eISSN: 2229-3213 pISSN: 2229-3205
The Journal of Applied Science and Social Science
Volume 16,Issue 01 January , 2026

ANALYSIS OF THE ARCHITECTURE AND EFFICIENCY OF TELEMEDICINE SYSTEMS FOR REMOTE PATIENT MONITORING IN RESOURCE-LIMITED AREAS (RURAL, DISTRICT)

Scientific advisor**: Jo'rayev Zafar Botirovich**
Candidate of Technical Sciences,
Professor of Andijan State Technical Institute
e-mail: zbjuraev@gmail.com
Tel:+998934424230
Nabiev Akhrorbek Rasuljon ugli
Andijan State Technical Institute
"Medical-Biological Devices, Systems and Complexes" specialization
1st year master's student

Abstract: This article analyzes the architecture of telemedicine systems for remote patient monitoring, its main components and mechanisms that ensure its effectiveness in regions with limited resources.Abstract: This article analyzes the architecture of telemedicine systems for remote patient monitoring, its main components and mechanisms that ensure its effectiveness in regions with limited resources. In conditions of low availability of medical services in rural and district areas, telemedicine systems play an important role in ensuring uninterrupted delivery of medical services. The article is devoted to the technological architecture of telemedicine systems, communication channels, information exchange, patient monitoring devices and criteria for evaluating the effectiveness of the system.The article is devoted to the technological architecture of telemedicine systems, communication channels, information exchange, patient monitoring devices and criteria for evaluating the effectiveness of the system.

Keywords: telemedicine, digital healthcare, remote counseling, health monitoring, technological limitations.

Introduction

The introduction of digital technologies and the development of remote medical services in the modern healthcare system is becoming an urgent problem all over the world.The introduction of digital technologies and the development of remote medical services in the modern healthcare system is becoming an urgent problem all over the world. Low availability of medical services, lack of qualified specialists, and limited infrastructure have a particularly negative impact on public health, especially in areas with limited resources, such as rural areas and rural areas. In these circumstances, telemedicine systems based on remote patient monitoring are becoming an important tool in ensuring the continuity and quality of medical services.

Remote patient monitoring expands the possibilities of real-time monitoring of medical indicators, early diagnosis and rapid decision-making by doctors.Station monitoring of patients expands the possibilities of monitoring medical indicators in real time, early diagnosis and rapid decision-making Station monitoring of patients expands the possibilities of monitoring medical indicators in real time, early diagnosis and rapid decision-making by doctors. This approach is especially important for patients with chronic diseases, the elderly, and those segments of the population who need constant medical supervision. Thanks to telemedicine technologies, the distance between the patient and the doctor is reduced, healthcare costs are reduced and territorial inequality in the provision of medical services is eliminated.

The modernization of the healthcare system and the introduction of digital medical technologies in the Republic of Uzbekistan have been identified as one of the priorities of state policy.The democratization of the healthcare system and the introduction of digital medical technologies in the Republic of Uzbekistan have been identified as one of the priorities of state policy. In particular, Decree of the President of the Republic of Uzbekistan dated December 7, 2018 No. PF-5590 defines as an important task the fundamental improvement of the healthcare system, improving the quality of medical services and the widespread introduction of modern information and communication technologies. The decree emphasizes the need to improve the efficiency of providing medical care to the population through the introduction of digital technologies and remote medical services in the healthcare system [1].

The healthcare sector also directly includes regulatory legal acts adopted in order to accelerate the processes of digital transformation in the country.The sphere of healthcare also directly relates to regulatory legal acts adopted in order to accelerate the processes of digital transformation, in particular, Decree of the President of the Republic of Uzbekistan dated October 5, 2020 No. PP-4862 defines the tasks of information systems development., electronic databases and remote medical services in healthcare institutions as part of the development of the digital economy and the widespread introduction of an e-government system. The resolution emphasizes the importance of effective use of telemedicine technologies to expand access to medical services for residents of rural and remote areas[2].

Analysis of literature on the topic

In recent years, the issues of digitization of the healthcare system, in particular telemedicine and remote monitoring of patients, have been actively studied by domestic and foreign researchers.

