The Internet of Medical Things Application - Challenges and Future Directions

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***Abstract*—The Internet of Medical Things (IoMT) is about medical devices that collect process and transmit health information. IoMT devices can solve a wide range of medical problems, as their data help healthcare providers monitor key indicators in real-time, leading to accurate diagnosis and prevention or exacerbation of diseases. This makes it a perfect application in the world, improving care for people and making it available to a wider range of users. The advantages of the Internet of Medical Things (IoMT) and their promising future lead to their rapid entry into the form of services in our daily lives. Every place becomes a centre of care, not just between the four walls of a healthcare facility. This means that care is available whenever it is needed. Also with the help of the Internet of Medical Things, software applications based on augmented reality can be developed to work under Android, to train medical students and surgical staff. A close-to-real environment and intelligent tools' operation can be modeled. The Internet of Medical Things enables more accurate diagnoses, fewer errors, and lower costs of care. This technology with the help of applications for portable devices allows patients to send their health information to doctors for proper monitoring of their diseases. And also reliable monitoring of patients' vital signs in minimally invasive surgery. One of the main applications of IoMT is to improve healthcare in remote areas. The goal of this paper is the development of a new class of IoMT, which will meet the modern needs of Bulgarian healthcare in remote settlements. That is why the work considered the architecture and classification, the application, pros, and cons of the Internet of Medical Things, reveals the main challenges facing this field, and outlines the directions for its development.**

Keywords—IoT, IoMT healthcare, IT Medical device, Mechatronics

I. INTRODUCTION

The Internet of Medical Things (IoMT) is about medical devices that collect, process, and transmit health information [1, 2]. IoMT devices can solve a wide range of medical problems, as their data help healthcare providers monitor key indicators in real-time, leading to accurate diagnosis and prevention or exacerbation of diseases. This makes it a perfect application in the world, improving care for people and making it available to a wider range of users.

The advantages of the Internet of Medical Things (IoMT) and their promising future lead to their rapid entry into the form of services in our daily lives.

Health care and modern technologies occupy a key role in people's daily lives - Based on the advantages provided by IoMT, health care includes these services in its daily activities. One estimate mentions that 60% of global health organizations are already making attempts to use IoMT [3]. Despite the rapid and widespread spread of IoMT, there is no shortage of challenges related to its implementation, data management, and construction [4].

These technologies are effectively and efficiently changing the healthcare sector towards better patient care and management. The future of healthcare is inextricably linked to digital technology and real-time data management. In recent years, technologies related to individual patient monitoring, diagnosis, treatment, and rehabilitation have been advancing quite rapidly.

As the health problems of the population are progressively increasing, this leads to a search for solutions and an imperative to develop an intelligent health monitoring system. In the hectic everyday life, people do not have time to visit hospitals. This affects the state of health and aggravates diseases. To improve the health status, an intelligent healthcare monitoring system should be installed An intelligent system sends an alert to the respective hospital or the respective patient about the patient's health status.

The intelligent health system (Figure 1) monitors the patient's temperature, blood pressure, and heart rate. If there is a change in these parameters, the warning is a short message (SMS) that is sent to the patient's caregiver or doctors.

The Internet of Things (IoT) is emerging for an efficient, intelligent healthcare system. Overall, IoT is an effective and promising technology IoT consists of a set of devices such as sensors, computing devices, and storage devices that operate based on the data collected by the sensors, and the data is stored in the form of a database The stored database in IoT can be accessed and controlled anywhere at any time through internet technology.

Figure 1 shows a block diagram of an intelligent healthcare system.

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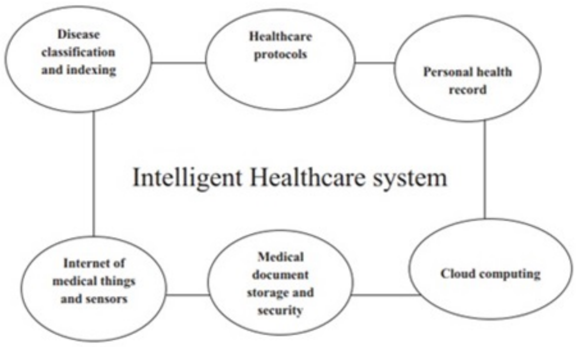

Fig. 1. Block diagram of an intelligent health system [5].

