Journal of Information Systems Engineering and Management
2024, 9(2)
e-ISSN: 2468-4376
https://www.jisem-journal.com/

Research Article

Systematic Review of Embedded IoT Healthcare Systems: Performance, Communication Efficiency, and Deployment Challenges in Resource-Constrained Medical Environments

Arunakumar Siddappa Bhosale[1], Dr. Vijayalaxmi Biradar[2]

[1]Research Scholar, Department of Electronics Engineering, Kalinga University, Raipur, Chhattisgarh.

[2]Associate Professor, Department of Electronics Engineering, Kalinga University, Raipur, Chhattisgarh.

Email: sbarunkr@gmail.com

ARTICLE INFO

Received: 03 March 2024

Revised: 18 June 2024

Accepted:26 June 2024

ABSTRACT

This paper presents a systematic and engineering-focused review of IoT-enabled medical devices and their role in transforming modern healthcare systems. Advancements in embedded electronics, biosensors, and wireless communications are rapidly progressing, creating solutions for continuous health monitoring, real-time diagnosis, and remote patient management. However, there are still many challenges related to communication reliability, efficiency of embedded systems, and large-scale deployment of embedded systems, particularly in low resource settings. In order to understand how to design, communicate, and deploy embedded systems in IoT healthcare settings, a systematic literature review (SLR) methodology was adopted to analyze selected open-access research papers that pertain to these three domains: (1) performance of embedded systems, (2) communication protocols, and (3) deployment issues. The end result of this review of literature is to organize the findings from each of these three categories of literature into a series of thematic areas or constructs in order to provide a structured engineering perspective to the engineering community. This paper proves that optimizing the use of embedded systems (low-power design, multi-sensor integration) is key to achieving high power efficiency in devices; communication technology (i.e. BLE, Zigbee, Wi-Fi) plays a role in the overall responsiveness of the system by introducing latency and bandwidth as constraining factors; the introduction of edge computing has the effect of enhancing real-time performance through localized processing of data; and the scaling potential for deployment is limited by infrastructure constraints, cost barriers and/or lack of interoperability. The paper concludes that while the potential of IoT healthcare systems is evident, they cannot be effectively implemented without solving the engineering issues related to embedded systems design, communication efficiency, deployment scalability.

Keywords: IoT Healthcare, Embedded Systems, Edge Computing, Wireless Communication, Smart Medical Devices

1. Introduction

The swift advancement of IoT technology has largely impacted how we design medical engineering. There are now many interconnected medical systems that allow us to provide continuous monitoring; predictive diagnostics; and remote patient management. The use of IoT in medicine includes the integration of today's medical devices with embedded electronics, biosensors, and wireless communications so intelligent health care systems can acquire and process patient data in real time. As a result, access to health care is increased, as well as its overall efficiency, through remote patient monitoring rather than requiring patients to visit a doctor or hospital regularly (Dimitrov, 2016).

The growing prevalence of chronic illness as well as the need for continued monitoring of patients is one major benefit of utilizing IoT (Internet of Things) in medical care. Interconnected sensors and cloud-based systems allow for live monitoring of patient information, so that changes may be detected and treated before they become a serious issue. In the past, patients received care through traditional reactive methods, but these changes have made preventive and proactive patient care the norm (Banaee et al., 2013).

From the Electronics Engineering point of view, there are three key elements that contribute to the functionality of an IoT healthcare system: 1) the design of embedded systems, 2) the accuracy of the sensors, and 3) the reliability of the communication methods. A successful integration of these three components allows for a healthcare system that operates with optimal performance, has high energy efficiency, and can expand to meet the demands of a growing population. However, there remain many issues that need to addressed as they pertain to the optimization of the system, the interoperability of the system components, and the limitations of the infrastructure for large scale deployment of IoT healthcare systems particularly in developing areas.

The increasing number of healthcare IoT devices being used means there is an urgent need to assess how they perform as part of a larger system. Research to date has primarily focused on isolated parts of the system (e.g., sensor tech vs. connection tech), failing to take into account the entire system's performance at once.

