Analysis of Energy Efficiency Indicators in IoT-based Systems

Ilkhom Siddikov
Full Professor of the Tashkent institute of irrigation and agricultural mechanization engineers National research university
Tashkent, Uzbekistan
ikhsiddikov@mail.ru

Halimjon Khujamatov
Dean of the Faculty of "Komputer engineering"Tashkent University of Information Technologies named after Muhammad al-Khwarizmi
Tashkent, Uzbekistan
kh.khujamatov@gmail.com

Azizbek Temirov
PhD student of the Namangan state university
Namangan, Uzbekistan
aaotemirov@gmail.com

Ernazar Reypnazarov
PhD student of the Tashkent University of Information Technologies named after Muhammad al-Khwarizmi
Tashkent, Uzbekistan
reypnazar0vernazar@gmail.com

Doston Khasanov
Associate Professor of the Tashkent University of Information Technologies named after Muhammad al-Khwarizmi
Tashkent, Uzbekistan
dhasanov0992@gmail.com

2022 International Conference on Information Science and Communications Technologies (ICISCT) | 978-1-6654-7229-6/22/$31.00 ©2022 IEEE | DOI: 10.1109/ICISCT55600.2022.10146855

***Abstract* — This article examines several use cases for IoT in industries. It can contribute to the efficient use of power, data exchange between devices and the network. When it comes to smart transportation, ensuring the safety of drivers and passengers in the IoT is paramount. Similarly, healthcare is open to a number of potential benefits offered by the IoT in terms of patient health monitoring and early diagnosis. For this purpose, IoT provides non-disruptive monitoring of machines used in various industries, thereby increasing equipment life and operational efficiency.**

Keywords—Internet of Things IoT, intelligent decision-making systems, sensors, energy-saving applications, fog computing.

I. Introduction

Advent of the Internet, smart life has become a reality. It is a system that benefits people by saving time, cost and energy. Energy is one of the most important aspects of the Internet. Real-time remote monitoring, application management function plays a major role in energy saving. Energy-saving applications are the so-called assets of the IoT. Its persistence will lead to billions Internet of things that will be able to communicate with each other and exchange data back and forth. However, communication between these devices requires a certain amount of energy to receive, transmit and store information. High-performance IoT applications consume large amounts of energy that are scarce in nature. This article examines the common aspects of IoT that lead to high energy consumption. In addition, solutions are offered to reduce energy consumption in IoT-based applications.

IoT has many definitions. It describes it as "A Cyber-Physical Ecosystem *of Interdependent Sensors and Actuators Enabling Intelligent Decision Making*". IoT is "*Internet*" and "*thing*" is a combination of words. Simply put, it can be defined as a thing (device/system) that has some computational intelligence to act accordingly and communicate with other objects as well as people over the Internet.

Real-time monitoring and control of devices has been implemented through IoT. Remote monitoring and application management not only saves time and money, but also saves energy. For example, Cysco's Wi-Fi smart light has Wi-Fi connectivity and allows the user to control all aspects of the light from their mobile app [1]. If the user leaves the house and forgets to turn off the lights, they can easily turn it off via mobile phone. This smart bulb can turn off at sunrise (automatically turn on at sunset). There are many functions offered in one bulb. The main focus here is that the smart light's automatic and remote control and control features help reduce energy wastage. The concept of IoT has created energy efficient applications. The idea of using smart and connected devices is evolving. This leads to the spread of the Internet throughout the world. Even industry and government are embracing IoT as a source of energy savings. Many countries have started to create "Smart Cities" by using internet-based devices to save energy [2].

To detect the environment, a gateway to transfer the collected data, and a cloud to manage and store the data. IoT applications aggregate and analyze data based on the data produced by these connected IoT devices. Internet - application automation and remote access reduce energy loss. To be energy efficient, these applications also need energy to run. From sensing to data sharing and storage, energy is required, and powering billions of such devices requires a large amount of energy [3].

Internet of things, energy consumption has a negative effect on increasing energy consumption. We all know that energy resources are not enough in nature, and using them at such a rate in the future may be dangerous. On the one hand, IoT has presented itself as a way to save energy through energy-efficient applications, but on the other hand, its energy efficiency has been compromised.

