyov Eurasian National University, 06-08 June.DOI:10.1145 / 3330431.3330439
3. A. Sarinova, A. Zamyatin, Hyperspectral regression lossless compression algorithm of aerospace images. E3S Web of Conferences 149, 02 03 (2020)https://doi.org/10.1051/e3sconf / 20201490 RPERS 2019.
4. A. Sarinova, A. Zamyatin, The Compression Algorithm of Hyperspectral Aerospace Images with Use of Mathematical Processing and Intrabands Correlation. Journal of Siberian Federal University. Engineering & Technologies, 2018, 11 (8). pp. 882-891. VAK RF.
5. Dunaev P.A.A method for assessing the quality of digital TV images transmitted over a multiservice network using GPON connection technology. In the book. Bulletin of SibSUTI No. 3, 2015. From 11-22. Novosibirsk city.
6. Dunayev P., [Abramov S.](https://library.kazatu.kz:2057/authid/detail.uri?origin=resultslist&authorId=57196511639&zone=),[Sansyzbay K.](https://library.kazatu.kz:2057/authid/detail.uri?origin=resultslist&authorId=57216492773&zone=),[Kismanova A.](https://library.kazatu.kz:2057/authid/detail.uri?origin=resultslist&authorId=57225091069&zone=) [The IP channel bandwidth during transmission of the video and tomography signals](https://library.kazatu.kz:2057/record/display.uri?eid=2-s2.0-85109152171&origin=resultslist&sort=plf-f&src=s&st1=Dunayev&st2=Pavel&nlo=1&nlr=20&nls=count-f&sid=de9bd52596ba5f478b1a83c557ad8c68&sot=anl&sdt=aut&sl=35&s=AU-ID%28%22Dunayev%2c+Pavel%22+57208718183%29&relpos=0&citeCnt=0&searchTerm=)... [Journal of Theoretical and Applied Information Technology](https://library.kazatu.kz:2057/sourceid/19700182903?origin=resultslist)99 (12), 2021. P. 2834-2844. (<http://www.jatit.org/volumes/Vol99No12/5Vol99No12.pdf>, percentile 36)
7. P. Dunayev,Ye. Sarsikeyev, O. Galtseva, G. Narimanova. Mathematical Model of the Throughput of an IP Network Switching Node with a Non-constant Amount of Space in the Router RAM. Progress in Material Science and Engineering, Studies in Systems, Decision and Control 351, Springer Nature Switzerland AG 2021, P. 81-88. (DOI: 10.1007 / 978-3-030-68103-6\_8, percentile 60)
8. P. Dunayev,Ye. Sarsikeyev.[Method of objective assessment of the quality of digital TV image transmitted over NGN network using GPON access technology](http://iop.msgfocus.com/c/1il5bqZ1V5YjSqioIVsQlxqwSS)... IOP Conference Series: Materials Science and Engineering 516 (2019) 012011. (doi: 10.1088 / 1757-899X / 516/1/012011, percentile 23).
9. Dunaev P.A.,Sarsikeev E. Zh., Kaliev Zh. Zh. Influence of data transmission over the Internet on the bandwidth of a multiservice network channel. KazATK Bulletin No. 4 (115), 2020. С 225-233. Almaty city. (https://www.kaznu.kz/content/files/pages/folder21075/%D0%B2%D0%B5%D1%81%D1%82%D0%BD%D0%B8%D0%BA%204% 20 (115)% 202020-2.pdf).
10. Dunaev P.A.,Sarsikeev E. Zh., Kaliev Zh. Zh. Experimental studies of the quality of digital television images using ETTH connection technology. KazATK Bulletin No. 4 (115), 2020. С 233-240. Almaty city. ([https://www.kaznu.kz/content/files/pages/folder21075/%D0%B2%D0%B5%D1%81%D1%82%D0%BD%D0%B8%D0%BA%204%20 (115)% 202020-2.pdf)](https://www.kaznu.kz/content/files/pages/folder21075/%D0%B2%D0%B5%D1%81%D1%82%D0%BD%D0%B8%D0%BA%204%20(115)%202020-2.pdf))...
11. Dunaev P.A., Abramov S.S. IP network switching node performance.Communication Bulletin No. 8. August, 2021.S. 2-5. (<http://www.vestnik-sviazy.ru/upload/iblock/168/168566270c28c19f58b8c16c361b08b1.pdf>).
12. P.A. Dunaev,S.Yu. Ryabtsunov, M.A. Shukraliev.Comparative analysis of router configurations affecting signal bandwidth changes. TUSUR reports, volume 19, No. 1, 2016. P 40-45. Tomsk. (https://journal.tusur.ru/storage/44857/issue-2016-1-19.pdf?1465985874).
13. Dunaev P.A., Ryabtsunov S.Yu. Statistical modeling of an IPTV network to estimate the channel throughput taking into account the packet service time. TUSUR reports, volume 20, No. 3, 2017. С 172-177. Tomsk. (DOI: 10.21293 / 1818-0442-2017-20-3-172-176).
14. Ekaterina Fedorova, Anatoly Nazarov, Svetlana Paul. Discrete Gamma Approximation in Retrial Queue MMPP / M / 1 Based on Moments Calculation // LNCS. 2017. Vol. 10684. P. 121-131. doi.org/10.1007/978-3-319-71504-9\_12. Q2 WoS.
15. Nazarov A., Phung-Duc T., Paul S., Lizyura O. Diffusion Approximation for Multiserver Retrial Queue with Two-Way Communication // LNCS. 2020. Vol. 12563: Distributed Computer and Communication Networks. P. 567-578.[https://doi.org/10.1007/978-3-030-66471-8\_43. Q2](https://doi.org/10.1007/978-3-030-66471-8_43.%20%20Q2) **Scopus.**
16. Nazarov A., Paul S., Pavlova E. Method of asymptotic diffusion analysis of queueing system M | M | N with feedback // LNCS. 2020. Vol. 12023. P. 131-143.<https://doi.org/10.1007/978-3-030-62885-7_10> **Q2 Scopus.**
17. Nazarov A., Moiseev A., Phung-Duc T., Paul S. Diffusion Limit of Multi-Server Retrial Queue with Setup Time // Mathematics. 2020. Vol. 8, No. 12. P. 2232-1-2232-20. URL: https://www.mdpi.com/2227-7390/8/12/2232 (date of access: 21.12.2020).[https: // doi: 10.3390 / math8122232](https://doi:10.3390/math8122232) Q1 WoS.
18. Moiseev A., Nazarov A., Paul S. Asymptotic Diffusion Analysis of Multi-Server Retrial Queue with Hyper-Exponential Service // Mathematics. 2020. Vol. 8, No. 4. P. 531-1-531-16.<https://doi.org/10.3390/math8040531> **Q1 WoS**...