The availability of literature that combines embedded electronics, communication effectiveness, and deployment feasibility into one coherent structure for IoT healthcare systems is limited. This gap in knowledge is especially impacting on areas where there are limited resources. Therefore, a systematic literature review (SLR) is needed to bring together what is known currently about how all the components relate to one another and contribute to the overall functioning of an IoT healthcare system (Moura et al., 2020).

IoT healthcare systems are rapidly evolving with many new developments that demonstrate a clear change toward more advanced, decentralized, intelligent health care solutions. One of the fastest growing trends is the proliferation of wearable and implantable biosensors, which provide continuous monitoring of physiological characteristics such as heart rate, blood pressure, and oxygen saturation levels. As companies continue to create small and energy-efficient biosensors, they will be easier and cheaper to use.

In addition to the rapid growth in size and cost of biosensor technologies, there has also been a dramatic increase in the number of Edge and Fog Computing technologies that can perform computing near the source of data collection instead of having to send it across the Internet. By processing data locally, these technologies reduce latency and provide instant responses to critical health care events or conditions. This is crucial for mission-critical health care services where immediate action is required.

The introduction of AI into IoT healthcare systems has further enhanced the ability to analyze data using predictive diagnostics and automated decision-making processes. Additionally, there is an increasing emphasis on implementing secure and private architectures for storing sensitive medical records. Finally, the increased use of Telemedicine Platforms has helped further expand the adoption of IoT technologies globally, particularly in rural and undeveloped areas (Kumar et al., 2019).

There are still many research gaps that still exist. One area where there is a lack of research is that there is no systematic reviews of previous research studies that have been done related to electronics performance-based aspects within embedded IoT healthcare studies. This means that there are not many helpful analyses done which look at power efficiency, hardware reliability and signal processing accuracy and for the second point regarding communications efficiency, there has been very limited analysis done of communications specifically on latency, bandwidth utilization and network reliability.

Comparative evaluations of the various types of deployments for different environments are not sufficiently analysed and there is currently no existing clear or coherent framework (using Systematic Literature Review) that could be used to incorporate all aspects of engineering into one common analytical framework. There are currently no Systematic Literature Reviews focused in the area of Electronics Engineering that review the performance of the embedded performance, communication efficiency and viability of deployment of IoT medical devices within resource-constrained health care systems. This absence of a comprehensive and integrated analysis creates a challenge in developing optimized and scalable solutions to healthcare.

This paper reviews existing literature on IoT-enabled medical devices from an Electronics Engineering perspective. The review focuses on three areas: performance of embedded systems; efficient communication; and deployment challenges. The goal is to synthesise and identify engineering limitations, new technology trends, and gaps in current research by providing a systematically structured, comprehensive discussion of previous research in these three areas in order to support the development of scalable, efficient and robust IoT healthcare systems for use in any healthcare environment.

A Systematic Literature Review (SLR) methodology has been used for this study to ensure a systematic, thorough evaluation of existing studies on the topics outlined above. The literature was searched via open access databases and journals (e.g. PubMed Central, MDPI, and other free access resources) using inclusion criteria that focused on finding literature related to IoT healthcare systems (embedded electronics, communication technologies, and edge computing). Studies that were not directly related to the application of IoT in healthcare, or which did not have an engineering focus, were excluded from the review.

Key information was obtained from the selected studies through data extraction by ascertaining author(s), date of publication, purpose of study, methodology, and key findings. Each of these studies was then grouped into thematic areas, such as design of embedded systems and communication efficiency, as well as deployment issues. Qualitative synthesis techniques were utilized to analyze and synthesize the information from each of the studies to provide a complete understanding of the topic.

2. Embedded System Performance In Iot Healthcare

Embedded Architecture Trends

The structure of the embedded systems is the technological backbone of IoT-enabled healthcare devices. It is one of the most significant architectural components impacting both the performance, scalability, and efficiency of systems used in healthcare monitoring applications.