The intelligent health system (Figure 2) monitors the patient's parameters through various wireless diagnostic devices. If there are some deviations in their values, a message (SMS) is sent, and information about the patient's health status is transferred to the caregiver, doctors, hospitals, or other healthcare institutions. It is accumulated and stored in the electronic medical records of patients [5].

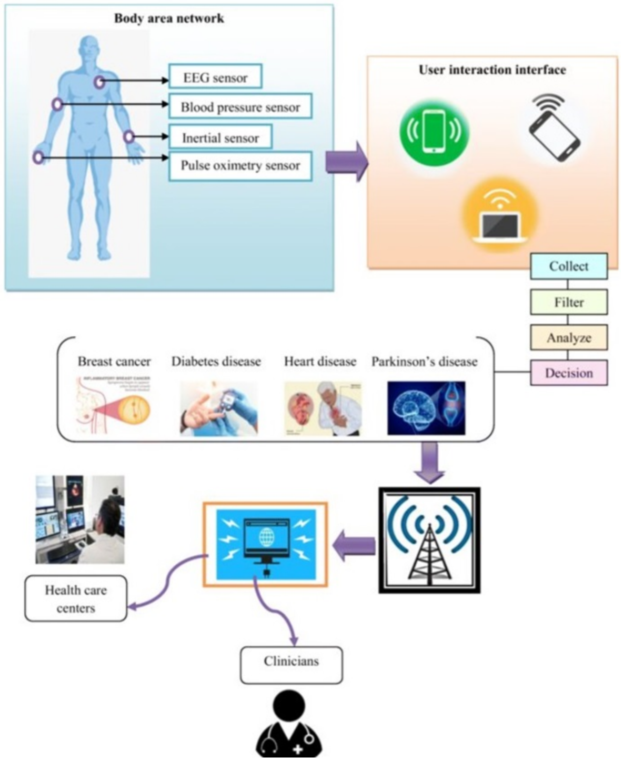

Fig. 2. An IoMT-enabled healthcare monitoring system in terms of data collection [6].

The development of Telecommunications, IoMT, and smart body sensors, change people's lives beyond recognition and ensure their better health care. IoMT holds in its hands a powerful weapon in the field of the health industry, linking its potential with caregivers, health service providers, mobile sensors with software, ICT, and, last but not least, patient care. The healthcare industry is expanding its market, placing huge demands on the techniques and services that are offered. According to the level of technical development, the healthcare system must be developed based on the decision-making capacity. One of the issues to be solved is related to the inclusion of cognitive behavior in IoMT devices. For this purpose, data must be collected from these devices, and then submitted for further processing. Preprocessing is performed to remove corrupted data and noise from it. Data conversion into computerized data is accomplished using reliable, wired, or wireless network communications that serve as a higher-performance transport medium. Next comes collection and feature extraction from the data. Finally, classification, analysis, and obtaining results related to the patient's disease.[6].

There are a lot of pros and cons of IoMT, but future directions of Medicine and healthcare are related to IoMT here's why The goal of this paper is the development of a new class of IoMT, which will meet the modern needs of Bulgarian healthcare in remote settlements. That is why the work considered the application, pros, and cons of the Internet of Medical Things, reveals the main challenges facing this field, and outlines the directions for its development.

II. Architecture and Classification, Applications, and Pros and cons of the Internet of Medical Things

There are two types of IoMT applications – focused on the clinical outcomes of IoMT and those that are related to the technology of IoMT.

An IoMT architecture may consist of various components and services [7]. Figure 3 shows IoMT as a part of the IoT.

IoMT classification based on site of use (body-oriented IoMT, hospital-based, healthcare office-related IoMT and ubiquitous IoMT).

According to the application (cardiovascular, renal, pulmonary, endocrine, medicinal, and others).

According to the results (IoMT for fitness only, IoMT for clinical assessment and observation, and remote monitoring of patients IoMT).