II. Levels of Energy Efficiency in the Internet of Things

To date, many studies have been conducted on reducing the energy consumption of Internet systems. However, the implementation of these proposed ideas and solutions was rarely done in real time. It should be noted that energy is consumed not only at the sensitive stage of the Internet, but also at other stages of data transmission, processing, storage, and analysis to ensure the operation of its components and Internet devices [4-7]. Table 1 lists the energy consumption factors responsible for energy consumption in each IoT phase. These factors are very common and are often not taken into account when implementing IoT applications. If any of the above factors can be controlled in IoT systems, you will be able to save a lot of energy.

978-1-6654-7229-6/22/$31.00 ©2022 IEEE

TABLE I. IoT LEVELS

Levels	Components	Factors requiring energy
LEVEL I : Sensory	Sensors/Actuators, RFID, Camera, Embedded Systems	• It requires 24/7 power and operates using sensor data. • Charging the batteries. • Continuous sensing.
LEVEL II : Network	Gateway, LAN (Wi-Fi /Ethernet) / WAN (GSM/5G)	• Requires power to operate gateways/LAN/WAN. • Seamlessly send data to the cloud. • Sending large amounts of data to the cloud. • Data transmission takes a long time due to inefficient routing and protocols.
LEVEL III: Preparation for analysis and process	An endpoint in the form of a server, a gateway	• Power is required to run edge servers.
LEVEL IV: Collect and analyze	Data center i.e. cloud service	• Storing and processing such large data requires a lot of energy.

As you can see from the above section, every component of the internet consumes a lot of energy as it interacts with each other. The following solutions are offered to increase the energy efficiency of the Internet:

- Charging batteries to run Internet applications is a big challenge in IoT. Because it requires a large amount of electricity. In addition to electricity, energy harvesting is also a good option. The authors introduced the concept of “Energy-Harvesting Internet of Things”. This is a two-step process of maximizing energy. In the first stage, the energy obtained from different sources is collected by the combiners, and in the second stage, all the energy collected from different sources is combined. As a result, the collected total energy is used by energy sensor nodes. This concept can solve the problem of dependence on a single energy source used for collection [7-9].
- Another study proposed an energy efficient scheduling algorithm. This algorithm uses three different steps for sensor scheduling. In the duty mode (On-duty stage) the sensors work at full capacity, and when they are empty, they go into pre-shutdown mode, that is, they “receive” and “transmit” only the necessary commands. The last stage, i.e. off stage, is the main stage of energy saving. At this point, the sensor can enter standby, sleep, and shutdown modes depending on the sensor's activity [10].
- The concept of Nb-IoT, its architecture and energy efficiency features are discussed. Its LPWA technology provides significant energy savings. Discusses how LTE networks are useful for deploying NB-IoT in networks. It also provides three options for NB-IoT deployment: stand-alone, protected band, and in-band depending on spectrum range [11].
- The authors presented a long-haul scheduling algorithm to optimize the energy consumption of WSNs. This algorithm prevents retransmissions by pre-routing messages from long distances. Preventing retransmissions increases network lifetime. This reduces the energy consumption when transmitting packets. It also reduces the number of retransmitted packets. This helps in effective data transfer [12].
- Network protocols play a very important role in energy conservation. This protocol solves the problem of high energy consumption by intermediate nodes when forwarding packets from sensitive nodes to head node due to limited transmission distance. The proposed protocol uses the residual energy of the nearest link as well as the residual energy of all nodes in the network. It helps in sending packets by using minimum number of hops which reduces energy loss [13].
- A sleep and wake-up mechanism was proposed in the architecture for the green IIoT (Industrial Internet of Things: Industrial IoT). Traffic balancing is proposed to reduce energy consumption. A sleep scheduling mechanism has been introduced to further improve energy efficiency. It puts nodes to sleep when they are idle and wakes them up when needed [14].
- An energy-efficient solution for smart home applications was proposed through machine learning and city detection. Urban sensing data such as: crowd-sourced data, photovoltaic panel data (PV panels data), housing utilities are collected from various urban household sources. Data obtained through machine learning is used to make smart applications more efficient [15].
- Fog computing is gaining popularity in IoT in terms of energy efficiency. Two technologies are used: local computing for energy conservation in IoT and fog computing for micro-grids for renewable energy. Things of Internet Gateway is designed to make decisions about where to run IoT applications in the cloud or in the district based on local energy consumption and weather information. The energy efficiency of cloud computing was also evaluated in terms of energy efficiency of cloud and cloud computing and network service organization quality in 5G mobile network. It also suggested that in 5G networks, the cloud can spread to the cloud to increase the mobility of the virtual network [16-19].