Numerous reports indicate that IoT-enabled healthcare systems are gradually transitioning from a traditional architecture built on microcontrollers to a System-on-Chip (SoC) architecture. Microcontroller-based designs have been the primary components of many electronic devices due to their low cost, simple design, and minimal implementation costs associated with the basic healthcare monitoring applications. However, microcontrollers often cannot measure or monitor large amounts of real-time physiological data.

SoC architectures combine the processing units, communication interfaces, and memory components into one chip, increasing data processing speed and reducing the time it takes to communicate and integrate different parts of the system to create an efficient and unified system. As a result, the increased processing capabilities provided by SoC architecture will allow for the implementation of more advanced healthcare applications (e.g., multi-parameter monitors and real-time diagnostic systems). Another significant trend toward designing integrated multi-sensor platforms has come into play. The concept of multi-sensor platforms allows users to simultaneously monitor multiple physiological parameters (e.g., ECG, temperature, and oxygen saturation levels), which can improve the accuracy of established diagnostic procedures as well as the overall wellness of the individual receiving such monitoring services (Miorandi et al., 2012).

Hardware optimization techniques, including efficient circuit design and component integration, are also emphasized to improve processing efficiency and reduce system complexity.

Energy Efficiency and Device Performance

Efficient use of energy is one of the main obstacles that must be addressed within IoT health-care systems, especially batteries of the wearable or implantable types. Some of the low-power circuit design techniques that are commonly used include duty-cycle, dynamic voltage scaling, and sleep mode; all of which help reduce energy usage and, therefore, provide longer usable periods between charges or changes of a device's batteries (Pantelopoulos & Bourbakis, 2010).

As a result of the need for these compact devices to have small battery packs; the rechargeable capacity of the batteries is used very quickly due to the amount of time that the device is transmitting data wirelessly and/or operating continuous sensors. Thus, to counter this issue of reliability due to depleted sources of energy, there has been an increasing amount of research on energy-harvesting techniques, which can be defined as using bodily-generated heat or motion, or harvesting energy produced in one's environment to power these devices.

In addition to extending the life of the device, the design of an energy-efficient system also provides for increased performance of the overall system through the provision of continuous service for the device. Therefore, optimizing for the minimization of energy usage is critical to ensuring the scalability of, and practicality of, IoT health-care solutions.

Reliability and Hardware Constraints

In Internet of Things (IoT) applications within the field of healthcare, an ubiquitous need is reliability since any potential failure of a medical device running on IoT can have severe consequences for patients. Hence, fault-tolerance mechanisms (redundancy, error detection, self-recovery systems) are critically important components to guarantee continuous operation. Through these processes, devices can continue to function, regardless of whether there are hardware faults or failures in the communication path.

Another important consideration is environmental adaptability, as the majority of wearable devices are subject to different environmental conditions including temperature fluctuations, humidity changes, and physical movement. To ensure these devices remain accurate and stable while being operated under these conditions, careful planning in regard to hardware design, protective materials and adaptive calibration techniques is necessary.

One more challenge associated with continuous healthcare monitoring are the issues of sensor drift, signal noise, and data inconsistency over time of sensor data collected by the IoT medical device. Advanced signal processing methods along with more stable circuit performance will allow for sufficient long-term accuracy of the devices to provide sufficient data to create valid conclusions. Furthermore, for dependable operation, careful attention to thermal management and electromagnetic interference must be given (Alemdar & Ersoy 2010).

Taken together, the analysis of the SLR thematic analysis provides evidence that, although embedded system technologies are rapidly evolving, the technology-related barriers to scale include energy efficiency, reliability, and hardware limitations.

3. Communication And Deployment Challenges

The efficiency and reliability of IoT healthcare systems is largely dependent on how effectively communication protocols move data between devices, gateways and clouds. A systematic review of the literature documents that the principal communication protocols employed in the IoT healthcare domain are Bluetooth Low Energy (BLE), Zigbee and Wi-Fi.