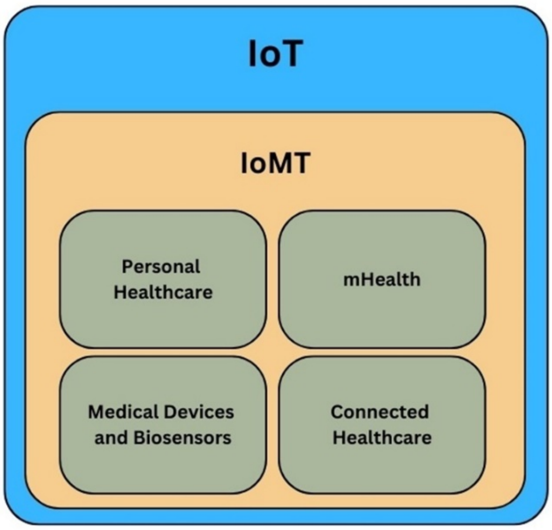

Fig. 3. IoMT as a part of IoT.

IoMT includes the following devices:

- **IoT sensors** Advances in microelectromechanical systems (MEMS) and sensor technologies have led to the development of a wide range of medical sensors serving the human body. Data sources such as health monitoring devices and mobile devices use a wide range of sensors such as infrared sensors, medical sensors, radio frequency identification (RFID) cameras, and sensors that are included at the perception level, which is the lowest layer of the IoMT (GPS). Sensing systems detect changes in their surroundings, identify objects, locations, demographics, and magnitudes, and then convert those data into computerized data using reliable, wired or wireless network communications that serve as a higher-performance transport medium

A pulse oximeter, electrocardiogram, thermometer, fluid level sensor, and blood pressure devices also find a place here.

- **Temperature Sensors**

Some of the temperature sensors are shown in Figure 4.

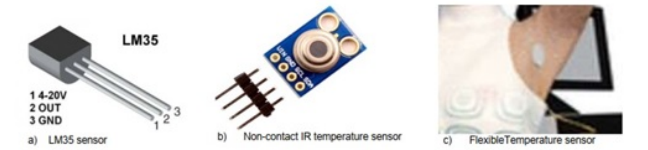

Fig. 4. Temperature sensors [8].

The DS18B20 [9, 10] is a commonly used temperature sensor. For determining a patient's body temperature a wearable patient monitoring device. That is shown in Figure 5.

Fig. 5. Temperature sensors DS18B20 [9].

MAX30205 Temperature sensors accurately read temperature and signal overtemperature. The MAX30205 is suitable for wearable devices due to its high precision and low operating voltage. Since it is digital, it can be easily integrated into any system.

Sensors can be both wearable [11] and implanted sensors [12]. Here we can also talk about a revolutionary change that these devices bring to fitness and individual patient care. The use of radio frequency identification in these IoMTs is also being developed.[13]:

- **IoT Gateway** provides connectivity to IoMT devices and services, and integrates, modulates, and controls connected sensors.[14] In addition to the conventional cloud computing system, fog computing infrastructure is also gaining popularity among healthcare IoT providers.[15] Because the sensors need communication with the gateway to function properly. This connectivity must be created using networks to share and maintain centralized information. Transmission takes place over a wide range and can have a very short or relatively long range. Examples of short-range communication include radio frequency identification (RFID), Zigbee, and Wireless Fidelity. Examples of a wide range of communication include cloud computing, blockchain technology, and so on. Some types of Gateway are listed. Fig 4.

- **Zigbee**

Zigbee enables seamless transfer of integrated data between medical devices. It ensures the dissemination of information even when some of the devices are not functioning properly. The frequency range of Zigbee is comparable to that of Bluetooth (2.4 GHz), but the communication range is significantly greater. Consisting of routers, end nodes, and a processing center, it enables data aggregation and analysis. Zigbee has low power consumption, high transfer rate, and network capacity.

This is a wireless local area network (WLAN) with a longer transmission range. It is a popular gateway mode used in hospitals due to the fast and efficient construction of the network capacity, increased compatibility with smartphones, and the provision of tight control and security. The disadvantages are related to significantly higher energy consumption and network instability.

• Machine Learning: This includes applied computing and computational methodologies that enable predictive algorithms and data execution[16]. The application of machine learning to medical data is transforming patient risk stratification, especially in infectious diseases[17].

• User Management: The Services may allow restriction and grouping of users. In general, time-based and event-driven architectures are good solutions for passing processing information to the IoMT.

