Mehran University Research Journal of Engineering and Technology

https://doi.org/10.22581/muet1982.2329

2025, 44(2) 85-92

Illuminate the integration of body area network with the existing telehealth infrastructure in Balochistan

Bilal Ahmed [a, *], Bushra Haq [b], Kamran Ali [c], Anum Tanveer Kiyani [c]

[a] *Monitoring, Evaluation, Learning, Mercy Corps Pakistan*

[b] *Faculty of Information and Communication Technology, Balochistan University of Information Technology, Engineering and Management Sciences*

[c] *Faculty of Science & Technology, Middlesex University*

[*] Corresponding author: Bilal Ahmed, Email: talktobilal@outlook.com

Received: 08 December 2021, Accepted: 27 March 2025, Published: 01 April 2025

KEYWORDS

Body Area Networks (BAN)

Sensor nodes

Sensor network

Ehealth

Telehealth care

Digital health

ABSTRACT

Healthcare services remain the priority to ensure a healthy and prosperous society. However, providing quality healthcare remained a question for the service providers, especially in Pakistan. The population has concerns about visiting healthcare facilities, and globally, 50% of the population hesitates to do so, with a further 60% of denials observed during the pandemic. The major barriers for visitors are the low quality of the healthcare services and a lack of human resources at the facilities. In Balochistan, the government has initiated several eHealth centers within existing health facilities in various locations; however, the system currently only allows doctors to see and communicate with patients. In this paper, the authors discuss the challenges and propose an idea for integrating the Body Area Network (BAN) with the existing eHealth system, along with suggestions for rolling out the integrated system across all health facilities in Balochistan. This system will enable real-time monitoring of patients, as well as record important health information for follow-ups and medical records.

1. Introduction

Providing healthcare services is fundamental to human basic needs and living standards. Health is the most important investment in human capital, necessary to fully realize potential by contributing to the protection and empowerment of individuals [1]. However, healthcare services in developing countries, particularly Pakistan [2], require significant improvement. The rapid evolution of medical technology, combined with a shortage of healthcare facilities and staff, poses a significant challenge. It is particularly evident given the comparatively large population, which makes it challenging to provide quality healthcare services on a census basis [3]. Due to a lack of access, minor illnesses in patients often worsen and develop into major infections. These scenarios can be observed in developing countries in Asia and Africa, where the population's health is compromised due to a large population and insufficient medical infrastructure. As an example, the outbreaks of COVID-19 and Ebola in Asia and Africa relatively quickly turned from epidemic to pandemic and cost thousands of lives. In contrast, the quality of healthcare services and accessibility can ensure treatment at an epidemic level and save many lives [4].

Like all other developing countries, Pakistan faces critical issues, including a high population rate and an imbalance in healthcare services. Additionally, it is unfortunate that Pakistan lacks a formal knowledge management solution in the health sector. In contrast, adopting a proper knowledge management system can provide a sustainable healthcare system in the country [5]. Moreover, accessibility is also a challenge for healthcare staff in providing services [6] in remote

areas, particularly in cases where the number of referrals to healthcare facilities is increasing. The reason includes that healthcare staff are less than required for the population, and professionals prefer to be placed in big cities or provincial capitals. According to the World Health Organization (WHO), the recommended number of doctors is 3 to 4 per 1,000 people, and the desired number of nurses and community healthcare workers per 1,000 population is four each [7]. According to the World Health Organization's Global Health Workforce Statistics, there are 1.1 doctors, 0.5 nurses, and 0.1 community healthcare workers per 1,000 population in Pakistan as of 2019 [8]. However, Gallup Pakistan has analyzed the Pakistan Statistical Yearbook 2022, stating that the number of doctors has increased by 61% since 2022, where the number of nurses has increased by 50% and community healthcare workers by 40% [9]. Pakistan's healthcare workforce has experienced significant growth over the past decade. However, Fig. 1 compares the recommended healthcare workforce with the existing density of healthcare workers in Pakistan as of 2019 and 2022.