In recent years, the issues of digitization of the healthcare system, in particular telemedicine and remote monitoring of patients, have been actively studied by domestic and foreign researchers. In Uzbekistan, this area was directly related to improving the quality of medical services, especially in regions with limited resources, and in many scientific studies it was interpreted as an important socio-practical problem.

Analyzing the issues of the introduction of information technologies in healthcare, Ismailov notes that telemedicine services are an effective mechanism for reducing territorial inequality. According to the author, ”telemedicine technologies expand access to qualified medical care for the population living in rural areas, as well as significantly reduce the distance between doctor and patient" [3]. This opinion reveals the social importance of remote monitoring of patients.

Also R.akzhe R. A. Kzhe R. A. Kadyrov and M. S. Abdullaev's scientific articles highlight the organizational and technological aspects of telemedicine systems. The authors pay special attention to the issues of network infrastructure and information security during the implementation of the system, as well as R. A. Kadyrov and M. S. Abdullaev's scientific articles highlight the organizational and technological aspects of telemedicine systems. The authors pay special attention to the issues of network infrastructure and information security when implementing remote monitoring systems. They argue that ”the development of flexible telemedicine platforms that can operate even in low-speed Internet conditions is important for regions with limited resources" [4]. This approach is directly consistent with the subject of this study.

N. A. Karimov's research extensively covers the concept of an electronic health system (e-Health), and telemedicine is considered an integral part of it. The author substantiates the increased effectiveness of the fight against chronic diseases using remote monitoring of patients with scientific data. Karimov's research extensively covers the concept of an electronic health system (e-Health), and telemedicine is considered an integral part of it. The author substantiates the increased effectiveness of the fight against chronic diseases using remote monitoring of patients with scientific data. Karimov believes that ”data collected through telemedicine serves as an important source of information for doctors when making clinical decisions" [5]. This vision shows the impact of telemedicine systems on medical outcomes.

Uzbek researcher D.Zbzbek researcher D. B. Yusupov studied the issues of digital transformation of healthcare, analyzed the economic efficiency of the introduction of telemedicine researcher D. B. Yusupov studied the issues of digital transformation of healthcare, analyzed the economic efficiency of the introduction of telemedicine services in rural areas. His study notes that due to remote monitoring, the number of patient hospitalizations has decreased, and the costs of the healthcare system have been optimized [6]. These results confirm the practical effectiveness of telemedicine systems.

Also S.akzhe S. T. Rakhzhe S. T. Rakhmonova and L. U. Mirzayeva's scientific work analyzes the architecture of telemedicine systems and their components. The authors evaluate the interaction between sensor devices, data transmission channels and central ones, as well as S. T. Rakhmonova and L. U. In scientific work, the issue of architecture of telemedicine systems and their components is analyzed. The authors assess the interaction between touch devices, data transmission channels, and central servers as an important factor. They claim

that ”the modular architecture of telemedicine systems allows them to be adapted to different regional conditions" [7]. This analytical resource indicates the need to choose a suitable architecture for limited areas.

A.. J. Tursunov's article discusses the prospects of using IoT technologies in remote monitoring of patients. The author notes that small-sized energy-efficient sensors play an important role in the implementation of telemedicine systems in rural areas. Tursunov's article discusses the prospects of using IoT technologies in remote monitoring of patients. The author notes that small-sized energy-efficient sensors play an important role in the implementation of telemedicine systems in rural areas. He . J. In the article. Tursunov's article discusses the prospects of using IoT technologies in remote monitoring of patients. The author notes that small-sized energy-efficient sensors play an important role in the implementation of telemedicine systems in rural areas. He believes that ”monitoring systems based on the Internet of Things make it possible to collect and analyze medical data in real time" [8]. This approach sheds light on the technological foundations of modern telemedicine architecture. In addition, Z. Q. Nazarov and S. E. In the Khudoiberdievs' research, the personnel issue and technological literacy of users were considered an important factor in the introduction of telemedicine services. The authors note that the effectiveness of telemedicine systems depends not only on the technical infrastructure, but also on the level of training of medical personnel and patients [9]. Russian scientific articles published in recent years also discuss the regulatory framework for telemedicine systems. In particular, I. M. Saidov points out that the development of telemedicine services is inextricably linked to government policy, arguing that presidential decrees and decrees serve as the basis for scientific and practical research [10].Aidov points out that the development of telemedicine services is inextricably linked to government policy, arguing that presidential decrees and decrees serve as the basis for scientific and practical research [10]. This approach shows the importance of the legal framework for the sustainable development of telemedicine systems.