List of certificates for intellectual property:

1. Isabekova B.B., Kabdualiev N.M., Kletsel M.Ya., Neftisov A.V. Power direction relay on reed switches / Innovative patent No. 28736 (19) KZ (13) A4 (11) 28736 (51) G01R 19/30 (2006.01) [Text] /: applicant and patent holder PSU named after S. Toragyrova (KZ). - No. 2013 / 1281.1; declared 09/30/2013; publ. 07/15/2014 bulletin No. 7 - 4s ..

2. Isabekova B.B., Zhantlesova A.B. Patent RU 2554285-C1 Method for measuring short-circuit current / applicant "National Research Tomsk Polytechnic University" 2014110583/28, Appl. 03/19/2014. Publ. 06/27/2015. Bul. No. 18.

3. Isabekova BB, Bogdan A.V., Kletsel M.Ya., Isabekova BB, Mashrapova R.M. Relay on reed switches. Patent for invention 2707277 RU H01H57 / 00 (2006.01) / applicant and patentee Federal State Budgetary Educational Institution of Higher Education "Kuban State Agrarian University named after IT Trubilin". - 2019115572, app. 05/21/2019; published: 26.11. No. 33. -7s.

4. Certificate for intellectual property rights 008473 RK. DelayProg (computer program) / Sarinova A.Zh. - No. 20942; declared 10/14/2021; Publ. 10/15/2021 ;. - Ministry of Justice of the Republic of Kazakhstan.

5.Certificate for intellectual property rights 008473 RK. DelayProg (computer program) / P.A. Dunaev, S.Yu. Ryabtsunov. - No. 1105; declared 04/07/2017; Publ. 05/23/2017. - Ministry of Justice of the Republic of Kazakhstan. Dunaev P.A., Ryabtsunov S.Yu.

6.Certificate of entering information into the state register of rights to objects protected by copyright. DelayProg 2 (computer program) / P.A. Dunaev. - No. 6789; Object creation date 10/11/2019; Publ. 04.12.2019. - RGP"National Institute of Intellectual Property" Ministry of Justice of the Republic of Kazakhstan

**6. Research environment**

The applicant has his own material and technical base, presented in table 2.

Table 2- Material and technical base **Kazakh Agrotechnical University named after S. Seifullin**

|  |  |  |  |
| --- | --- | --- | --- |
| No. | Type of equipment, device, inventory | Appointment of equipment, device, inventory | Team members with equipment skills |
|  | Nvidia Jetson Embedded Platform | Artificial Intelligence Computing Platform | Isabekova B.B., Sarinova A.Zh, Dunaev P.A. |
|  | Pycom Data Controller Kit | Programmable microcontroller | Isabekova B.B., Sarinova A.Zh, Dunaev P.A.  Paul S.V. |
|  | Orbitty Carrier Controller Board | Designed for NVIDIA® Jetson ™ modules, equipped with USB 3.0, USB 2.0 OTG, HDMI, Gigabit Ethernet, microSD, 2x UART 3.3V, I2C and 4x GPIO interfaces. Designed for embedded robotic in a small form factor | Isabekova B.B., Sarinova A.Zh, Dunaev P.A.,  Amir E.K. |
|  | Astro Carrier controller board | Designed for NVIDIA modulesAstro has 2 GbE ports, an HDMI port, 8 U.FL video inputs and 3 CSI-2 camera inputs, the board is additionally equipped with a USB 2.0 port, 2 USB 2.0 ports, HD audio output and various serial and GPIO interfaces, a mini-PCIe slot and a connector mSATA. Astro features an industrial temperature range of -40 ° C to 85 ° C. | Isabekova B.B., Sarinova A.Zh, Dunaev P.A.,  Amir E.K. |
|  | Computer Core i5, 8400, 2.8, 16 Gb / 1 Tb / 256 SSD / GTX1050 / 21.5 '' | To work with computational, graphics and simulated operations | Isabekova B.B., Sarinova A.Zh, Dunaev P.A.,  Amir E.K.  Paul S.V. |
|  | 8-channel hub card | For connecting computer and peripheral devices | Dunaev P.A.,  Amir E.K. |
|  | Routers Teltonika RUT240 (GSM), Teltonika RUT850 (GPS), Teltonika RUT950 (3 / 4G) | Connecting to remote objects using different protocols / methods | Isabekova B.B.,  Sarinova A.Zh,  Dunaev P.A.,  Amir E.K. |
|  | ArcGIS10.1 software | Mapping, algorithms, geodatabase creation | Isabekova B.B.,  Sarinova A.Zh,  Paul S.V. |
|  | ENVI 5.5 software | Mapping, decoding of cosmic images | Isabekova B.B.,  Sarinova A.Zh  Paul S.V. |
|  | ERDAS 2018 software | Mapping, decoding of cosmic images | Isabekova B.B.,  Sarinova A.Zh  Paul S.V. |
|  | Hyperspectral Camera, Headwall | Aerial photography with 270 channel camera | Isabekova B.B.,  Sarinova A.Zh,  Dunaev P.A. |
|  | Multispectral camera | Aerial photography with 5 channel camera | Isabekova B.B.,  Sarinova A.Zh,  Dunaev P.A. |
|  | UAV helicopter type | Aerial photography  Field studies | Sarinova A.Zh,  Dunaev P.A.,  Amir E.K. |
|  | UAV  Aircraft type | Aerial photography  Field studies | Sarinova A.Zh,  Dunaev P.A.,  Amir E.K. |
|  | GPS Navigator | Coordination  Field studies | Sarinova A.Zh,  Dunaev P.A.,  Amir E.K. |