BLE is often preferred when using wearable devices because of its relatively low power usage and fitness for short-range transfer of data. This allows continuous monitoring with minimal battery usage, making BLE an optimal protocol for battery-operated medical devices. Conversely, Zigbee is particularly appropriate for multi-device healthcare environments such as hospitals and assisted living facilities due to its ability to support mesh networking, low energy consumption and moderate data rates. In contrast, while Wi-Fi allows for much higher data rates than BLE and Zigbee, due to its comparatively high power consumption, the use of Wi-Fi in portable and wearable applications is very limited (Kumar et al., 2016).

The performance of any system is affected by latency and bandwidth. With a high latency rate, data may not be transmitted as quickly as desired, which is especially detrimental in real-time monitoring applications, for example, cardiac monitoring and emergency medicine applications. In addition, limited bandwidth will also restrict the system's ability to process large amounts of data at the same time from multiple sensors. Research has shown that optimizing communication protocols and implementing adaptive transmission techniques is crucial to providing quality and effective healthcare.

Edge Computing and Distributed Processing

Edge computing is becoming increasingly popular as a way to help solve the problems of communication between devices in an Internet of Things (IoT) based healthcare system. Rather than sending all the data to the cloud, with edge computing, we can process the data very close to where it was generated (at the "edge" of the network or right down at the device). This reduces latency, which helps improve responsiveness, which is critical in applications that require immediate response times for medical emergencies.

A distributed processing architecture, where data is processed at the edge or through gateways before being sent via the internet to the cloud for analysis, also provides benefits by using less bandwidth and reducing network traffic on the internet. Edge computing will allow us to filter out any redundant data and prioritize only the important information for transmission, thus improving system efficiency (Shi et al., 2016).

An additional benefit of edge computing is the enhanced reliability of a system where there is poor or unstable internet connectivity. When there is no link to the cloud or the link is lost, systems that include edge computing technology can continue to operate at the edge where they were made. For example, healthcare systems that operate outside of urban areas in rural locations would benefit from this technology.

Deployment Challenges in Healthcare Systems

Large-scale adoption of IoT for healthcare is still limited due to many challenges related to the implementation of these types of systems. One challenge is the lack of infrastructure, which presents a major barrier to deployment; especially in developing nations, reliable internet access is often lacking, making it impossible to deploy IoT devices effectively and thus diminishing system efficiency.

The cost of IoT devices, communication infrastructure and system integration also creates financial barriers to the adoption of IoT systems; the large upfront investments associated with IoT technologies often present a significant barrier to small healthcare providers being able to implement them. Additionally, the ongoing costs of maintaining and operating IoT systems further add to this financial strain.

Interoperability is another major challenge for the deployment of IoT systems in that many of the devices produced by different manufacturers employ their own proprietary communication protocols and data formats. Due to the lack of standardization, it is not easy to integrate multiple devices into a single healthcare system. As a consequence, enabling the seamless exchange of data and coordinating between systems continues to pose significant barriers to achieving fully functional and seamless IoT healthcare systems (Al-Fuqaha et al., 2015).

The SLR thematic analysis supports the conclusion that solving the communication and deployment challenges will require an effort combining engineering innovation with the creation of standard protocols and the development of new infrastructure. In particular, improving communication efficiency, utilizing edge computing solutions, and enabling interoperability, are critical elements in facilitating the growth and scale of IoT deployed in the healthcare environment.

4. Systematic Literature Review Analysis

This research project used an SLR to evaluate IoT-enabled healthcare systems. We found that the three most crucial determinants of success for an IoT-based medical device are performance of the embedded system, communication efficiency, and feasibility of deployment. While all of the studies presented significant advancements in biosensors worn on the body, the architecture of embedded systems, and communication interoperability, they still had significant engineering challenges that hinder large-scale adoption of IoT based medical devices in developing countries.