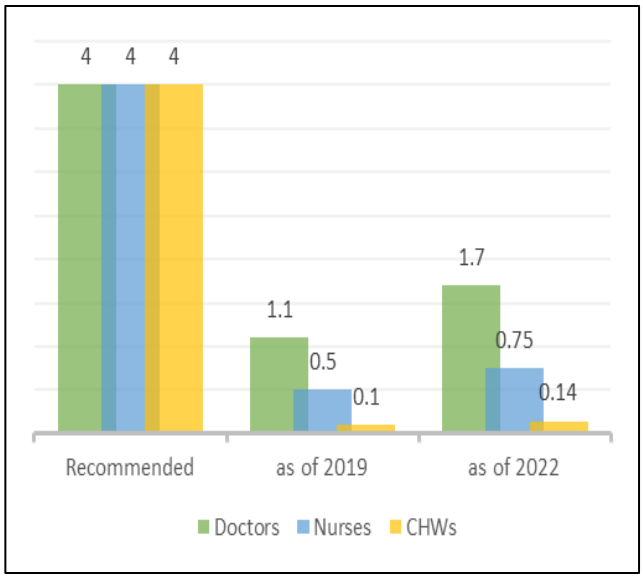

Fig. 1. The Density of Doctors, Nurses, and CHWs, over 1,000 People

Many illnesses cannot but cured in remote localities and may require advanced hospital services, doctors, and remote patient management systems to diagnose and treat patients. With the support of remote management systems, patients can access primary healthcare services at their doorstep, thereby preventing them from traveling to large cities due to various barriers, including poverty, transportation, and long distances [10]. Even if patients can access hospitals in provincial or district capitals by any means, how hospitals and doctors manage patient queues remains questionable, and patients often suffer from long waiting times [11]. Moreover, these questions may also arise in the mind after the outbreak of the deadliest virus marking the pandemic, namely COVID-19, which should considered.

However, on a larger scale, these questions and queries can be addressed with a solution to the eHealth system [12]. Many people perceive The eHealth system as a simple e-commerce business for medicines, so it is often misinterpreted. Still, eHealth is a system that enables hospitals and healthcare facilities from different locations to connect, allowing patients from remote areas to consult with doctors in the provincial capital. eHealth is an application of Telemedicine, like mHealth and Telehealth [13]. A simple architecture of a telemedicine system is represented in Fig. 2. The system utilizes the internet as its primary resource and requires a computer and web camera to enable the doctor to see and talk to the patient remotely. The eHealth system provides easy access to healthcare services and offers interactive, quick, and remote care. Therefore, an eHealth system is a term in Information Technology that refers to a medical information system designed to provide tech-enabled healthcare services to patients [14, 15].

Pakistan is facing numerous challenges in its healthcare system, and the health sector requires more focus, particularly on technology-based solutions, to enhance healthcare services and improve patient access to healthcare facilities [16]. However, the government recognizes the importance of information technology in the health sector; nevertheless, a pressing need remains for an eHealth Policy and Strategy to ensure successful implementation nationwide, particularly in Balochistan [17].

The eHealth services are initiated by the government in four different locations in Balochistan [18]. These eHealth services offer a video conferencing system that connects the basic health unit with the hospital in the provincial capital. The doctor can examine and consult with the patient, provide a diagnosis, and prescribe treatment and medication as needed. Many other private institutions are also offering eHealth services nationwide today. However, all the services offered by public and private institutions are limited to the basic eHealth system. Understanding and integrating Body Area Network (BAN) enabled devices with the existing eHealth system, incorporating Sensor Nodes, is crucial. BAN can provide an opportunity to connect directly with the patient and record their basic health information, such as blood pressure and heart rate.

In this paper, the authors discuss the basic challenges and barriers patients face when visiting health facilities for healthcare services. They present a

solution for integrating the Body Area Network (BAN) with the existing eHealth Infrastructure and suggest rolling out the integrated system across the entire Basic Health Units (BHUs) of Balochistan.