III. ENERGY-EFFICIENT SOLUTIONS FOR THE INTERNET OF THINGS.

Recommended solutions are based on the above review. It is mainly related to the main aspects of the Internet, which are very common and cause energy loss. Table 2 shows ways to reduce energy consumption in IoT:

A. Combination of multiple sensors

Sensors are a key part of the Internet of Things. There are different sensors in the market that are used in different Internet applications. Sensors differ depending on the field of application. For example, an LDR sensor is used where the application is based on illumination, an IR sensor is used where the application is based on object tracking, etc. Different sensors can be used in the same application to make it more energy efficient. If one sensor controls the program, then the other sensor can be scheduled for a certain time depending on the program. Then it can control the already running program to save more energy. All advanced sensors can be programmed using pre-recommended methods.

TABLE II. ENERGY EFFICIENT SOLUTIONS FOR IOT

Levels	Factors requiring energy	Energy efficient solutions
Sensor	• It requires 24/7 power and operates using sensor data. • Charging the batteries. • Continuous sensing.	• Effective programming • A combination of several sensors • Data filtering • Collect power _ • scheduling algorithm
Network	• Requires power to operate gateways/LAN/WAN. • Seamlessly send data to the cloud. • Sending large amounts of data to the cloud. • Long time due to inefficient routing and protocols • data transfer during.	• Effective communication protocol • Efficient routing • periodic data transfer • Data filtering • NB-IoT
Analysis and process preparation	• Power is required to run edge servers.	• Local computing with fog computing
Collection and analysis	• Storing and processing such large data requires a lot of energy.	• Foggy computing • analysis of real-time and non-real-time applications

B. Periodic data transfer

Sending measured data to the cloud helps in remote monitoring of IoT-based systems. Continuously sending data to the cloud requires a lot of energy. Continuous data transmission through the Gateway requires a lot of energy [20]. Because the Gateway consumes more energy in data transmission. For applications that do not require continuous data transfer and continuous monitoring, periodic data transfer can be a good way to save energy. During periodic data transfer, data is periodically sent to the cloud at set intervals. Thus, the power consumption of the gateway is reduced when the data is not sent to the cloud.

C. Data filtering

Data mining is the most common area where big data is generated. Internet of Things devices generate enormous amounts of data. It can be a combination of both redundant and important information [21]. Sending all the data directly to the cloud consumes a lot of energy to transfer them. If a useful method is used to filter data, filter redundant data, and send only useful data to the cloud, the data volume will be reduced, and the reduced data transmission will save energy to a certain extent. This method can be implemented in different phases of IoT. The received data can be filtered during the reading phase of the application programming. Some filters and library are created to filter noisy data. In addition, data can be filtered at the gateway of the Internet of Things, that is, at the border [22]. Gateway not only provides communication between devices and the cloud. The software installed in the gateway has different roles, which help to filter the data and determine which data is redundant or noisy. Filters this data accordingly and sends it to the cloud. Therefore, the size of the filtered data is smaller than the original data, which requires less energy during transmission. In addition, it saves energy at the cloud stage by storing and processing only filtered data.

D. Efficient programming

This method is used to improve energy efficiency in every phase of IoT. All other methods are based on this approach. Effective programming from the first phase of Internet implementation plays an important role in energy conservation. Working on the hardware is an internal system (microcontroller) that controls all Internet applications, and developers have the ability to control the system's energy consumption [16, 23]. Based on the software that writes the code, they can save energy by efficiently using energy-saving modes, interrupts, sleep-wake protocols, and more.

E. Local calculation

Its relevance is discussed in section b)-In addition, advanced computing can save energy in IoT. It does not transfer all the data from the device to the cloud at once. It stores data with the local device for processing and analysis. As a result, the reverse data traffic to the central data center is reduced. The above data filtering method is part of local calculations. Only part of the data can be sent to the cloud [24]. This, in turn, requires long-term storage and analysis. This helps save energy when sending large amounts of data directly to the cloud. Fog computing is a form of advanced edge computing that helps save energy in IO.