The reviewed studies showed that optimization at the device level (i.e., low power designs, multi-sensor integration) has a direct impact on the overall efficiency of the system. In addition, communication technology such as BLE, ZigBee, and Wi-Fi play a key role in the development of real-time transmission of data, but have challenges related to latency and bandwidth. There has been an increase in the deployment of edge computing as a solution to improve system performance and decrease reliance on centralized cloud-based systems. However, as can be seen from the reviewed studies, the major challenges to deploying an IoT based medical device in developing countries are associated with infrastructure gaps, costs, and interoperability issues that are contributing to slow adoption on a large-scale basis. (Al-Fuqaha et al., 2015; Shi et al., 2016).

Table 1: Systematic Literature Review (SLR) Table

Author (Year)	Objective	Methodology	Key Findings	Conclusion
Dimitrov (2016)	IoT in healthcare overview	Review	Improved remote monitoring	IoT enhances healthcare delivery
Banaee et al. (2013)	Data mining in wearable sensors	Review	Effective health monitoring	Data analytics is crucial
Alemdar & Ersoy (2010)	Wireless sensor healthcare systems	Survey	Reliable monitoring	WSN important for healthcare

Journal of Information Systems Engineering and Management
2024, 9(2)
e-ISSN: 2468-4376
https://www.jisem-journal.com/

Research Article

			systems	
Pantelopoulos & Bourbakis (2010)	Wearable systems	Review	Continuous monitoring possible	Wearables improve care
Miorandi et al. (2012)	IoT architecture	Review	Integration challenges	Standardization needed
Kumar et al. (2016)	IoT technologies	Review	Protocol efficiency issues	Optimization required
Al-Fuqaha et al. (2015)	IoT communication protocols	Survey	Protocol trade-offs	Need efficient communication
Shi et al. (2016)	Edge computing	Conceptual	Reduced latency	Edge improves performance
Rahmani et al. (2018)	Fog computing healthcare	Framework	Faster processing	Edge/fog beneficial
Stankovic (2014)	IoT research directions	Review	Scalability challenges	Further research needed
Gubbi et al. (2013)	IoT vision and applications	Review	Broad applicability	Infrastructure critical
Islam et al. (2015)	IoT healthcare survey	Review	Monitoring benefits	Security challenges exist
Farahani et al. (2018)	IoT healthcare architecture	Review	Integration issues	Need optimized systems

The analysis of the literature review shows that the primary factor affecting the performance of IoT devices is the efficiency of embedded systems. A number of studies have shown that using an optimized microcontroller or SoC-based architecture, along with a properly integrated sensor, will result in improved accuracy in data collection and higher responsiveness within the system. Conversely, using an improperly designed embedded system will cause excess energy usage, decreased operational lifetime, and unreliable performance; ultimately, these characteristics will severely impact overall healthcare results (Pantelopoulos & Bourbakis, 2010).

The reliability of communication is another essential factor for a system to be effective. The comparison of different types of communication protocols shows that while both Zigbee and BLE are low power users, their range and overall data throughput are often less than that of Wi-Fi, which, although more expensive to use, has a much higher maximum bandwidth than Zigbee or BLE. These differences result in the healthcare system's ability to provide real-time monitoring and timely interventions being hampered, especially in critical care situations (Al-Fuqaha etal, 2015).

By using Edge Computing, a system's responsiveness can be improved through the use of localized data processing. Systems that have edge processing capabilities will have lower latency, use less bandwidth and allow for real-time decision-making. These capabilities are particularly important when immediate action is necessary, such as in emergency healthcare applications. Additionally, this region of Edge Computing creates a better overall system, providing more efficient and reliable healthcare networks when integrated with embedded systems (Shi et al., 2016).

Globally, the deployment of IoT healthcare is more significant in developing regions due to limitations within their infrastructure, high implementation costs, and lack of standardization. Moreover, integration issues can further complicate any type of system integration as often devices from many different manufacturers will not work well together because they use different protocols to communicate with each other. The successful implementation of a full-scale healthcare IoT system must involve the collaboration of stakeholders in engineering design, policy development, and infrastructure investment.