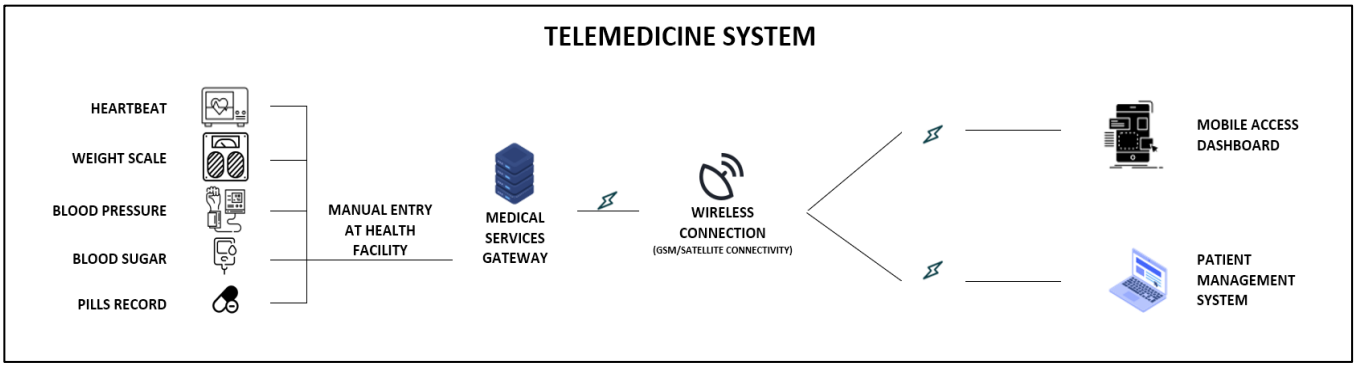

Fig. 2. Architecture of a Telemedicine System (Including mHealth, Telehealth, And eHealth Systems)

2. Literature Review

Telemedicine is the provision of healthcare services through information and communication technologies. Telemedicine has grown rapidly worldwide and in Pakistan [19]. M. H. Nagra et al. conducted a study on a telemedicine service established by Faisalabad Medical University in Allied Hospital and DHQ Hospital, which provided 24/7 services and connected patients through landline numbers for telephonic conversations, Skype IDs for video consultations, and WhatsApp numbers for instant messaging during the COVID-19 outbreak. The study concluded that telemedicine was crucial in providing patients with timely, correct, and appropriate diagnosis and medical advice [20]. A. U. Rehman et al. also proposed connecting non-practicing female doctors with rural areas of Pakistan through a telemedicine approach using any internet connection, including GSM, WiMAX, and/or satellite connections. With this, numerous virtual clinics could be established, allowing patients from remote villages to visit clinics and consult with registered doctors for diagnosis and treatment [21].

As the era of healthcare becomes increasingly ubiquitous, technology is booming rapidly in the U-healthcare era, with telemedicine emerging and new systems, including mHealth, Telehealth, and eHealth, being introduced into the healthcare system. In this regard, H. Yoo et al. presented a communication channel that transmits electric signals from the human body, known as Human Body Communication (HBC), which operates within three physical layers of wireless body area network technology [22]. F. Touati et al. expressed that there is a significant possibility of achieving next-generation u-Health through the combination of mobile and ubiquitous Telemedicine, with the integration of WBAN [23]. A. Saboor et al. emphasized that the evolution of wireless standards has also facilitated remote monitoring of health problems. These standards support the system to monitor, process, and transmit remotely [24]. Furthermore, S. Sharma et al. have elaborated on the capabilities of wireless physiological body sensor nodes for sensing and processing essential signals and communicating with the network coordinator, who then transmits the signals for remote monitoring [25].

Moreover, M. U. H. Al Rasyid et al. discussed the implementation of a muscle strain sensor, specifically Electromyogram (EMG), with the Wireless Body Area Network (WBAN), as it is beneficial for patients, and the applications can be accessed by any mobile device [26]. E. Baba et al. developed a wearable WBAN application that utilizes four sensor nodes to measure physiological signals, including ECG, oxygen saturation, heart rate, and breathing, facilitating extensive remote health monitoring [27]. M. Gowtham et al. highlighted a key observation regarding the security of data gathered through WBAN technology and discussed the major challenges of WBAN/BAN, i.e., establishing secure communication between sensors and the data sink to address security and privacy concerns. To ensure secure communication, he introduced a fully homomorphic encryption algorithm to implement a secure communication channel between the data sink and third-party access. This method can also enhance healthcare monitoring in telecom systems using BAN-enabled implantable devices, which will not compromise patient mobility [28].

E. Jovanov et al. have elaborated on integrating m-Health with mobile computing, medical sensors, and communication technologies through mobile applications. Intelligent sensors in WBAN/BAN are an emerging technology with the potential for discreet health monitoring [29]. In scattered localities with high population density, accessing healthcare services for everyone poses a significant challenge, and traditional methods are often inefficient. Therefore, N. A. Anoop et al. mentioned that WBAN/BAN-enabled health monitoring systems are a leading technology

that provides remote explanatory diagnosis [30]. B. Braem et al. also mentioned that BAN is rapidly growing, and the need for BAN is increasing in healthcare for remote and improved patient care [31].