F. Application-based real-time and real-time data analysis and processing

IoT facilitates real-time actions based on user access to real-time data. processing and analyzing data in real time takes both energy and time. Real-time data processing and analysis is not required in IoT. Other features of the app help the user to make real-time decisions. Application-based real-time data analysis can be done on a weekly or monthly basis to observe patterns in analyzing the reasons for taking appropriate action [25]. This real-time analysis saves energy in real-time.

IV. REQUIREMENTS FOR MASS IOT AND APPLICATIONS

As data rates increase and communication between devices improves, many IoT applications will be implemented, leading to the creation of large-scale IoT networks. The scale of the mass Internet of Things will be billions of cars, vehicles, sensors connected to the Internet [26]. We list some requirements for mass applications of IoT in Table 3.

Massive IoT supports many new applications such as autonomous driving, augmented reality gaming, predictive maintenance of machines, automated surgery systems and smart grids. In terms of communication requirements, mass IoT requires extreme reliability of 99.99999 %. This is especially necessary for critical tasks where human safety is at stake, such as safe driving and health- related operations. Moreover, these large IoT networks can provide sub-1ms latencies. This is necessary to deliver timely information so that applications can make the right decisions.

TABLE III. PUBLIC REQUIREMENTS FOR IOT APPLICATIONS

App	• Autonomous driving; • Augmented and virtual reality based on "Gaming"; • Machine Based Prediction; • Automated medical operations
Reliability (Package Success Rate)	≥99.99999%
Delay	≤1ms
Data transfer speed	Up to 1Gbit/s
Wireless technology	Bluetooth Zigbee IEEE 802.11 Cellular V2V

Are many potential candidates for related wireless technologies This choice depends on the nature of the application as well as constraints such as communication distance, data rate, etc., as shown in Table 4. For example, if the communication is between two Internet sensors located next to each other (distance is less than 100 m), Zigbee or Bluetooth can be used. For energy sensitive applications, Zigbee or Bluetooth Low Energy (BLE: Bluetooth Low Energy) may be good choices. For applications that require connectivity over a distance of approximately 100 m, IEEE 802.11 technology can be used to meet these requirements. Similarly, if the desired sensor connection range is high (more than 300 m), 6G communication is the most suitable option. Similarly, V2X (vehicular networks) or IEEE 802.11p cellular communication standards for applications such as automotive networks are provided by various working groups, industry manufacturers, and government organizations. Issue 17 of the 3rd Generation (3GPP) Partnership Project contains the latest standards related to 5G communications.

TABLE IV. SELECTION OF WIRELESS TECHNOLOGIES BASED ON APPLICATION REQUIREMENTS

Communication range (m)	Bitrate (bit/s)	Wireless technology
100	250k	ZifBee
60	1M	BLE
100	54M	IEEE 802.11
100-1000	1T	6G
100-500	10G	Cellular V2V

Efficient allocation of resources is important for reliable data exchange between nodes and servers of the Internet. As the spectrum resource is limited due to the large amount of data generated by IoT nodes, it is important to offer smart ways to use the spectrum. Techniques such as cognitive spectrum management can be used to share spectrum lines with multiple nodes in the Internet. Transpin power is also an important resource that must be carefully distributed. In order to save the energy of Internet nodes, adaptive energy transfer methods are required so that they can be active for a long time without charging.

Fog computing is one of the important parts of future Internet networks. Fog nodes located next to Internet of things provide the storage and computing power of the Internet. The Internet of Things network can cache popular and useful content on these Fog nodes. Therefore, cache allocation is one of the important tasks. In addition, Internet of Things nodes cannot perform all tasks locally and thus overload many tasks on these fog nodes. For this reason, optimal offloading algorithms are required to ensure efficient use of fog nodes' computing resources [27].

Latency management is another important element of reliable data transmission in IoT. IoT applications will perform poorly if data exchange does not occur with the required latency. Many new applications, such as autonomous driving and industrial automation, place strong demands on latency. For this reason, delay management is required. Intelligent retransmissions can add diversity and increase the probability of fast packet reception at the receiver. In addition, optimal environment access methods should be developed to ensure fast and fair channel access to IoT nodes [28].