Event-driven processes involve sensors transmitting data when the sensor is appropriately stimulated [18]. In the time-based architecture, it sends signals at the specified time interval [19]. It can send requests to the end device or sensor and collect the required data regularly at certain time intervals [20].

At the beginning of the IoMT services are the sensors included in this process, which collect and send data via the Internet to the cloud system. There, this information is analyzed and interpreted, and the results obtained are classified and communicated to the doctor and the patient with an application platform or directly in the form of a unified display setting in a product infrastructure environment (Figure 2).

Generally, Application Constrained Protocol, Message Queuing Telemetry Transport, Extensible Message and Presence Protocol, and Extended Message Queuing Protocol are used to send data from IoT sensors to servers [16].

Pross and Coss

A significant improvement has been made to the healthcare system as a result of the development of remote health monitoring, smart devices, telemedicine, wearable ozone treatment devices, and sensor patches. These innovations ensure better disease prevention through testing, early identification, and treatment. IoMT enables real-time data to be displayed to doctors about a patient's condition. The future of IoMT or smart hospitals is what humanity needs, but for them to exist and develop, a serious industry standardization policy is also needed for effective implementation.

There are many benefits of IoMT in the healthcare industry, including:

• Remote patient monitoring: IoMT enables patient consultation and monitoring remotely, thus reducing the frequency of hospital visits;

• Reduced healthcare costs: by reducing the frequency of hospital visits and using smart healthcare systems, IoMT reduces overall healthcare costs;

• Continuous monitoring of patients with chronic diseases: IoMT enables continuous monitoring of patients with chronic diseases both in hospitals and remotely. Instead of annual preventive examinations, continuous monitoring allows healthcare providers to collect up-to-date information on vital health indicators. Facilitates effective communication between patients and healthcare providers as they can discuss and address concerns based on real-time data;

• Personal Emergency Response Services (PERS): PERS can significantly reduce emergency response times. Immediate communication with the monitoring center ensures that appropriate help is dispatched immediately, minimizing the impact of injuries, complications, and adverse health effects. Rapid intervention is especially critical in cases such as heart attacks, strokes, and accidents where every second counts.

Challenges to the effective implementation of IoMT are interoperability, insufficient data privacy provisions, security, and costs associated with the use of outdated infrastructure. Provided that steady technological improvement and effective implementation are ensured, successful implementation of IoMT can be ensured. It should also be noted that IoT implementation costs are quite high and many applications are still experimental. At the same time, investments in the medical Internet of Things can bring a quick return if well calculated.

In recent years, several deficiencies in the healthcare sector related to the medical infrastructure have been manifested. Solving problems related to automation, remote monitoring of patients and virtual hospital environments is a challenge.

IoMT Security and Privacy

Security and privacy issues are some of the biggest challenges facing Internet of Things (IoT) systems. Currently, before Current IoMT devices are vulnerable to exploitation due to inadequate verification and outdated technology. In recent years, the IoMT has been at the forefront of cyber attacks. A significant number of healthcare companies using IoT have reported security issues and vulnerability to cyber-attacks. A solution can be a smart card controlled by the user himself with a single login to the system.

III THE MAIN CHALLENGES FACING THE INTERNET OF MEDICAL THINGS AREA

Despite the widespread use of sensors, not all health parameters can be detected, reported, and monitored. Some authors observe parameters that cannot be accounted for by IoMT.[21] as well as liver function readings, thyroid function tests, screening for sepsis, and infections such as malaria and tuberculosis. Despite advances in modern technology, parameters for individual patients cannot be measured and monitored - Lack of sufficient sensitivity of IoMT devices cannot perceive human moods related to the psychological state of patients such as depression, anger, hallucinations, hypotension, and similar neurological manifestations.

There are medical devices that must be convincingly proven to have better performance than conventional methods available in clinical practice - as shown in Figure 6. Such medical devices are ECG, remote temperature reading, urine output, and fluid balance, and need further testing before they can be widely adopted in clinical practice.

Fig. 6. Conventional methods available in clinical practice for measuring and monitoring vital signs [8].

IoMT devices generate a huge amount of data in various formats, data compilation and interoperability are critical. IoMT devices depend on the network to exchange data. The use of fog and edge computing reduces network traffic and leads to efficient use of resources overcoming bandwidth limitations [22].