A. H. Baig et al. highlighted that the growing access to the internet and the rapid boom in wireless technology industrialize the world and raise the profile in almost every industry within Pakistan. Information and communication technologies continued to rise in the healthcare sector using wireless technology [32]. B. Ahmed et al., in their paper, emphasize the adaptability of automated information systems and discuss the case study of Balochistan [33]. These papers express the importance of wireless networks and information systems used by body area networks and patient management systems.

While existing studies have significantly advanced telemedicine and WBAN applications, critical gaps persist in technical interoperability, real-world validation, and socio-economic adaptability, particularly in low-resource regions like Balochistan. To systematically address these limitations, Table 1 synthesizes key shortcomings in prior work and aligns them with recent advancements, underscoring the necessity of integrating BAN with telehealth infrastructure to overcome context-specific challenges.

Table 1

Critical analysis of existing studies with limitations and recent advances

Author(s) and Year	Study Focus	Key Contributions	Limitations	Recent References Addressing Limitations
Nagra et al. (2021). [20]	Telemedicine during COVID-19	The paper highlighted the role of telemedicine in facilitating timely diagnosis and remote consultations.	Limited to urban hospitals; lacked integration with real-time sensor data.	Bilal et al. (2022). [43] identified gaps in rural infrastructure and proposed hybrid telemedicine models for low-resource settings.
Salam et al. (2019). [21]	Telemedicine for rural areas	The paper proposed virtual clinics utilizing the internet and GSM to connect remote patients with doctors.	It did not address energy efficiency or socio-economic barriers (e.g., internet costs).	Intorne et al. (2023). [46] in their paper designed low-power WBAN protocols to reduce energy consumption in remote monitoring.
Yoo et al. (2013). [22]	Human Body Communication (HBC)	The paper introduced HBC as a physical layer for WBANs.	Focused on technical aspects; ignored interoperability with legacy systems.	Kennedy (2023). [45] analyzed interoperability challenges in telehealth and proposed middleware solutions for seamless integration.
Gowtham et al. (2017). [28]	Security in WBANs	The paper proposed Homomorphic Encryption for Secure Data Transmission.	Tested in simulated environments; lacked real-world validation in rural clinics.	Preethi Chandra et al. (2023). [44] systematically reviewed the security gaps in WBANs, emphasizing the importance of field testing for encryption protocols in low-resource healthcare settings.
Al Rasyid et al. (2015). [26]	WBAN for muscle strain monitoring	The paper developed a mobile-compatible WBAN for tracking muscle activity.	Limited sensor diversity (only EMG); no long-term patient data analysis is available.	Recent studies (e.g., Malviya et al., 2023) [47] expanded sensor types (ECG, SpO2) and integrated AI for predictive analytics in chronic disease management.

3. Discussion

According to the World Bank and the WHO, at least 50% of the global population lacks access to basic health services [34]. A large population resides in extremely remote localities, which prevents them from accessing health facilities, or the available facilities are not well-equipped to manage patients. The primary reason for the low-quality health services in these facilities is the shortage of human resources in the health sector in Pakistan, particularly in Balochistan. For every 1000 population, there are only 0.08% doctors, 0.06% nurses, and 0.01% community health

workers [35]. Due to the lack of health facilities and healthcare workers, the number of visitors to basic health units is already low, and the population cannot access quality health services. This situation also impacted the populations living in the remote areas of Balochistan.

During the pandemic, the situation worsened, and the number of patients visiting the health facilities reduced by 60% [36]. However, a few startups have emerged with telehealth, which aims to connect remote healthcare facilities with qualified doctors and provide high-quality diagnostic services to patients [37]. These eHealth services connect health facilities with doctors through an application that works on laptops and mobile devices. The Government of Balochistan has also initiated the eHealth services in four different locations in Balochistan with the name of Telemedicine, which aims to provide remote healthcare services, including health assessments and consultations through telecommunication infrastructure where the doctors in provincial headquarters can connect with the patients to evaluate, diagnose, and treat through common technology [18].