In general, the analyzed literature shows that the research of Uzbek scientists in the field of telemedicine and remote monitoring of patients mainly covers technological, organizational and social aspects. In general, the analyzed literature shows that the research of Uzbek scientists in the field of telemedicine and remote monitoring of patients mainly covers technological, organizational and social aspects. However, the issues of appropriate architecture and comprehensive assessment of effectiveness in general, the analyzed literature shows that the research of Uzbek scientists in the field of telemedicine and remote monitoring of patients mainly covers technological, organizational and social aspects. However, the issues of appropriate architecture and integrated performance assessment for regions with limited resources have not yet been systematically studied. Thus, this scientific article is aimed at summarizing existing research and in-depth analysis of the effectiveness of telemedicine systems.

Research methodology

In this study, the existing scientific literature on telemedicine systems was systematically analyzed. The architecture of remote patient monitoring models, which are used in regions with resource limitations, was studied in a comparative way. The effectiveness of telemedicine systems was evaluated on the basis of functional, technological and organizational criteria. The results obtained were summarized and practical recommendations were developed.

ANALYSIS AND RESULTS

Within the framework of this study, the effectiveness of telemedicine systems introduced for remote patient monitoring in resource-restricted areas (villages and districts) was analyzed. In the analysis process, the cases before and after the introduction of telemedicine systems were comparedithin the framework of this study, the effectiveness of telemedicine systems introduced for remote patient monitoring in resource-restricted areas (villages and districts) was analyzed. In the analysis process, the cases before and after the introduction of telemedicine systems were compared. The focus was on patient coverage rates, physician response times, number of hospital appeals, and early emergency detection rates. The results of the analysis show that the rate of patient coverage has increased significantly with the introduction of telemedicine systems.he results of the analysis show that the rate of patient coverage has increased significantly with the introduction of telemedicine systems. If he results of the analysis show that the rate of patient coverage has increased significantly with the introduction of telemedicine systems. If initially the proportion of patients covered by medical monitoring was on average 45%, the rate reached 75% when telemedicine was introduced. This situation suggests that remote monitoring technologies are reducing territorial restrictions and expanding access to medical services. Physician response time is also one of the important efficacy criteriahysician response time is also one of the important efficacy criteria. According to the results of the study, until the introduction of telemedicine systems, the doctor's response averaged 60 minutes, while by remote monitorhysician response time is also one of the important efficacy criteria. According to the results of the study, until the introduction of telemedicine systems, the doctor's response averaged 60 minutes, while by remote monitoring and electronic notifications this figure was reduced to 25 minutes. This increased the availability of emergency emergency emergency medical services. Also, Remote Patient Monitoring has had a positive effect on the decrease in the number of hospital applications.lso, Remote Patient Monitoring has had a positive effect on the decrease in the number of hospital applications. While the traditional system did not see a lso, Remote Patient Monitoring has had a positive effect on the decrease in the number of hospital applications. While the traditional system did not see a decrease in hospital referrals, the rate dropped by an average of 40% following the introduction of telemedicine. This situation served to optimize the cost of the healthcare system while reducing the burden on medical facilities.

Early emergency detection rates have also improved significantlyarly emergency detection rates have also improved significantly. While early detection rates for such cases were around 30% prior to the use of telemedicine systems, real-time datarly emergency detection rates have also improved significantly. While early detection rates for such cases were

Table 1
Performance indicators of telemedicine systems in resource-constrained areas

< / Score >	**Before telemedicine was introduced**	**After the introduction of telemedicine**
Patient coverage rate (%)	45	75
Physician response time (daq.)	60	25
Reduced hospital referrals (%)	0	40
Early detection of emergency cases (%)	30	65

Source: Compiled by the author based on analysis conducted at local healthcare facilities and open statistical data.

The diagram (above) visually compares the data presented in the table and clearly demonstrates that all key indicators have changed positively after the introduction of telemedicine systems. In general, the results obtained scientifically confirm the high efficiency of the introduction of telemedicine systems for remote patient monitoring in resource-limited regions.