The industrial partner is Company "В и Д" LLC (ТОО Фирма «В и Д»), which, within the framework of the agreement, provides the material and technical base for conducting experiments, as well as co-financing the project.

For the successful implementation of the project, as well as for conducting scientific research and development work, using the material and technical base of the partner, the following scientific trips are planned:

1. Almaty, Kazakhstan. Kazakh National Agrarian Research University. Participation in the International Scientific and Practical Conference of Young Scientists "Scientific view of the young: searches, prospects, innovations in the agro-industrial complex." Exchange of experience in the direction of the project.

2. Pavlodar, Kazakhstan. Toraigyrov University. Participation in the International Scientific Conference of young scientists, undergraduates, students and schoolchildren "Satpayev Readings". Exchange of experience in the direction of the project.

3. Moscow, Russia.Russian State Agrarian University - Moscow Agricultural Academy named after K.A. Timiryazev. Participation in the International Conference "Agrotechnology-2021", Round table "Industry 4.0: technological transformation of NDE 4.0". Exchange of experience in the direction of the project.

4. Karaganda city, Kazakhstan. Participation in the International Scientific and Practical Conference "Saginov Readings". Exchange of experience in the direction of the project.

5. Moscow, Russia. Russian State Agrarian University - Moscow Agricultural Academy named after K.A. Timiryazev. Participation in the International Conference "Agrotechnology-2021", Round table "Industry 4.0: technological transformation of NDE 4.0". Exchange of experience in the direction of the project.

6. Almaty, Kazakhstan. Kazakh National Agrarian Research University. Participation in the International Scientific and Practical Conference of Young Scientists "Scientific view of the young: searches, prospects, innovations in the agro-industrial complex." Exchange of experience in the direction of the project.

7. Karaganda, Kazakhstan. Participation in the International Scientific and Practical Conference "Saginov Readings". Exchange of experience in the direction of the project.

8. Pavlodar, Kazakhstan. Toraigyrov University. Participation in the International Scientific Conference of young scientists, undergraduates, students and schoolchildren "Satpayev Readings". Exchange of experience in the direction of the project.

9. Tomsk, Russia... Tomsk Polytechnic University. VI International conference on innovations in non-destructive testing SibTest 2022. Exchange of experience in the Research and Production Laboratory "Pure Water" (<https://tpu.ru/university/structure/department/view?id=7886>), internship

10. Davisstate, USA,University of California. Acquaintance with the research and laboratories of the College of Engineering, exchange of experience, internship.

**7. Justification of the requested funding**

A summary calculation of the project implementation costs is presented in Table 2.

Table 2 - Summary cost estimate for the requested amount

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| No. | Expense item name | Funding volume, thousand tenge | | | |
| Total | year 2022  (1st year) | year 2023  (2nd year) | year 2024  (3rd year) |
| 1 | Labor remuneration (including taxes and other obligatory payments to the budget) | 47 788, 020 | 14 055, 300 | 16 866, 360 | 16 866, 360 |
| 2. | Business trips | 6 895, 489 | 2 276, 796 | 3510, 444 | 1 108, 249 |
| 3 | Scientific and organizational support, other services and works | 9,100,000 | 1,000,000 | 3,300,000 | 4,800,000 |
| 4. | Purchase of materials (for individuals and legal entities), purchase of equipment and (or) software (for legal entities) | 7 427, 509 | 6 393, 707 | 59, 393 | 974, 409 |
| 5. | Rental costs, operating costs of equipment and machinery used to carry out research | 3,750,000 | 1,250,000 | 1,250,000 | 1,250,000 |
| Total | | 74961,018 | 24975,803 | 24986,197 | 24999,018 |

Detailed information on years and expense items is presented in tables 3-7 AIS "NCSTE" <https://is.ncste.kz/>...

Below are explanations of the respective items of expenditure.

Under the item "Remuneration (including taxes and other obligatory payments to the budget)" remuneration for the work of the research group is assumed, taking into account vacation pay, except for compensation and incentive payments. On the development of new knowledge, methods and means, the formation of the personnel elite of the Kazakhstani economy, the achievement of project results. The distribution of wages in accordance with the planned volume of work, the share of labor participation, existing knowledge and skills, and the quality of labor results is presented in Table 3.

In the article "Business trips"business trips across Kazakhstan (table 4) of the members of the research group in Almaty (National Center for State Scientific and Technical Expertise) were planned to check and submit the annual report. Based on the calculation of 1 MCI in 2022 it is 3063 tenge, 2023 - 3201 tenge, 2024 - 3462 tenge, rent of residential premises is not more than 7 MCI per day for the city of Almaty, no more than 6 MCI in cities of regional significance.

A business trip is planned to Tomsk (National Research Tomsk State University) to exchange experience and write joint publications in international databases Scopus (table 5) In the Russian Federation, per diem is no more than 80 US dollars per day, accommodation is no more than 220 US dollars per day for a standard room.