Accurate forecasting of data traffic can support latency management techniques such as knowing upcoming traffic on the Internet server, and fog nodes can better manage it. That's why artificial intelligence (AI) methods that estimate the frequency and volume of data can be very effective. In addition, other network technologies can support the IoT network for fast data transfer. Similarly, the Unmanned Aerial Vehicle (UAV) and automotive network can act as relays for data traffic generated by IoT nodes [29].

Outage probability is another useful metric for resource allocation, as it indicates the distance the transmitter and receiver are out of range. As a result, the node can choose the optimal transmission power and modulation scheme based on IoT application requirements [30]. A higher transmission power increases the transmission range and thus reduces channel noise. On the other hand, a low modulation period reduces the data transmission rate, but increases the transmission range (Table 5).

TABLE V. RELIABILITY METRICS USED FOR THE INTERNET

Reliability indicators	The main idea of indicators	Application
Package delivery speed	Percentage of packets received successfully	IoT resource allocation
Possibility of deletion	The receiver is out of range of the transmitter	IoT resource allocation
Channel occupancy rate	Channel load measurement in the network	IoT resource allocation
Package arrival time	The time difference between two consecutive packets at the receiver	IoT latency management Transport networks
End-to-end latency	Total time to receive the package	IoT latency management
Reliability range	Communication range over which packets are received with probability Gr	Transport networks
Security awareness range	Transport security and message reliability for reliable range detection	Transport networks
Signature verification delay	Total time required to verify message signature	IoT security

Is another metric that calculates the time difference between two consecutive packets at the receiver. Many IoT applications require a certain time limit between receiving packets so that data transmitted by Internet sensors does not expire. Variable packet reception times can cause unnecessary delays in transmitting sensor measurement results to the server. This reduces the accuracy of program data analysis. The end-to-end delay of a packet is an important measurement that tells how much delay is needed to transmit a packet. As discussed above, high end- to -end latency can be caused by poor channel conditions, network overload, or ineffective redundancy. Latency management techniques can be evaluated based on the end- to -end latency metric.

V. CONCLUSION

Energy is an important source of life, and its presence in nature is not enough. Many technologies have been developed and are still being developed to save energy. Initially, IoT was recognized as a way to save energy. This is also proven by its energy efficient applications. However, its energy consumption is very high and will increase in the future with the increasing number of Internet of Things applications. Power diffusion is essentially a process that depends on how the components at each stage of the Internet work and interact with other components. In the future, we should try to develop more energy-efficient solutions for IoT-based applications. The solutions discussed in this section can be integrated into IoT -based applications to save energy. Subsequently, any prototype of Internet applications is developed, and the proposed energy-saving solutions to achieve energy savings are included in this program.

REFERENCES

[1] K. E. Khujamatov, D. T. Khasanov and E. N. Reypnazarov, "Modeling and Research of Automatic Sun Tracking System on the bases of IoT and Arduino UNO," 2019 International Conference on Information Science and Communications Technologies (ICISCT), 2019, pp. 1-5, doi: 10.1109/ICISCT47635.2019.9011913.

[2] A. Kabulov, I. Saymanov, I. Yarashov and F. Muxammadiev, "Algorithmic method of security of the Internet of Things based on steganographic coding," 2021 IEEE International IOT, Electronics and Mechatronics Conference (IEMTRONICS), 2021, pp. 1-5, doi: 10.1109/IEMTRONICS52119.2021.9422588.

[3] A. Muradova and K. Khujamatov, "Results of Calculations of Parameters of Reliability of Restored Devices of the Multiservice Communication Network," 2019 International Conference on Information Science and Communications Technologies (ICISCT), 2019, pp. 1-4, doi: 10.1109/ICISCT47635.2019.9011932.

[4] K. E. Khujamatov, D. T. Khasanov and E. N. Reypnazarov, "Research and Modelling Adaptive Management of Hybrid Power Supply Systems for Object Telecommunications based on IoT," 2019 International Conference on Information Science and Communications Technologies (ICISCT), 2019, pp. 1-5, doi: 10.1109/ICISCT47635.2019.9011831.