Currently, various telemedicine monitoring systems are widely used for patients with cardiovascular diseases, diabetes and other chronic diseases, and the market for such systems is constantly growing. The allocation of funds for the introduction of digital solutions in medical practice is also increasing [12. Personalized medical care and remote healthcare systems are possible with the integrated development of hardware and software [11].

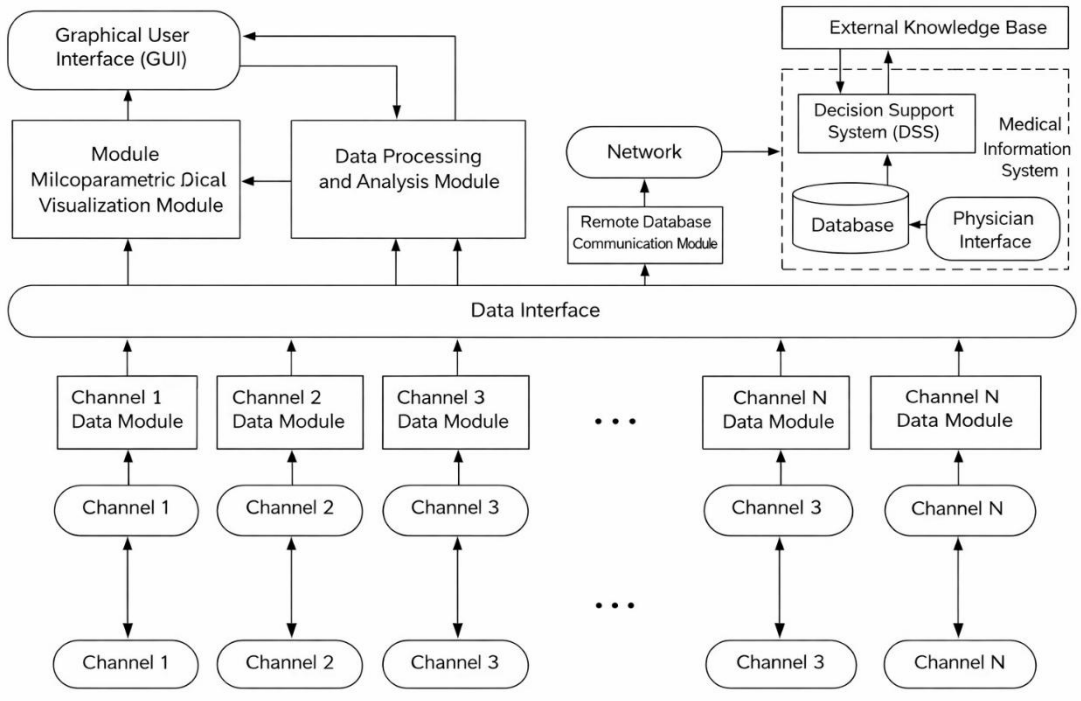
Many major manufacturers offer high-precision and reliable medical monitoring devices and systems, the effectiveness of which is largely determined by the availability of applications that allow the transmission, processing and visualization of the collected data in a user-friendly format, as well as the availability of appropriate network infrastructure for remote storage, analysis and data exchange with other medical systems. One example of such a system is a multi-parameter telecommunication system for monitoring COVID-19 patients in self-isolation [13]. In this system, information about the patient's condition is transmitted to the doctor via a smartphone, which must have a special WeChat application installed. The doctor periodically talks to the patient by phone using a special questionnaire and, based on the answers, subjectively assesses their condition. This subjective assessment is supplemented by measurements of temperature and blood saturation, obtained using a thermometer and pulse oximeter, which the patient must have and be familiar with. Based on this information, decisions are made about the need for treatment adjustment, rehabilitation, or hospitalization.

A telemedicine system has been developed for remotely adjusting the dose of drugs for cardiovascular diseases in patients living at home [14]. The system consists of three components: home medical devices (tonometer and scales) with a wireless gateway interface and a web application on the doctor's computer. The parameters that are automatically measured by the patient include weight, systolic and diastolic blood pressure, and heart rate. This system automatically measures the patient's condition and remotely prescribes drug doses based on the patient's current condition.