At the final stage of the project, a business trip is planned to the state of Davis, United States of America (University of California) per diem not more than 100 US dollars per day, accommodation not more than 260 US dollars per day for a standard room, in accordance with the decree of the Government of the Republic of Kazakhstan dated May 11, 2008 No. 256 "On approval of the Rules for reimbursement of business travel expenses at the expense of budgetary funds, including to foreign countries."

In the article "Scientific and organizational support, other services and works" for the qualitative achievement of the goal, it is planned:

In the article "Purchase of materials (for individuals and legal entities), purchase of equipment and (or) software (for legal entities)", it is planned to purchase equipment and materials for the implementation of the project plan, namely, the purchase of equipment, materials and components for creating individual elements of the device , as well as information and measuring technology for laboratory experiments. To reduce the risk of providing a material and technical base for the project, the cost of equipment is taken into account with a possible increase in price in subsequent years (30%).

In the item "Rental costs, operating costs of equipment and machinery used for the implementation of research" plannedoperating costs of equipment and technology used to carry out research. Expenses related to electricity, heat, water supply and sewerage, as well as banking operations.

**8. Project implementation plan**

Detailed, sequential work plan for the project according to table 8.

Table 8 - Timetable for project development.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| No. | Name  tasks and activities for their implementation | Period of execution | | | Expected results of the project implementation (in the context of tasks and activities), completion form |
| Start  (month) | Ending  (month) | |  |
| year 2022 | | | | | |
| 1 | Construction of new probabilistic models of processes of information and communication systems of multiple random access in the form of queuing systems with repeated calls (Retrial Queueing) of various configurations | 03.2022 | | 04.2022 | New probabilistic models of processes of information and communication systems of multiple random access will be built in the form of queuing systems with repeated calls (Retrial Queueing) of various configurations |
| 2 | Development of new and improvement of existing methods for studying the created mathematical models, including the method of initial moments, the method of diffusion approximation, modifications of asymptotic analysis under various limiting conditions | 05.2022 | | 06.2022 | New methods will be developed and existing methods for studying the created mathematical models will be developed, including the method of initial moments, the method of diffusion approximation, modifications of asymptotic analysis under various limiting conditions. |
| 3 | Determination of the main probabilistic characteristics of the created models, including the assessment of the area of ​​applicability of approximations and the calculation of the characteristics of the reservation of the used resources of the transmitted data in precision farming technologies | 07.2022 | | 08.2022 | The main probabilistic characteristics of the created models will be determined, including the assessment of the area of ​​applicability of approximations and the characteristics of the reservation of the used resources of the transmitted data in precision farming technologies will be calculated |
| 4 | Research of Markov resource RQ-systems and determination of the main probabilistic characteristics of the created models in info-communication networks | 09.2022 | | 10.2022 | Research of Markov resource RQ-systems will be carried out and the main probabilistic characteristics of the created models in info-communication networks will be determined. |
| 5 | Determination of the exact probabilistic characteristics for the number of claims in the orbit in the considered communication systems with exponential distribution functions of the probabilities of the service time on the server | 11.2022 | | 31/12/2022 | Exact probabilistic characteristics will be determined for the number of claims in the orbit in the considered communication systems with exponential distribution functions of the probabilities of the service time on the server.  One (1) application for participation in the international conference will be submitted. |
| year 2023 | | | | | |
| 6 | Investigation of non-Markov RQ-systems with non-exponential distribution function of service time on the device, construction of an approximation of the probability distributions of the number of requests in the orbit of data transmission of info-communication systems | 01.2023 | | 03.2023 | Research will be carried out on non-Markov RQ-systems with a non-exponential distribution function of the service time on the device and approximations of the probability distributions of the number of requests in the orbit of data transmission of info-communication systems will be constructed |
| 7 | Development of a web portal for info-communication systems for data transmission from clients of Smart-platforms | 04.2023 | | 06.2023 | A web portal will be developed for info-communication systems for transferring data from clients of Smart platforms |
| 8 | Testing the developed web portal, analysis and correction when errors are detected | 07.2023 | | 08.2023 | The developed web portal will be tested, analysis and correction will be carried out if errors are detected |
| 9 | Development and adaptation of a web portal to ensure the collection, processing, decision-making and data transmission of info-communication systems | 09.2023 | | 10.2023 | A web portal will be developed and adapted to ensure the collection, processing, decision-making and data transmission of info-communication systems |
| 10 | Development of recommendations for the use of a web portal, obtaining a title of protection for intellectual property | 11.2023 | | 31/12/2023 | Recommendations for the use of the web portal will be developed and an intellectual property title will be obtained.  1 (one) report will be submitted / accepted / published for participation in an international conference indexed by Scopus and / or WoS databases.  A study guide based on the results of research work will be developed. |
| year 2024 | | | | | |
| 11 | Development of a hardware complex for  Smart platform prototype,  used in precision farming as exemplified by the management of the machine and tractor fleet | 01.2024 | | 03.2024 | A hardware complex will be developed for  Smart platform prototype,  used in precision farming as exemplified by the management of the machine and tractor fleet |
| 12 | Experimental studies of the developed hardware complex for  Smart platform prototype,  used in precision farming as exemplified by the management of the machine and tractor fleet | 04.2024 | | 06.2024 | Experimental studies of the developed hardware complex will be carried out for  Smart platform prototype,  used in precision farming as exemplified by the management of the machine and tractor fleet |
| 13 | Testing, verification, approbation and reproduction of the results of the developed mathematical, software and hardware for decision making and data transmission on the example of the management of the machine and tractor fleet | 07.2024 | | 08.2024 | Testing, verification, approbation and reproduction of the results of the developed mathematical, software and hardware for decision making and data transmission will be carried out on the example of the management of the machine and tractor fleet |
| 14 | Preparation of the final report on research work for 2022-2024. | 09.2024 | | 10.2024 | A final research report for 2022-2024 will be prepared. |
| 15 | Development of recommendations for further application and dissemination of work results, filing an application for a title of protection | 11.2024 | | 31/12/2024 | Development of recommendations for further application and dissemination of work results, filing an application for a title of protection.  2 (two) articles and (or) reviews will be published in peer-reviewed scientific journals in the scientific direction of the project, indexed in the Science Citation Index Expanded of the Web of Science database and (or) having a CiteScore percentile in the Scopus database of at least 35 (thirty five);  One (1) article or review will be published in a peer-reviewed foreign or domestic edition recommended by CCSES (КОКСОН). |