Healthcare data is important and confidential information about the patient and his health condition. Confidentiality and security of health data are not only important from an ethical point of view but also important regarding data theft. Data theft, manipulation, and malicious data lead to significant financial losses and emotional harm. There is a need to improve the privacy and security of health data, which can be accomplished with well-designed access control, physical device security, security awareness, encrypted data transfer over HTTPS, firewalls, ingress/egress filtering structures, and Internet Protocol security.

IV FUTURE DIRECTIONS OF IOMT AND INTENTION FOR OUR FUTURE WORK

Increased investment by tech giants is increasing interest in the healthcare industry. Many startups are targeting the IoMT sector to grow their business. One of the future directions is the use of ultra-low power electromagnetic waves in the early detection of breast cancer. In addition, biosensors are capable of detecting certain viral infections, including the Ebola virus, Coronavirus, and others, and can bring a big change in managing pandemics.

The use of an extracellular matrix-based, composite, and stimuli-responsive material changes the way tissue 3D bioprinting was previously perceived.

Using NASA's intelligent probe neural networks and multiple microsensors helps distinguish between normal cells and cancer cells. This will change the detection of a normal margin during tumor resection, leading to a reduction in recurrences. The use of electromagnetic acoustic techniques has revolutionized blood flowmetry, thermometry, and dosimetry during cancer radiotherapy, measuring blood oxygen saturation pressure.

Perfluorocarbon nanoparticles (NPs), cerium oxide NPs, and platinum NPs cross the blood-brain barrier and can be successfully applied in the diagnosis and treatment of stroke:

IoMTs have improved efficiency, a result of embedded sensors and technology in smart devices, whose results are accurate and take less time. Human error in management and data processing is reduced. With the help of smarter technology. IoMT and automation can save a significant amount of money in healthcare every year.

Our team has experience in developing IoMT elements such as electronic records and ECG devices, which can also be used as a means of controlling access to patient data [23, 24]. Possibilities are being explored to develop an electronic thermometer based on the DS18B20, the use of which we again have experience in temperature measurement. We also have experience in the application of unified modelling languages in the design of laparoscopic delivery instruments [25], which will be beneficial in the design of other IoMT devices as well.

With the help of the Internet of Medical Things, software applications based on augmented reality can be developed to run on Android, to train medical students and surgical staff. Within this direction of the task, various studies will be conducted to model the operation of an intelligent instrument for the study of biological tissues, in an environment close to the real one, for the needs of minimally invasive surgery. As part of the research, a diagnostic device was designed to monitor the ECG of patients during surgery. The results obtained by the device will be able to be monitored remotely using the control program on a computer (Local Operator Station) and/or directly from a display of the instrument directly connected to the patient. It is planned to use innovative solutions related to the construction and connection of the ECG device with an existing robotic laparoscopic execution tool. The device can also be used as a means of controlling access to the information contained in the patient database.

Expected results: Development of software tools for simulating the response of biological tissue during interaction with tactile tools for training medical students and surgical staff in minimally invasive surgery with the application of the Internet of Medical Things and augmented reality; Training methodology based on the developed simulation environment; Designing diagnostic instruments to an existing robotic laparoscopic delivery tool to monitor patient vital signs (ECG, abdominal CO2, pulse, etc.) during surgery.

In addition to everything listed above, it is necessary to carry out:

1. Designing a simulation environment using augmented reality to simulate the response of biological tissue during interaction with tactile tools.

2. Application of Medical Internet of Things and Augmented Reality in Designing Software Tools for Teaching Medical Students and Specialists in the Field of Minimally Invasive Surgery.

3. Software applications related to diagnostics and training of medical students and surgical personnel, and methodology for working with the designed diagnostic modules for monitoring important vital signs of patients.