However, all initiatives by public and private institutions are currently limited to video conferencing systems using telecommunication devices; none of these systems enable the devices to directly connect to the patient's body and record basic information, such as blood pressure and heartbeat. There is a dire need for a system that connects with the patient's body and records essential information. This solution will enable the doctor to check the patient's status in real time, maintain a database record, and refer to the information during follow-up visits. In this way, health facilities can ensure coverage, accessibility, and quality of services for visiting patients.

In this paper, the authors are presenting a solution for the existing eHealth infrastructure with the integration of Body Area Network (BAN) and Sensor Network in all the BHUs of Balochistan, and the proposed architecture of the Body Area Network integrated with the existing Telehealth Infrastructure is also presented in Fig. 3. In addressing the barriers patients face in accessing basic health facilities, it is crucial to equip basic health units with BAN-based devices and establish eHealth infrastructure throughout Balochistan. Largely, the lack of adequate public transportation options and the cost of transportation can be a barrier to care [38]. For those living in rural areas or extremely remote locations, the time and distance required to reach the hospital may prevent them from seeking treatment. The Basic Health Units (BHUs) alleviate the burden of transportation challenges, enabling patients to access services easily.

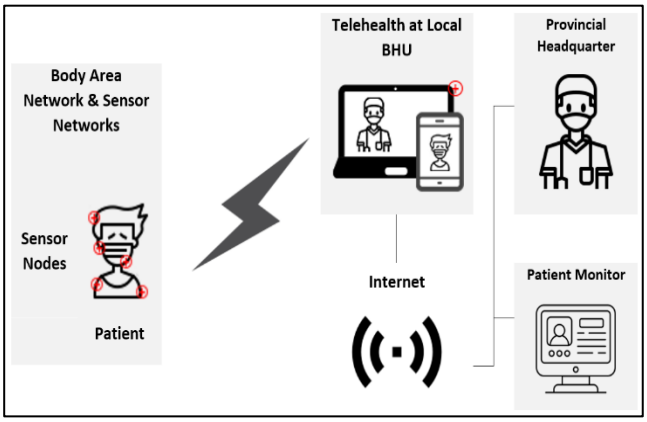

Fig. 3. Proposed Architecture of Body Area Network Integrated with the Existing Telehealth Infrastructure

The BHUs with BAN-enabled devices and connectivity, addressing provincial headquarters, ensure culturally competent services in a setting that may be less intimidating to the patient. It is a great opportunity to introduce communities to basic health units and encourage them to be more receptive to receiving basic health services.

Significant advancements in wireless communications can ensure real-time personal health monitoring through BAN devices [39]. The BAN can be attached to the human body and, with the support of low-powered sensors, connect with telecommunication devices to send real-time reports. The reports can be stored in a central database, and entries can be identified through a unique patient ID. The patient's stored data in the database can be retrieved later during subsequent follow-up visits.

The BAN can be applied in the healthcare sector, as sensor networks can provide interfaces for patient monitoring, diagnosis, and the collection of human physiological data [40]. As mentioned, patient physiological data can be stored in a database through the sensor network for a specified duration. They can be used for diagnostics, medical investigations, and follow-ups [41]. These kinds of sensors attach to patients and can also be installed in basic health units, which will monitor visiting patients in real-time, just like the health smart home designed by the Faculty of Medicine in Grenoble, France [42].

Moreover, sensor networks can be beneficial when prescribing medication to patients. The sensor nodes attached to patients can identify their allergies and support doctors in prescribing the required medications. These sensor nodes can reduce the need for additional tests to identify the correct medication and help minimize the side effects of the medicines [41].

4. Future Directions

Below are some future research directions that stem from the literature review and gaps identified in the critical analysis table regarding the use of Body Area Networks (BAN) in telehealth systems:

The existing telehealth systems do not support real-time feeds from BANs, which makes timely clinical decision-making difficult. Future work can focus on creating adaptive data funnels that integrate high-rate physiological data streams with low latency and minimal data loss during processing.

Most current BAN methods have battery and power challenges for remote applications. Research is needed on lightweight communication protocols and energy harvesting techniques that can prevent the need for frequent sensor charging while maintaining data integrity and accuracy.

The high cost associated with telehealth services and limited connectivity in resource-constrained areas restricts the widespread adoption of BANs. These studies create opportunities to explore sustainable financing options, community-based partnership initiatives, and localized pilot projects to improve accessibility and affordability.