**9. Expected results**

Two (2) articles and (or) reviews will be published in peer-reviewed scientific journals in the scientific direction of the project, indexed in the Science Citation Index Expanded of the Web of Science database and (or) having a CiteScore percentile in the Scopus database of at least 35 (thirty five). One (1) article or review will be published in a peer-reviewed foreign or domestic edition recommended by CCSES (КОКСОН). Each article will contain information about the identification registration number and name of the project, indicating grant funding as a source.

New probabilistic models of processes of information and communication systems of multiple random access will be built in the form of queuing systems with repeated calls (Retrial Queueing) of various configurations

New methods will be developed and existing methods for studying the created mathematical models will be developed, including the method of initial moments, the method of diffusion approximation, modifications of asymptotic analysis under various limiting conditions.

The main probabilistic characteristics of the created models will be determined, including the assessment of the area of ​​applicability of approximations and the characteristics of the reservation of the used resources of the transmitted data in precision farming technologies will be calculated

Research of Markov resource RQ-systems will be carried out and the main probabilistic characteristics of the created models in info-communication networks will be determined.

Exact probabilistic characteristics will be determined for the number of claims in the orbit in the considered communication systems with exponential distribution functions of the probabilities of the service time on the server.

One (1) application for participation in the international conference will be submitted.

Research will be carried out on non-Markov RQ-systems with a non-exponential distribution function of the service time on the device and approximations of the probability distributions of the number of requests in the orbit of data transmission of info-communication systems will be constructed

A web portal will be developed for info-communication systems for transferring data from clients of Smart platforms.

The developed web portal will be tested, analyzed and corrected if errors are detected.

A web portal will be developed and adapted to ensure the collection, processing, decision-making and data transmission of info-communication systems.

Recommendations for the use of the web portal will be developed and an intellectual property title will be obtained.

A study guide based on the results of research work will be developed.

A hardware system will be developed for a prototype Smart-platform used in precision farming on the example of managing a machine and tractor fleet.

Experimental studies of the developed hardware complex for the prototype of the Smart-platform used in precision farming will be carried out using the example of managing a machine and tractor fleet.

Testing, verification, approbation and reproduction of the results of the developed mathematical, software and hardware for decision-making and data transmission will be carried out on the example of managing a machine and tractor fleet.

A final research report for 2022-2024 will be prepared.

Recommendations will be developed for the further application and dissemination of the results of the work, filing an application for a title of protection.

**10. Bibliography**

1. Samouylov, K., Naumov, V., Sopin, E., Gudkova, I., Shorgin, S. Sojourn Time Analysis for Processor Sharing Loss System with Unreliable Server // Analytical & Stochastic Modeling Techniques & Applications ASMTA, 2016. P. 284-297.

2. Tikhonenko OM Service system with processor sharing and limited resources // Automation and telemechanics. 2010. T. 71. No. 5. S. 803-815.

3. Naumov V., Samuilov K., Samuilov A. On the total amount of resources occupied by serviced customers // Automation and Remote Control. 2016.Vol. 77.No. 8.P. 1419-1427.

4. Naumov V.A., Samuilov K.E. On modeling queuing systems with multiple resources // Bulletin of RUDN. Series: Mathematics, Informatics, Physics. 2014. No. 3. C. 60-64.

5. Haenggi M. Stochastic Geometry for Wireless Networks // Cambridge University Press. 2012.

6. Vishnevsky V.M., Dudin A.N., Klimenok V.I. Stochastic systems with correlated flows. Theory and application in telecommunication networks. Moscow: TECHNOSPHERE, 2018.564 p.

7. Lakatos L., Szeidl L., Miklos T. Introduction to Queueing Systems with Telecommunication Applications. Springer US, 2013.

8. Stepanov S.N. Teletraffic theory. Concepts, models, applications. M.: Hotline - Telecom. 2016.860 s.

9. Vishnevsky V.M., Dudin A.N., Klimenok V.I. Stochastic systems with correlated flows. Theory and application in telecommunication networks. M .: Advertising and publishing center "TECHNOSPHERE", 2018.564 p.

10. Stepanov S.N. Basics of teletraffic of multiservice networks. Moscow: Eco-Trends, 2010.392 p.

11. Artalejo JR, Gomez-Corral A. Retrial Queueing Systems: A Computational Approach. - Springer, 2008.309 p.

12. Tikhonenko O., Kempa WM On the queue-size distribution in the multi-server system with bounded capacity and packet dropping // Kybernetika. 2013. Vol. 49, No. 6.P. 855-867.

13. Tikhonenko O., Kempa WM Performance evaluation of an M / G / n-type queue with bounded capacity and packet dropping // International Journal of Applied Mathematics and Computer Science. 2016. Vol. 26, No. 4.P. 841-854.

14. Naumov V., Samouylov K. Analysis оf multi-resource loss system with state dependent arrival and service rates // Probab. Eng. Inform. Sc., 2017. Vol. 31. No. 4.P. 413-419.

15. Naumov V., Samouylov K., Sopin E., Andreev S. Two approaches to analysis of queuing systems with limited resources // Ultra-Modern Telecommunications and Control Systems and Workshops Proceedings. - IEEE, Piscataway, NJ, USA, 2014. P. 485-488.