Overall, the SLR confirms that while IoT healthcare systems have strong potential, their effectiveness depends on overcoming key engineering challenges related to embedded design, communication efficiency, and deployment scalability.

5. Conclusion And Recommendations

Conclusion

Through a systematic review of literature, we examined the medical system with respect to Electronics Engineering of the Internet of Things (IoT). After analysis of IoT devices, we found that they changed the way patients receive care by giving the ability for continuous monitoring, real-time data collection and remote management of patients. The new technology provided more accurate results, quicker medical intervention, and greater access to care for patients who were in areas far away from traditional providers or who did not have access to many resources.

Despite their potential value to the medical field, however, an engineering analysis demonstrated that there were engineering limitations that prevented IoT healthcare systems from delivering efficient performance when providing care. The performance of embedded systems has a direct impact on how well IoT devices work. Device reliability and ability to provide long-term use were affected by embedded system limitations of processing speed, power supply and sensor integration. In addition, communication performance has a critical role in how responsive a healthcare system is. The ability to receive real-time data from a patient through an IoT device is important for making timely decisions in life-critical situations. Problems such as latency issues with the internet, limited bandwidth and unstable connectivity made it difficult to receive real-time data from an IoT device that could assist with providing timely medical care.

In addition, scalability of deployment was a major obstacle, especially in developing areas of the world. Due to inadequate infrastructure, expensive implementations, and lack of interoperability of devices, IoT based healthcare systems have not been widely adopted globally. The review also indicated that while edge computing has improved responsiveness of systems and provided redundancy to centralised processing, integration into currently existing healthcare systems is still a work in progress.

Overall, the SLR has reaffirmed that IoT based healthcare systems have considerable capabilities for transformation but require significant improvements in design, communication framework/architecture and deployment schemes before they can be successfully implemented on a large scale and maintained sustainably.

Recommendations

In addressing the identified challenges in IoT-enabled healthcare systems and improving their overall effectiveness, the following recommendations are proposed from an engineering perspective.

The first recommendation is to design energy-efficient embedded systems that can operate for long periods of time without needing to be replaced or maintained frequently. This can be accomplished through the development of low-power circuits, optimization of microcontroller architectures for low-energy operation, and/or the use of energy harvesting technologies to supplement the energy supply of the system. Improving the energy efficiency of embedded systems will improve the reliability and usability of devices that make up an IoT-enabled healthcare system.

The second recommendation is to standardize communication protocols so that data can be transferred between devices seamlessly and that there is interoperability between devices. By establishing a common standard for communications, there will be fewer compatibility issues, which will facilitate the integration of heterogeneous devices into a unified healthcare ecosystem. Furthermore, providing protocols that are optimized for low latency and efficient bandwidth usage will assist with real-time monitoring.

A third area to develop is a strong Secure Framework to protect confidential healthcare data. Incorporating strong encryption technologies, secure means of authenticating devices, and advanced techniques for identifying intruders on the computer network itself will be essential at both the network and device level. By making sure that the privacy of data and the security of computer systems are their main goals, healthcare organizations will be able to cultivate consumers' trust and increase the use of IoT technologies in healthcare.

Fourth, improving infrastructure that can scalable support the deployment of IoT is another area that needs development, especially in developing countries. The provisioning of reliable internet access, devices for edge computing, and healthcare IT systems will allow the efficient implementation of IoT solutions in the healthcare sector. Building public-private partnerships and providing policy support will be a major contributor to the acceleration of infrastructure development.

Finally, promoting interdisciplinary research in the area of IoT and healthcare is needed to address the complex issues that are associated with implementing IoT. Collaboration with electronics engineers, healthcare workers, data scientists, and legislators will lead towards developing innovative solutions that are both technically sound as well as clinically effective.

In summary, by working to overcome these issues, IoT-enabled healthcare systems will be able to utilize their full capabilities and make a significant contribution to the development of contemporary healthcare delivery.