Despite existing encryption methods for BANs, these approaches do not undergo comprehensive evaluation in a low-connectivity testbed. Research focusing on threat modeling emphasizing patient privacy and usability can develop strong and scalable security frameworks for real-world clinical settings.

Finally, the current use of BANs in telemonitoring often employs a one-sensor type, which narrows down the range of monitored parameters. Integrating multiple sensors (ECG, SpO_2, blood pressure) with AI-based analytics can improve predictive monitoring and facilitate timely interventions.

5. Conclusion

This paper concludes that Body Area Networks can be widely used in healthcare services and integrated with existing Telemedicine infrastructure, especially in Balochistan. The paper also discussed how the sensor network can support doctors in properly diagnosing patients and prescribing the required medications while monitoring them remotely. Moreover, the paper also suggests that the entire Basic Health Units (BHUs) of Balochistan province can be connected to the provincial headquarters through telecommunication infrastructure, and sensor networks can be configured with the existing infrastructure using Body Area Networks (BAN). With the support of the BAN, the government can also roll out the smart health system in the province.

6. References

[1] WHO, Primary health care on the road to universal health coverage: 2019 global monitoring report. World Health Organization, 2021. [Online]. Available: https://iris.who.int/handle/10665/344057.

[2] S. A. Javed and F. Ilyas, “Service quality and satisfaction in healthcare sector of Pakistan: the patients’ expectations”, International Journal of Health Care Quality Assurance, vol. 31, no. 6, pp. 489–501, 2018.

[3] K. Taylor, M. Steedman, A. Sanghera, and M. Thaxter, “Medtech and the Internet of Medical Things”, Deloitte, 2020. [Online]. Available: https://www.deloitte.com/middle-east/en/Industries/life-sciences-health-care/research/medtech-internet-of-medical-things.html.

[4] Y. Guan, B. J. Zheng, Y. Q. He, X. L. Liu, Z. X. Zhuang, C. L. Cheung, S. W. Luo, P. H. Li, L. J. Zhang, Y. J. Guan, K. M. Butt, K. L. Wong, K. W. Chan, W. Lim, K. F. Shortridge, K. Y. Yuen, J. S. M. Peiris, and L. L. M. Poon, “Isolation and characterization of viruses related to the SARS coronavirus from animals in southern China”, Science, vol. 302, no. 5643, pp. 276–278, 2003.

[5] J. Karamat, T. Shurong, N. Ahmad, S. Afridi, S. Khan, and N. Khan, “Developing sustainable healthcare systems in developing countries: examining the role of barriers, enablers and drivers on knowledge management adoption”, Sustainability, vol. 11, no. 4, 2019.

[6] S. A. Zaidi and S. A. Sahibzada, “Issues in Pakistan's Health Sector [with Comments]”, The Pakistan Development Review, vol. 25, no. 4, pp. 671–682, 1986.

[7] WHO, Regional Office for the Eastern Mediterranean, Country Cooperation Strategy for WHO and Pakistan: 2011–2017. World Health Organization, 2013. [Online]. Available: https://iris.who.int/handle/10665/113228.

[8] “Community health workers (per 1,000 people) – Pakistan | Data”, data.worldbank.org. [Online]. Available: https://data.worldbank.org/indicator/SH.MED.CMHW.P3?locations=PK.

[9] B. I. Gillani, “Healthcare in Pakistan 2010-2020”, Gallup Pakistan, 2022. [Online].

Available: https://gallup.com.pk/wp/wp-content/uploads/2022/12/Health-pr.pdf.

[10] N. Brohi, M. F. Sohu, and M. Y. Bhatti, “Implementation of Remote Patient Information Monitoring System in Pakistan”, International Journal of Computer Science and Emerging Technologies, vol. 3, no. 1, pp. 9–16, 2019.

[11] J. Wu, X. Tian, and Y. Tan, “Hospital evaluation mechanism based on mobile health for IoT system in social networks”, Computers in Biology and Medicine, vol. 109, pp. 138–147, 2019.

[12] A. Humayun, S. Shahabuddin, S. Afzal, A. A. Malik, S. Atique, and U. Iqbal, “Healthcare strategies and initiatives about COVID-19 in Pakistan: Telemedicine a way to look forward”, Computer Methods and Programs in Biomedicine Update, vol. 1, 2021.