16. Samouylov K., Sopin E., Vikhrova O. Analysis of queueing system with resources and signals // Comm. Com. Inf. Sc., 2017. Vol. 800. P. 358-369.

17. Sopin E., Vikhrova O., Samouylov K. LTE network model with signals and random resource requirement // 9th Congress (International) on Ultra Modern Telecommunications and Control Systems and Workshops Proceedings. - Munich, Germany: IEEE, 2017. P . 101-106.

18. Gorbunova A.V., Naumov V.A., Gaidamaka Yu.V., Samuylov K.E. Resource queuing systems as models of wireless communication systems // Informatics and its applications, 2018. V. 12. Issue. 3.S. 48-55.

19. Naumov V.A., Samuilov K.E., Samuylov A.K. On the total amount of resources occupied by serviced requests // Automation and Telemechanics. 2016. No. 8. S. 125-135.

20. Naumov V.A., Samuylov K.E. Analysis of networks of resource queuing systems // Automation and telemechanics, 2018. No. 5. S. 59-68.

21. Naumov V.A., Samuilov K.E. On modeling queuing systems with multiple resources // Bulletin of RUDN. Series: Mathematics. Informatics. Physics. 2014. No. 3. S. 60-64.

22. Nazarov A.A., Moiseeva S.P. Methods of asymptotic analysis in the theory of queuing // Tomsk: Izd-vo NTL, 2006.112 p.

23.Nazarov A.A., Paul S.V., Lizyura O.D. Asymptotic analysis of an RQ-system with N types of called claims in the limiting condition of a large delay of claims in orbit // Vestn. Volume. state un-that. UVTiI. 2019. No. 48, pp. 13-20.

24. Nazarov A., Paul S. A Cyclic Queueing System with Priority Customers and T-Strategy of Service // CCIS. 2016. Vol. 678. P. 182-193.

**3. "Calculation of the requested funding"**

Tables 1-15 are presented on the portal <https://is.ncste.kz/>...

**Hardware and software**

1. Server
2. GIS system <https://www.esri-cis.ru/ru-ru/industries/agriculture>
3. SQL server
4. OC Linux
5. Domain
6. MySQL Community Server 8.0.27
7. PC for control
8. ASP.NET Core. Website development
9. MFP, keyboard and mouse

Table 1 - Composition of the research group for conducting scientific research

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| No. | Full name, degree / academic degree, academic title | Main place of work, position | Role in a project or program | Employment (full, part-time) | Project work period (months) | | |
| 1st year | 2nd year | 3rd year |
|  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |

Table 2 - Summary cost estimate for the requested amount

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Expense item name | Funding volume | | | |
| Total | 1st year | 2nd year | 3rd year |
| Salary (Remuneration) | 17280000 | 5760000 | 5760000 | 5760000 |
| Scientific business trips (business trips) within the Republic of Kazakhstan | 153208 | 76604 | 76604 | 0 |
| Scientific business trips (business trips) outside the Republic of Kazakhstan | 16212016 | 3690462 | 9356092 | 3165462 |
| Third Party Services (Other Services and Works) | 0 | 0 | 0 | 0 |
| Purchase of materials | 0 | 0 | 0 | 0 |
| Purchase of equipment and (or) software (for legal entities) | 1478770 | 1478770 | 0 | 0 |
| Scientific and organizational support | 40,000 | 0 | 0 | 40,000 |
| Premises for rent (individuals) | 0 | 0 | 0 | 0 |
| Equipment and machinery rental | 0 | 0 | 0 | 0 |
| Operating costs of equipment and technology used to carry out research | 0 | 0 | 0 | 0 |
| Taxes and other obligatory payments to the budget | 2226240 | 607680 | 665280 | 953280 |

Table 3 - Remuneration

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| No. | Position | Employment (full / not full) |  | Labor remuneration, tenge | | | | | |  |
| Rate, tenge per month | **1st year** | | **2nd year** | | **3 year** | | Total (column 6 + column 8 + column 10) |
| Number of months of work | Amount (column 3 × column 4 × column 5) | Number of months of work | Amount (gr. 3 × gr. 4 × gr. 7) | Number of months of work | Amount (column 3 × column 4 × column 9) |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
| 1. | scientific adviser | 1.0 | 140,000 | 12 | 1680000 | 12 | 1680000 | 12 | 1680000 | 5040000 |
| 2 | Senior Researcher | 1.0 | 120,000 | 12 | 1,440,000 | 12 | 1,440,000 | 12 | 1,440,000 | 4320000 |
| 3 | Researcher | 1.0 | 120,000 | 12 | 1,440,000 | 12 | 1,440,000 | 12 | 1,440,000 | 4320000 |
| 4 | junior researcher | 1.0 | 50,000 | 12 | 600,000 | 12 | 600,000 | 12 | 600,000 | 1,800,000 |
| 5 | junior researcher | 1.0 | 50,000 | 12 | 600,000 | 12 | 600,000 | 12 | 600,000 | 1,800,000 |
| Total: | | | |  | 5760000 |  | 5760000 |  | 5760000 | 17,280,000 |

Table 4 - Business trips within the Republic of Kazakhstan

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| No. | Destination (name of settlement, region) | Reimbursement rates for 1 person, tenge3 | | Average annual number of man-days | | Average annual number of people on assignment, people | Average cost of one round trip, tenge | Total, thous. tenge group 7 × (group 3 × group 5 + group 4 × group 6) + group 7 × group 8 |
| daily allowance (2 MCI) | rental of living quarters | for daily expenses | renting a living space |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 1. | 2021 (1st year) | | | | |  | X |  |
| 1.1 | Pavlodar | 10604 | 12000 | 1 | 4 | 1 | 18000 | 76604 |
| 2. | 2022 (2nd year) | | | | |  | X |  |
| 2.1 | Pavlodar | 10604 | 12000 | 1 | 4 | 1 | 18000 | 76604 |
| Total (column 1 + column 2 + column 3) | | | | | |  | 36000 | 153208 |