References

[1] Alemdar, H., & Ersoy, C. (2010). Wireless sensor networks for healthcare: A survey. *Computer Networks, 54*(15), 2688–2710. https://doi.org/10.1016/j.comnet.2010.05.003

[2] Al-Fuqaha, A., Guizani, M., Mohammadi, M., Aledhari, M., & Ayyash, M. (2015). Internet of Things: A survey on enabling technologies, protocols, and applications. *IEEE Communications Surveys & Tutorials, 17*(4), 2347–2376. https://doi.org/10.1109/COMST.2015.2444095

[3] Banaee, H., Ahmed, M. U., & Loutfi, A. (2013). Data mining for wearable sensors in health monitoring systems: A review of recent trends and challenges. *Sensors, 13*(12), 17472–17500. https://doi.org/10.3390/s131217472

[4] Dimitrov, D. V. (2016). Medical Internet of Things and big data in healthcare. *Healthcare Informatics Research, 22*(3), 156–163. https://doi.org/10.4258/hir.2016.22.3.156

[5] Farahani, B., Firouzi, F., Chang, V., Badaroglu, M., Constant, N., & Mankodiya, K. (2018). Towards fog-driven IoT healthcare: Challenges and framework. *Future Generation Computer Systems, 78*, 659–676. https://doi.org/10.1016/j.future.2017.04.036
[6] Gubbi, J., Buyya, R., Marusic, S., & Palaniswami, M. (2013). Internet of Things (IoT): A vision, architectural elements, and future directions. *Future Generation Computer Systems, 29*(7), 1645–1660. https://doi.org/10.1016/j.future.2013.01.010
[7] Islam, S. M. R., Kwak, D., Kabir, M. H., Hossain, M., & Kwak, K. S. (2015). The Internet of Things for health care: A comprehensive survey. *IEEE Access, 3*, 678–708. https://doi.org/10.1109/ACCESS.2015.2437951
[8] Kumar, P., Lee, H.-J., & Lee, H. (2019). E-healthcare monitoring system based on IoT. *Wireless Personal Communications, 102*(1), 1–16. https://doi.org/10.1007/s11277-017-4849-4
[9] Kumar, S., Tiwari, P., & Zymbler, M. (2016). Internet of Things is a revolutionary approach for future technology enhancement: A review. *Journal of Big Data, 3*(1), 1. https://doi.org/10.1186/s40537-016-0041-7
[10] Miorandi, D., Sicari, S., De Pellegrini, F., & Chlamtac, I. (2012). Internet of Things: Vision, applications and research challenges. *Ad Hoc Networks, 10*(7), 1497–1516. https://doi.org/10.1016/j.adhoc.2012.02.016
[11] Moura, J., Hutchison, D., & Silva, B. (2020). IoT for healthcare: Systematic review and future directions. *Journal of Network and Computer Applications, 165*, 102699. https://doi.org/10.1016/j.jnca.2020.102699
[12] Pantelopoulos, A., & Bourbakis, N. G. (2010). A survey on wearable sensor-based systems for health monitoring and prognosis. *IEEE Transactions on Systems, Man, and Cybernetics, Part C: Applications and Reviews, 40*(1), 1–12. https://doi.org/10.1109/TSMCC.2009.2032660
[13] Rahmani, A. M., Gia, T. N., Negash, B., Anzanpour, A., Azimi, I., Jiang, M., & Liljeberg, P. (2018). Exploiting smart e-health gateways at the edge of healthcare Internet-of-Things. *Future Generation Computer Systems, 78*, 641–658. https://doi.org/10.1016/j.future.2017.02.014
[14] Shi, W., Cao, J., Zhang, Q., Li, Y., & Xu, L. (2016). Edge computing: Vision and challenges. *IEEE Internet of Things Journal, 3*(5), 637–646. https://doi.org/10.1109/JIOT.2016.2579198
[15] Stankovic, J. A. (2014). Research directions for the Internet of Things. *IEEE Internet of Things Journal, 1*(1), 3–9. https://doi.org/10.1109/JIOT.2014.2312291