[5] I. K. Siddikov, K. A. Sattarov and K. E. Khujamatov, "Modeling of the transformation elements of power sources control," 2017 International Conference on Information Science and Communications Technologies (ICISCT), 2017, pp. 1-5, doi: 10.1109/ICISCT.2017.8188581.

[6] Khujamatov, H., Reypnazarov, E., Khasanov, D., Akhmedov, N. (2021). IoT, IIoT, and Cyber-Physical Systems Integration. In: Singh, K.K., Nayyar, A., Tanwar, S., Abouhawwash, M. (eds) Emergence of Cyber Physical System and IoT in Smart Automation and Robotics. Advances in Science, Technology & Innovation. Springer, Cham. https://doi.org/10.1007/978-3-030-66222-6_3

[7] S. Arsheen, A. Wahid, K. Ahmad and K. Khalim, "Flying Ad hoc Network Expedited by DTN Scenario: Reliable and Cost-effective MAC Protocols Perspective," 2020 IEEE 14th International Conference on Application of Information and Communication Technologies (AICT), 2020, pp. 1-6, doi: 10.1109/AICT50176.2020.9368575.

[8] A. Kabulov, E. Urunboev and I. Saymanov, "Object recognition method based on logical correcting functions," 2020 International Conference on Information Science and Communications Technologies (ICISCT), 2020, pp. 1-4, doi: 10.1109/ICISCT50599.2020.9351473.

[9] D. Khasanov, K. Khujamatov, B. Fayzullaev and E. Reypnazarov, "WSN-based Monitoring Systems for the Solar Power Stations of Telecommunication Devices", IIUM Engineering Journal, vol. 22, no. 2, pp. 98118, 2021.

[10] Tanwar, S., Khujamatov, H., Turumbetov, B., Reypnazarov, E., Allamuratova, Z. Designing and Calculating Bandwidth of the LTE Network for Rural Areas. International Journal on Advanced Science, Engineering and Information Technologythis link is disabled, 2022, 12(2), pp. 437–445

[11] Kabulov, A & Normatov, I & Karimov, A. (2020). Algorithmization control of complex systems based on functioning tables. Journal of Physics: Conference Series. 1441. 012141. 10.1088/1742-6596/1441/1/012141.

[12] K. Khujamatov, A. Lazarev, N. Akhmedov, E. Reypnazarov and A. Bekturdiev, "Methods for Automatic Identification of Vehicles in the its System," 2021 International Conference on Information Science and Communications Technologies (ICISCT), 2021, pp. 1-5, doi: 10.1109/ICISCT52966.2021.9670123.

[13] I. Siddikov, D. Khasanov, H. Khujamatov and E. Reypnazarov, "Communication Architecture of Solar Energy Monitoring Systems for Telecommunication Objects," 2021 International Conference on Information Science and Communications Technologies (ICISCT), 2021, pp. 01-05, doi: 10.1109/ICISCT52966.2021.9670354.

[14] Kabulov, A.V & Urunbaev, E. & Normatov, I. & Ashurov, A.. (2020). SYNTHESIS METHODS OF OPTIMAL DISCRETE CORRECTIVE FUNCTIONS. Advances in Mathematics: Scientific Journal. 9. 6467-6482. 10.37418/amsj.9.9.4.

[15] K.A. Bin Ahmad, H. Khujamatov, N. Akhmedov, M.Y. Bajuri, M.N. Ahmad, A. Ahmadian. Emerging trends and evolutions for Smart city healthcare systems. Sustain. Cities Soc. (May 2022), p. 103695, 10.1016/J.SCS.2022.103695

[16] H. Khujamatov, I. Siddikov, E. Reypnazarov and D. Khasanov, "Research of Probability-Time Characteristics of the Wireless Sensor Networks for Remote Monitoring Systems," 2021 International Conference on Information Science and Communications Technologies (ICISCT), 2021, pp. 1-6, doi: 10.1109/ICISCT52966.2021.9670122.

[17] I. Siddikov, K. Khujamatov, E. Reypnazarov and D. Khasanov, "CRN and 5G based IoT: Applications, Challenges and Opportunities," 2021 International Conference on Information Science and Communications Technologies (ICISCT), 2021, pp. 1-5, doi: 10.1109/ICISCT52966.2021.9670105.