[13] R. S. Khandpur, Telemedicine Technology and Applications (mHealth, TeleHealth and eHealth), 1st ed. New Delhi, India: PHI Learning Pvt. Ltd., pp. 326–353, 2017.

[14] S. Khoja, R. Scott, and S. Gilani, “E-health readiness assessment: Promoting ‘hope’ in healthcare institutions of Pakistan”, World Hospitals and Health Services, vol. 44, no. 1, pp. 36–38, 2008.

[15] D. H. J. Caro, “Deconstructing symbiotic dyadic e-health networks: transnational and transgenic perspectives”, International Journal of Information Management, vol. 28, no. 2, pp. 94–101, 2008.

[16] A. Rauf, F. K. Hamdani, M. Qadir, S. Farid, and M. Alam, “Transformation towards cost-effective and intelligent e-health systems: a regional study”, Technical Journal of University of Engineering & Technology Taxila, vol. 25, no. 4, pp. 36–45, 2020.

[17] N. Ullah, P. Khan, N. Sultana, and K. S. Kwak, “A telemedicine network model for health applications in Pakistan: current status and future prospects”, International Journal of Digital Content Technology and its Applications, vol. 3, no. 3, pp. 149–155, 2009.

[18] “Telehealth Clinics by PPHI Balochistan | PPHI Balochistan”, pphib.org, 2020. https://pphib.org/pphi-b/telemedicine/

[19] A. Ahmed and M. Ahmed, “The telemedicine landscape in Pakistan—why are we falling behind?”, JPMA. The Journal of the Pakistan Medical Association, vol. 68, no. 12, pp. 1820–1822, 2018.

[20] M. H. Nagra, S. Ehsan, U. Ahmad, M. Ali, H. A. Hussain, and A. Bakar, “Retracted: Implementation of a telemedicine service during COVID-19 pandemic in Pakistan”, International Journal of Clinical Practice, vol. 75, no. 8, 2021.

[21] M. H. Salam and S. Jamil, “Virtual clinic: A telemedicine proposal for remote areas of Pakistan”, Proc. 2013 Third World Congress on Information and Communication Technologies (WICT 2013), pp. 46–50, 2013.

[22] J. C. Wang, M. Leach, Z. Wang, E. G. Lim, K. L. Man, and Y. Huang, “Wireless body area network and its applications”, Proc. 2015 International SoC Design Conference (ISOCC), pp. 169–170, 2015.

[23] F. Touati and R. Tabish, “U-healthcare system: State-of-the-art review and challenges”, Journal of Medical Systems, vol. 37, pp. 1–20, 2013.

[24] A. Saboor, A. Mustafa, R. Ahmad, M. A. Khan, M. Haris, and R. Hameed, “Evolution of wireless standards for health monitoring”, Proc. 2019 9th Annual Information Technology, Electromechanical Engineering and Microelectronics Conference (IEMECON), pp. 268–272, 2019.

[25] S. Sharma, A. L. Vyas, B. Thakker, D. Mulvaney, and S. Datta, “Wireless body area network for health monitoring”, Proc. 2011 4th International Conference on Biomedical Engineering and Informatics (BMEI), vol. 4, pp. 2183–2186, 2011.

[26] M. U. H. Al Rasyid, D. Prasetyo, I. U. Nadhori, and A. H. Alasiry, “Mobile monitoring of muscular strain sensor based on Wireless Body Area Network”, Proc. 2015 International Electronics Symposium (IES), pp. 284–287, 2015.

[27] E. Baba, A. Jilbab, and A. Hammouch, “A health remote monitoring application based on wireless body area networks”, Proc. 2018 International Conference on Intelligent Systems and Computer Vision (ISCV), pp. 1–4, 2018.

[28] M. Gowtham and S. S. Ahila, “Privacy enhanced data communication protocol for wireless body area network”, Proc. 2017 4th International Conference on Advanced Computing and Communication Systems (ICACCS), pp. 1–5, 2017.

[29] E. Jovanov, “Wireless technology and system integration in body area networks for m-health applications”, 2005 IEEE Engineering in Medicine and Biology 27th Annual Conference, pp. 7158–7160, 2006.

[30] N. A. Anoop and T. K. Parani, “A real time efficient & secure patient monitoring based on Wireless Body Area Networks”, Proc. 2016 Online International Conference on Green Engineering and Technologies (IC-GET), pp. 1–5, 2016.