Table 5 - Business trips outside the Republic of Kazakhstan

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| No. | Destination (country, city) 4 | Name of expense item5 | Cost, tenge | Average annual number of man-days | Average annual number of people on assignment, people | Total, thous. tenge (gr. 4 × gr. 5 × gr. 6) |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 1. | 2021 (1st year) total | | X | X |  |  |
| 1.1. | Moscow, Moscow and Moscow region | Round-trip travel6, tenge | 150,000 | 6 | 3 | 2,700,000 |
| Accommodation, tenge per day | 9191 | 6 | 3 | 165438 |
| Daily allowance, tenge per day | 16668 | 6 | 3 | 300024 |
| Visa expenses, tenge | 0 | 0 | 0 | 0 |
| Medical insurance, tenge | 0 | 0 | 0 | 0 |
| Total | | |  |  | 3165462 |
| 2.2 | Tomsk, Tomsk region | Round trip travel, tenge | 18000 | 5 | 3 | 270,000 |
| Accommodation, tenge per day | 7000 | 5 | 3 | 105000 |
| Daily allowance, tenge per day | 10000 |  | 3 | 150,000 |
| Visa expenses, tenge | 0 | 0 | 0 | 0 |
| Medical insurance, tenge | 0 | 0 | 0 | 0 |
| Total | | |  |  | 525000 |
| 2. | 2022 (2nd year) total | | X | X |  |  |
| 2.1. | Moscow, Moscow and Moscow region | Round trip travel, tenge | 150,000 | 6 | 3 | 2,700,000 |
| Accommodation, tenge per day | 9191 | 6 | 3 | 165438 |
| Daily allowance, tenge per day | 16668 | 6 | 3 | 300024 |
| Visa expenses, tenge | 0 | 0 | 0 | 0 |
| Medical insurance, tenge | 0 | 0 | 0 | 0 |
| Total | | |  |  | 3165462 |
| 2.2 | Tomsk, Tomsk region | Round trip travel, tenge | 18000 | 5 | 3 | 270,000 |
| Accommodation, tenge per day | 7000 | 5 | 3 | 105000 |
| Daily allowance, tenge per day | 10000 |  | 3 | 150,000 |
| Visa expenses, tenge | 0 | 0 | 0 | 0 |
| Medical insurance, tenge | 0 | 0 | 0 | 0 |
| 2.3 | Total | | |  |  | 525000 |
| Pisa, Italy | Round trip travel, tenge | 150,000 | 15 | 2 | 4,500,000 |
| Accommodation, tenge per day | 20853 | 15 | 2 | 625590 |
| Daily allowance, tenge per day | 16668 | 15 | 2 | 500040 |
| Visa expenses, tenge | 30,000 | one | one | 30,000 |
| Medical insurance, tenge | 10000 | one | one | 10000 |
| Total | | |  |  | 5665630 |
| 3. | 2023 (3rd year) total | | X | X |  |  |
| 3.1. | Moscow, Moscow and Moscow region | Round trip travel, tenge | 150,000 | 6 | 3 | 2,700,000 |
| Accommodation, tenge per day | 9191 | 6 | 3 | 165438 |
| Daily allowance, tenge per day | 16668 | 6 | 3 | 300024 |
| Visa expenses, tenge | 0 | 0 | 0 | 0 |
| Medical insurance, tenge | 0 | 0 | 0 | 0 |
| Total | | |  |  | 3165462 |
| Total (column 1 + column 2 + column 3) | | | X | X |  | 16,212,016 |

Table 6 - Other services and works - not provided

Table 7 - Purchase of materials - not provided

Table 8 - Purchase of equipment and (or) software (for legal entities)

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| P / p No. | Name | Manufacturer, model, main characteristics | unit of measurement | Quantity, units | Unit cost, tenge | Total cost, tenge (column 5 × column 6) |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 1 | 2021 (1st year), total | | |  | X |  |
| 1.1. | Monoblock | Monoblock 23.8 "HP 24-F1007UR White (6PW85EA) | PC. | 4 | 344990 | 1379960 |
| 1.2. | Multifunction device | HP Europe Laser MFP 135W Printer-Scanner | PC. | one | 72890 | 72890 |
| 1.3 | Mouse | Wired mouse Logitech M100 (L910-005003) | PC. | 4 | 3990 | 15960 |
| 1.4 | Keyboard | Wired keyboard Sven KB-S300 black | PC. | 4 | 2490 | 9960 |
| Total | | | |  | X | 1,478,770 |

Table 9 - Scientific and organizational support

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| P / p No. | Services list | The result of the service, its main characteristics | unit of measurement | Number of units | Total cost, tenge |
| 1 | 2 | 3 | 4 | 5 | 6 |
| 3. | 2023 (3rd year), total | | X | X |  |
| 3.1. | patent | obtaining a software patent, registration in Kazakhstan, and Russia | PC. | 2 | 40,000 |
| Total (column 1 + column 2 + column 3) | | | X | X | 40,000 |

Table 10 - Rent of premises - not provided

Table 11 - Rent of equipment and machinery - not provided

Table 12 - Operating costs of equipment and technology used for the implementation of research - not provided