An integrated home telemonitoring system for patients with cardiovascular diseases [15] includes channels for measuring blood pressure, weight, and blood saturation, an electrocardiogram channel, and the ability to obtain echocardiogram data. The system supports videoconferencing between the doctor and the patient and is highly specialized.

A common problem for the systems described above is the integration of various data necessary to assess human health using several different parameters and subsequently make decisions on further patient management. As a result, there is a need to develop an integrated application that combines various data received from several types of devices and is able to analyze medical monitoring data, including in real time [11].

Solving the problem of integrating and analyzing multi-parameter monitoring data allows for timely detection of important human conditions, timely provision of medical care and adjustment of treatment. Figure 1 shows the architecture of a software system for telemedicine monitoring of human health.



The data obtained from the measurement channels are sent to the

corresponding channel data modules according to protocols capable of processing and structuring informative data, as well as further transmitting it to the Data Interface. In the Data Interface, the data are aggregated and converted from various device types into a unified format.

The Data Processing and Analysis Module performs logical processing of the received data according to specific algorithms (for example, it classifies values relative to normal ranges and calculates TIR, TBR, and TAR parameters over a defined period) and, based on the type of data, generates charts in the Multiparametric Data Visualization Module. The generated charts, along with all additional information about the parameter values, are displayed in the Graphical User Interface (GUI).

To address the main contradiction in the requirements for visual display of monitoring data, the interface can be organized according to a hierarchical principle. The hierarchical structure of displaying patient parameters is proposed as follows (starting from the top level):

1. General (integrated) characteristic of patient parameters ("normal" – "out of normal range").
2. Characteristics of a set of individual parameters (full set of parameters in the form – "out of normal range").
3. Detailed characteristics of individual patient parameters (visualization of values recorded directly on the patient in real-time, or the most recent recorded values in the case of periodic parameter registration), for example, the ECG signal, as shown in Fig. 2.

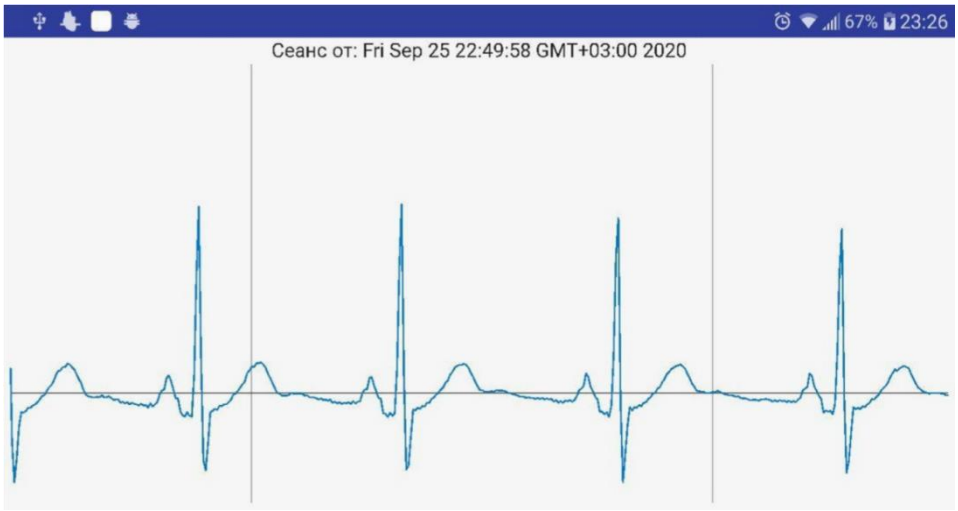


Fig. 2. Real-time ECG signal display on smartphone screen

The appearance of the indicator (mnemonic symbol) should clearly reflect at least three states:

1. The norm – all parameters are within the normal range.
2. Deviations – the values of one or more parameters exceed the limits of the norm, but the deviation values are not critical.

3. Critical condition – deviation of one or more parameters from the norm by critical values or complete lack of information on any parameters.

If a three-dimensional object is used as an image, then the transition from one mnemonic image to another can be realized using the apparatus of mixing functions, which allows you to display the intermediate state by mixing two geometric shapes.

CONCLUSION

This study focused on analyzing the architecture and effectiveness of telemedicine systems for remote patient monitoring in resource-limited areas (rural and district). The results of the study show that telemedicine systems allow for increased patient coverage, reduced response time for doctors, reduced hospital overload, and early detection of emergencies.