V CONCLUSIONS

The Internet of Medical Things (IoMT) is about medical devices that collect, process, and transmit health information. IoMT devices can solve a wide range of medical problems, as their data help healthcare providers monitor key indicators in real-time, leading to accurate diagnosis and prevention or exacerbation of diseases With the Internet of Medical Things, it is possible to achieve a low rate of medication adherence, provide treatment control tools where none are available, perform out-of-clinical patient monitoring when there is a shortage of qualified specialists, perform analysis and predictive modeling of data. The goal of this paper is the development of a new class of IoMT, which will meet the modern needs of Bulgarian healthcare in remote settlements. That is why the work considered the architecture and classification, the application, pros, and cons of the Internet of Medical Things, reveals the main challenges facing this field, and outlines the directions for its development. The directions for the team's future work regarding IoMT are shown, mainly including the application of innovative solutions related to the construction and connection of an ECG device, a new type of thermometer, as well as the application of the Internet of Medical Things and augmented reality in the design of software means for training medical students and specialists in the field of minimally invasive surgery and Software applications related to the diagnosis and training of medical students and surgical personnel, and a methodology for working with the designed diagnostic modules for monitoring vital signs of patients.

REFERENCES

1. G. Joyia , R. Liaqat, A. Farooq, and S. Rehman, “Internet of Medical Things (IOMT): Applications, benefits and future challenges in healthcare domain”, J Commun, Vol. 12:, pp. 240-247, 2017.
2. M. J. Sudha, and S. Viveka, “A Comprehensive Review of Architecture, Classification, Challenges, and Future of the Internet of Medical Things (IoMTs)”, Medical Journal of Babylon, Vol. 19 (3), pp. 311-317, 2022, DOI: 10.4103/MJBL.MJBL_5_22
3. Internet of Medical Things (IoMT): A New Era of Healthcare, 2019-2023, https://www.techsciresearch.com/blog/internet-of-medical-things-a-new-era-of-healthcare/284.html (last visited 05.10.2024)
4. F. Al-Turjman, M.H. Nawaz, and U.D. Ulusar, “Intelligence in the Internet of Medical Things era: A systematic review of current and future trends”, Computer Communications, Vol. 150, pp. 644-660, 2020, DOI: https://doi.org/10.1016/j.comcom.2019.12.030
5. M. Mehta, K. Passi, I.Chatterjee, and R. Patel, “Knowledge Modelling and Big Data Analytics in Healthcare: Advances and Applications” , Book, CRC Press, pp. 1-79, 2022, DOI: 10.1201/9781003142751
6. MD. Mobin Akhtar, Raid Saleh Ali Shatat, Abdallah Saleh Ali Shatat, Shabi Alam Hameed and Sakher (M.A) Ibrahim Alnajdawi, “IoMT-based smart healthcare monitoring system using adaptive wavelet entropy deep feature fusion and improved RNN”, Multimedia Tools and Applications, Vol. 82(22), pp. 17353–17390, 2023, DOI: 10.1007/s11042-022-13934-5
7. R. Hassan, F. Qamar, M.K. Hasan , A.H.M. Aman , and A. S. Ahmed, “Internet of Things and its applications: A comprehensive survey”, Symmetry, Vol. 12, No. 1674, pp. 1-29, 2020, DOI: 10.3390/sym12101674
8. M. K. Hazilah, Mohd Azri Mohd Izhar, Rudzidatul Akmam Dziyaudin, Nur Ezzati Shaiful, Robiah Ahmad, “A Comprehensive Review on Wireless Healthcare Monitoring: System Components”, IEEE Access, Vol. 12, IEEE Xplore, pp. 35008 – 35032, 2024, DOI: 10.1109/ACCESS.2024.3349547
9. R. Saha, S. Biswas, S. Sarmah, S. Karmakar, and P. Das, "A Working Prototype Using DS18B20 Temperature Sensor and Arduino for Health Monitoring”, SN Computer Science, Vol. 2, No. 33, pp. 1-21, 2021, DOI: https://doi.org/10.1007/s42979-020-00434-2
10. Maxim Integrated Products, Inc, “DS18B20, Programmable Resolution 1-Wire Digital Thermometer”, Data Sheet, pp. 1-20, 2015, www.maximintegrated.com (last visited 05.10.2024)
11. S. Yao, P. Swetha, and Y. Zhu, “Nanomaterial-enabled wearable sensors for healthcare”, Advanced Healthcare Materials, Vol. 7(1):1700889, pp. 1-27, 2018, DOI: https://doi.org/10.1002/adhm.201700889
12. T. Wu, J. M. Redouté, and M. R. Yuce, “A wireless implantable sensor design with subcutaneous energy harvesting for long-term IoT healthcare applications”, IEEE Access Vol. 6, pp. 35801-35808, 2018, DOI: 10.1109/ACCESS.2018.2851940
13. S. Amendola, R. Lodato, S. Manzari, C. Occhiuzzi, and G. Marrocco, “RFID technology for IoT-based personal healthcare in smart spaces”, IEEE Internet of Things Journal, Vol. 1(2), pp. 144-152, 2014, DOI: 10.1109/JIOT.2014.2313981