[18] K. Khujamatov, A. Lazarev and N. Akhmedov, "Intelligent IoT Sensors: Types, Functions and Classification," 2021 International Conference on Information Science and Communications Technologies (ICISCT), 2021, pp. 01-06, doi: 10.1109/ICISCT52966.2021.9670340.

[19] Kabulov, A & Normatov, I. (2019). About problems of decoding and searching for the maximum upper zero of discrete monotone functions. Journal of Physics: Conference Series. 1260. 102006. 10.1088/1742-6596/1260/10/102006.

[20] Isroilov.J.D. Linearization spectral characteristics through passage by means of akusto-optical reconstructed filters // International Conference on Information Science and Communications Technologies ICISCT 2016, 2nd, 3rd and 4th of November 2016, Tashkent, Uzbekistan. DOI: 10.1109/ICISCT.2016.7777386.

[21] Pulatov.Sh.U, Aliev.U.T.Isroilov.J.D.. Energy harvesters wireless charging technology // International Conference on Information Science and Communications Technologies (ICISCT) Applications, Trends and Opportunities, 2nd, 3rd and 4th of November 2017, Tashkent, Uzbekistan. DOI: 10.1109/ICISCT.2017.8188566+

[22] Khujamatov, K., Akhmedov, N., Reypnazarov, E., Khasanov, D. Traditional vs. the blockchain-based architecture of 5G healthcare. Blockchain for 5G Healthcare Applications: Security and privacy solutions, 2022, pp. 131–167

[23] Davronbekov D.A., Isroilov.J.D. Akhmedov B.I. Principle of organizing database identification on mobile devices by IMEI // International Conference on Information Science and Communications

Technologies ICISCT 2019, Tashkent, Uzbekistan - 2019. DOI: 10.1109/ICISCT47635.2019.9012000.

[24] Siddikov, I., Khujamatov, K., Khasanov, D., Reypnazarov, E. (2021). IoT and Intelligent Wireless Sensor Network for Remote Monitoring Systems of Solar Power Stations. In: Aliev, R.A., Yusupbekov, N.R., Kacprzyk, J., Pedrycz, W., Sadikoglu, F.M. (eds) 11th World Conference "Intelligent System for Industrial Automation" (WCIS-2020). WCIS 2020. Advances in Intelligent Systems and Computing, vol 1323. Springer, Cham. https://doi.org/10.1007/978-3-030-68004-6_24

[25] S. I. Khakimovich, S. K. Abdishukurovich, D. O. Ravshanovich and K. K. Ergashevich, "Modeling of the processes in magnetic circuits of electromagnetic transdusers," 2016 International Conference on Information Science and Communications Technologies (ICISCT), 2016, pp. 1-3, doi: 10.1109/ICISCT.2016.7777393.

[26] K. E. Khujamatov and T. K. Toshtemirov, "Wireless sensor networks based Agriculture 4.0: challenges and apportions," 2020 International Conference on Information Science and Communications Technologies (ICISCT), 2020, pp. 1-5, doi: 10.1109/ICISCT50599.2020.9351411.

[27] Kabulov, A & Normatov, I & Ashurov, A. (2019). Computational methods of minimization of multiple functions. Journal of Physics: Conference Series. 1260. 102007. 10.1088/1742-6596/1260/10/102007.

[28] Kabulov, A & Normatov, I & Ashurov, A. (2019). Computational methods of minimization of multiple functions. Journal of Physics: Conference Series. 1260. 102007. 10.1088/1742-6596/1260/10/102007.

[29] I. Siddikov, K. Sattarov, K. Khujamatov, O. Dekhkonov and M. Agzamova, "Modeling of Magnetic Circuits of Electromagnetic Transducers of the Three-Phases Current," 2018 XIV International Scientific-Technical Conference on Actual Problems of Electronics Instrument Engineering (APEIE), 2018, pp. 419-422, doi: 10.1109/APEIE.2018.8545714.

[30] K. Khujamatov, E. Reypnazarov, N. Akhmedov and D. Khasanov, "IoT based Centralized Double Stage Education," 2020 International Conference on Information Science and Communications Technologies (ICISCT), 2020, pp. 1-5, doi: 10.1109/ICISCT50599.2020.9351410.