The analysis comprehensively studied technological, organizational, and social aspects. It should be noted that the effectiveness of the system is not limited only to the technological infrastructure, but also to the level of use of technology by patients and medical staff, as well as the convenience of the user interface. Hierarchical interfaces and multi-parameter visualization modules play an important role in the understandable and effective presentation of data.

The results of the study also showed that adapting telemedicine systems to regional conditions and choosing an optimized architecture for areas with low-speed Internet and limited electricity supply ensure stable operation of the system. Comparison with Internet sources and local practical experiences shows that the implementation of remote patient monitoring systems in resource-limited areas significantly improves the quality of healthcare services.

References

1. O‘zbekiston Respublikasi Prezidentining Farmoni. O‘zbekiston Respublikasida sog‘liqni saqlash tizimini tubdan takomillashtirish bo‘yicha kompleks chora-tadbirlari to‘g‘risida: PF-5590-son, 7 dekabr 2018-yil. – Toshkent.
2. O‘zbekiston Respublikasi Prezidentining Qarori. Raqamli iqtisodiyotni rivojlantirish va elektron hukumat tizimini keng joriy etish chora-tadbirlari to‘g‘risida: PQ-4862-son, 5 oktyabr 2020-yil. – Toshkent.
3. Ismoilov X. X. Sog‘liqni saqlash tizimida telemeditsina texnologiyalarini joriy etish masalalari // Tibbiyot va innovatsiya. – Toshkent, 2019. – №2. – B. 45–49.
4. Qodirov R. A., Abdullayeva M. S. Telemeditsina tizimlarining texnologik asoslari // Axborot texnologiyalari. – Toshkent, 2020. – №4. – B. 32–38.
5. Karimov N. A. Elektron sog‘liqni saqlash va masofaviy monitoring tizimlari // Sog‘liqni saqlash axborotnomasi. – Toshkent, 2021. – №1. – B. 21–26.
6. Yusupov D. B. Qishloq hududlarida telemeditsina xizmatlarining iqtisodiy samaradorligi // Iqtisodiyot va sog‘liqni saqlash. – Toshkent, 2020. – №3. – B. 54–59.

7. Rahmonova S. T., Mirzayeva L. U. Telemeditsina tizimlarining arxitekturaviy yechimlari // Muhandislik va texnologiyalar. – Toshkent, 2022. – №2. – B. 40–46.
8. Tursunov A. J. IoT texnologiyalari asosida masofaviy bemor monitoringi // Raqamli texnologiyalar. – Toshkent, 2021. – №5. – B. 63–68.
9. Nazarov Z. Q., Xudoyberdiyev Sh. E. Telemeditsina xizmatlarini joriy etishda kadrlar tayyorlash masalalari // Pedagogika va tibbiyot. – Toshkent, 2019. – №4. – B. 71–76.
10. Saidov I. M. O‘zbekistonda telemeditsina rivojlanishining normativ-huquqiy asoslari // Huquq va jamiyat. – Toshkent, 2020. – №6. – B. 28–33.
11. Баранов В. А., Печерская Е. А., Сафронов М. И., Тимохина О. А. Информационно-измерительная система для телемедицинского мониторинга состояния больного COVID-19 // Измерение. Мониторинг. Управление. Контроль. 2021. № 1. С. 85-92.
12. Пугачев П. С., Гусев А. В., Кобякова О. С. [и др.]. Мировые тренды цифровой трансформации отрасли здравоохранения // Национальное здравоохранение. 2021. Т. 2, № 2. С. 5-12.
13. Xu H., Huang S., Qiu Ch. [et al.]. Monitoring and Management of Home-Quarantined Patients With COVID-19 Using a WeChat-Based Telemedicine System: Retrospective Cohort Study // Journal of Medical Internet Research. 2020. Vol. 22, № 7.
14. Leijdekkers P., Gay V., Lawrence E. Smart Homecare System for Health Tele-monitoring // Materials of the 1st International Conference on the Digital Society. Guadeloupe, 2007. doi:3.10.1109/ICDS.2007.37
15. Lobodzinski S., Jadalla A. Integrated heart failure telemonitoring system for homecare // Cardiology journal. 2010. Vol. 17, № 2.