14. T. Sigwele, Y. F. Hu, M. Ali, J. Hou, M. Susanto, and H. Fitriawan, “Intelligent and energy efficient mobile smartphone gateway for healthcare smart devices based on 5G”, IEEE Xplore, [In: 2018 IEEE Global Communications Conference (GLOBECOM). Abu Dhabi, UAE, December 2018. pp. 1-7], DOI: 10.1109/GLOCOM.2018.8648031

15. O. Akrivopoulos, I. Chatzigiannakis, C. Tselios, and A. Antoniou, “On the deployment of healthcare applications over fog computing infrastructure”, IEEE Xplore, [In: 2017 IEEE 41st Annual Computer Software and Applications Conference Workshops (COMPSAC). Italy, July 2017. pp. 288-93], DOI: 10.1109/COMPSAC.2017.178.

16. M. A. Ahmad, C. Eckert, A. Teredesai, “Interpretable machine learning in healthcare”, BCB '18: Proceedings of the 2018 ACM International Conference on Bioinformatics, Computational Biology, and Health Informatics. New York, NY, USA: Association for Computing Machinery; pp. 559-560, 2018, DOI: https://doi.org/10.1145/3233547.3233667.

17. J. Wiens, and E. S. Shenoy, “Machine learning for healthcare: On the verge of a major shift in healthcare epidemiology”, Clinical Infectious Diseases, Vol. 66(1), pp. 149–153, 2018, DOI: https://doi.org/10.1093/cid/cix731

18. R. B. Almeida, V. R. C. Junes, R. da Silva Machado, D. Y. L. da Rosa, L. M. Donato, A. C. Yamin, and et al., “A distributed event-driven architectural model based on situational awareness applied on Internet of Things”, Information and Software Technology, Vol. 111, pp. 144-158, 2019, DOI: https://doi.org/10.1016/j.infsof.2019.04.001

19. P. J. Windley, “API Access Control with OAuth: Coordinating interactions with the Internet of Things”, IEEE Consumer Electronics Magazin, Vol. 4(3), pp. 52 – 58, 2015, DOI: 10.1109/MCE.2015.2421571

20. B. Hu, Z. H. Guan, G. Chen, and X. Shen, “A distributed hybrid event-time-driven scheme for optimization over sensor networks”, IEEE Transactions on Industrial Electronics, Vol. 66 (9), pp. 7199 – 7208, 2019, DOI: 10.1109/TIE.2018.2873517

21. S.Y.Y. Tun, S. Madanian, and D. Parry, “Clinical perspective on Internet of Things applications for care of the elderly”, Electronics 9(11), No. 1925; pp. 1-28, 2020, DOI: https://doi.org/10.3390/electronics9111925

22. V. Ivanova, A. Boneva, S. Ivanov, and P. Vasilev, “A Wireless Device to Modular Robotized Instrument for Health Information”, Computer Science & Engineering: An International Journal (CSEIJ), AIRCC Publishing Corporation, Vol. 13 (2), pp. 21-33, DOI:10.5121/cseij.2023.13203,

[24] Boneva, V. Ivanova, P. Vasilev, S. Ivanov, and T. Ivanova, “Big Data Processing for Bulgarian Healthcare - Smart Cards and Some Simulating Decisions”, IEEE Xplore, [Proceedings of the 8th IEEE International Conference “Big Data, Knowledge and Control Systems Engineering” (BdKCSE’2023), A hybrid conference, 02–03 November 2023, Sofia, Bulgaria], IEEE, 2023, pp. 1-8, DOI: 10.1109/BdKCSE59280.2023.10339733.

[25] V. Ivanova, A. Boneva, and P. Vasilev, “Unified Modeling Language Application for Laparoscopic Instrument Design”, International Journal of Bioautomation, Vol. 28(3), pp. 117-132, 2024, DOI:10.7546/ijba.2024.28.3.000968