[31] B. Braem and C. Blondia, “An analysis of requirements to supporting mobility in body area networks”, Proc. 2012 International Conference on Computing, Networking and Communications (ICNC), pp. 89–93, 2012.

[32] A. Hafeez-Baig, S. Grist, and R. Gururajan, “Technology management, data management, improved outcomes, efficiency and software limitation influencing the use of wireless technology for healthcare in Pakistan”, Proc. 6th IEEE/ACIS International Conference on Computer and Information Science (ICIS 2007), pp. 1104–1110, 2007.

[33] B. Ahmed, B. Haq, K. Ali, and M. Iqbal, “Adaptability of automated information systems by the development sector in developing countries: a case study”, 2021 International Conference on Computing, Electronic and Electrical Engineering (ICE Cube), pp. 1–6 2021.

[34] World Health Organization. “World Bank and WHO: Half the world lacks access to essential health services, 100 million still pushed into extreme poverty because of health expenses”. Press Release 13 (2017).

[35] S. Zaidi, N. Idrees, and A. Riaz, “Primary health care systems (primasys): comprehensive case study from Pakistan”, World Health Organization, 2017. [Online]. Available: https://iris.who.int/handle/10665/341143.

[36] A. Mehrotra, M. E. Chernew, D. Linetsky, H. Hatch, and D. M. Cutler, “The impact of the COVID-19 pandemic on outpatient visits: A rebound emerges”, To the Point (blog), Commonwealth Fund, updated May 19, 2020. [Online]. Available: https://doi.org/10.26099/ds9e-jm36.

[37] S. Saeed and I. Zafar, “Annual Report 2019”, Sehat Kahani, 2019. Available: https://sehatkahani.com/wp-content/uploads/2019/07/SK-AnnualReport2019-compressed.pdf

[38] A. Islam, “Health sector reform in Pakistan: why is it needed?”, Journal of Pakistan Medical Association, vol. 52, no. 3, pp. 95–100, 2002.

[39] A. Rangarajan, “Emerging trends in healthcare adoption of wireless body area networks”, Biomedical Instrumentation & Technology, vol. 50, no. 4, pp. 264–276, 2016.

[40] N. Noury, T. Herve, V. Rialle, G. Virone, E. Mercier, G. Morey, A. Moro, and T. Porcheron, “Monitoring behavior in home using a smart fall sensor and position sensors”, Proc. 1st Annual International IEEE-EMBS Special Topic Conf. on Microtechnologies in Medicine and Biology (Cat. No.00EX451), pp. 607–610, 2000, doi: 10.1109/MMB.2000.893857.

[41] A. Sinha and A. Chandrakasan, “Dynamic power management in wireless sensor networks”, IEEE Design & Test of Computers, vol. 18, no. 2, pp. 62–74, 2001.

[42] V. Rialle, F. Duchene, N. Noury, L. Bajolle, and J. Demongeot, “Health ‘smart’ home: information technology for patients at home”, Telemedicine Journal and E-Health, vol. 8, no. 4, pp. 395–409, 2002.

[43] W. Bilal, K. Qamar, A. Siddiqui, P. Kumar, and M. Y. Essar, “Digital health and telemedicine in Pakistan: Improving maternal healthcare”, Annals of Medicine and Surgery, vol. 81, 2022.

[44] D. M. G. Preethi Chandra, L. Piyathilaka, U. Izhar, R. Samarasinghe, and L. C. De Silva, “Wireless Body Area Networks and Their Applications—A Review”, IEEE Access, vol. 11, pp. 9202–9220, 2023.

[45] K. Kennedy, “The Relationship Between Clinical Integration, Interoperability, and Patient Engagement in Electronic Health Records in the United States: A Socio-economic Health Study”, Ph.D. dissertation, Northcentral University, 2023.

[46] A. C. Intorne, K. K. S. Batista, A. Deshpande, R. Sroufer, R. T. Lopes, F. Shi, and Y. D. Lin, “Intelligent Healthcare Systems”, Intelligent Healthcare Systems, V. V. Estrela, Ed. Boca Raton, FL, USA: CRC Press, pp. 259–278, 2023.

[47] Rishabha Malviya and P. Goyal, Remote Patient Monitoring: A Computational Perspective in Healthcare. CRC Press, 2023.