Table 13 - Taxes and other obligatory payments to the budget

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| No. | Tax calculations | Taxable payroll fund or taxable amount, tenge | Amount, tenge | | | | | | |
| Bid, % | 20\_\_\_ year (1st year) | Bid, % | 20\_\_\_ year (2nd year) | Bid, % | 20\_\_\_ year (3rd year) | Total (column 5 + column 7 + column 9) |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| 1. | Calculation of Social Tax Expenses | 5184000 | 6 | 311040 | 6 | 311040 | 6 | 311040 | 933120 |
| 2. | Calculation of expenses for payment of social contributions to the State Social Insurance Fund | 5184000 | 3.5 | 18144 | 3.5 | 18144 | 3.5 | 181440 | 544320 |
| 3. | Compulsory social insurance contributions | 5760000 | 2 | 115200 | 3 | 172800 | 3 | 172800 | 460800 |
| 4. | Employer's compulsory pension contributions | 5760000 | 0 | 0 | 0 | 0 | 5 | 288000 | 288000 |
| 5 | Other obligatory payments to the budget: | 0 |  | 0 |  | 0 | 0 | 0 | 0 |
|  | Total | X | X | 607680 | X | 665280 | X | 953280 | 2,226,240 |

Table 14 - Implementation work plan

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| No. | Name of tasks, activities for the implementation of project tasks | Start of work | Duration, months | Expected results of the project implementation (in the context of tasks and activities), completion form | | |
| 1st year | 2nd year | 3rd year |
| 1. | Construction of new probabilistic models of processes of communication systems of multiple random access in the form of queuing systems with repeated calls (Retrial Queueing) of various configurations, including those with non-Poissonian non-ordinary incoming flows, namely: resource single- and multi-line RQ systems with and without conflicts , RQ systems with losses, with negative and impatient claims, RQ systems with priorities and preemption; | 06/01/2021 | 3 | new mathematical models of systems for transferring data transmission processes in info-communication networks in the form of queuing systems with repeated calls (Retrial Queueing system) with a random volume: single- and multi-line RQ systems, with a discrete and continuous volume of requests for additional resources, with and without conflicts conflicts, with impatient claims (losses), with negative claims (disabling the system), with priorities and preemption |  |  |
| 2 | Development of new and development of existing methods for studying these mathematical models, including the method of initial moments, the method of diffusion approximation, modifications of asymptotic analysis under various limiting conditions: high intensity of incoming flows and high load, long delay in the source of repeated calls, long "patience"; | 01/04/2021 | 4 | development of a modification of the asymptotic analysis method for research under conditions of high load, long delay in orbit, long patience of claims, etc. These methods will be used to study these models, as a result of which probabilistic characteristics of systems will be obtained, namely, the probability distribution of the number of claims in the system. |  |  |
| 3 | Finding the main probabilistic characteristics of these models, including assessing the area of ​​applicability of approximations and calculating the reservation characteristics of the resources used; | 01/08/2021 | 4 | experimental research reports. Publication in peer-reviewed scientific journals of the international base Scopus, CCSES (ККСОН). Participation in international conferences in Kazakhstan, Russia and Europe. |  |  |
| 4 | using the developed methods, investigate Markov resource RQ-systems and determine the main probabilistic characteristics of these models (for example, the probability distribution of the number of received claims in the system; the probability distribution of the number of claims in the orbit; the probability distribution of the time spent by the claim in the system / in the orbit; the probability distribution of the states of the device ). | 01/12/2021 | 4 |  | The theoretical results of the project will serve as a new stage in the development of queuing theory and teletraffic theory, as a result of which an information and competence base will appear for long-term scientific research in this scientific direction. |  |
| 5 | Using numerical matrix methods, find the exact probabilistic characteristics for the number of claims in the orbit in the systems under consideration with exponential distribution functions of the probabilities of the service time on the server. | 01/04/2022 | 4 |  | experimental research reports. Publication  in peer-reviewed scientific journals of the international database Web of Science, CCSES (ККСОН). |  |
| 6 | Construct modifications of the asymptotic method and apply them to study these models under conditions of high intensity of incoming flows, high load and long delay in the IPV, long patience (for systems with "impatient" requests "). | 01/08/2022 | 4 |  | reports of experimental studies of service parallelization algorithms. Publication in peer-reviewed scientific journals of the international base Thomson Reuters, Scopus. Participation in international conferences in Kazakhstan, Russia and Europe. |  |
| 7 | Using the developed methods, conduct a study of non-Markov RQ-systems with a non-exponential distribution function of the service time on the device, construct approximations of the probability distributions of the number of claims in the orbit; the distribution of probabilities of the time spent by the claim in the system / in the orbit. | 01/12/2022 | 3 |  | experimental research reports. Publication  in peer-reviewed scientific journals of the international database Web of Science, CCSES (ККСОН). |  |
| 8 | Development of software for calculating and visualizing on a computer the main characteristics of the systems under study, analyzing the analytical results obtained and comparing them with known special cases; evaluating the accuracy of the results and determining the limits of applicability of the developed approximations. | 01/03/2023 | 3 |  |  | development of software modules for calculating and visualizing on a computer the main characteristics of the systems under study, with the help of simulation, estimates of the accuracy of asymptotic results were obtained and the limits of their applicability were determined. |
| 9 | Development of documentation for the use of software. Description in the documentation of the developed mathematical models for the software. | 01/06/2023 | 3 |  |  | preparation of the final USDD (Unified system of design documentation) for new software. |
| 10 | Preparation of a research report for 2021-2023 | 01/09/2023 | 4 |  |  | obtaining a patent of the Republic of Kazakhstan and the Russian Federation. Publications in peer-reviewed scientific journals of the international base Web of Science, Thomson Reuters, Scopus, CCSES (ККСОН). Participation in international conferences in Kazakhstan, Russia and Europe. Writing a joint monograph based on the research. |

Table 15 - Partner Contribution Plan

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| dNo. | Partner name, address, contact information | Contribution form (no more than 50 words) | Deposit cost, thousand tenge | Application date (dd.mm.yyyy) |
| 1 | 2 | 3 | 4 | 5 |
| 1 | SP "Vasiliev"  Pavlodar,  Lomova street 181 / 1-21  87075546506  programtsu2017@gmail.com | Co-financing | 373902.34 | 15/02/2021 |