

Article

Improving Healthcare Facilities in Remote Areas Using Cutting-Edge Technologies

Mamoona Humayun ^{1,*}, Maram Fahaad Almufareh ¹, Fatima Al-Quayed ², Sulaiman Abdullah Alateyah ³ and Mohammed Alatiyyah ⁴

- ¹ Department of Information Systems, College of Computer and Information Sciences, Jouf University, Sakaka 72388, Saudi Arabia; mfulmufareh@ju.edu.sa
- ² Department of Computer Science, College of Computer and Information Sciences, Jouf University, Sakaka 72388, Saudi Arabia; ffalquayed@ju.edu.sa
- ³ Department of Computer Science, College of Science and Arts, Qassim University, Unaizah 52571, Saudi Arabia; salateyah@qu.edu.sa or dr.salateyah@gmail.com
- ⁴ Department of Computer Science, College of Sciences and Humanities-Aflaj, Prince Sattam Bin Abdulaziz University, Al-Kharj 16278, Saudi Arabia; m.alatiyyah@psau.edu.sa
- * Correspondence: mahumayun@ju.edu.sa

Abstract: Healthcare is a critical field of research and equally important for all nations. Providing secure healthcare facilities to citizens is the primary concern of each nation. However, people living in remote areas do not get timely and sufficient healthcare facilities, even in developed countries. During the recent COVID-19 pandemic, many fatalities occurred due to the inaccessibility of healthcare facilities on time. Therefore, there is a need to propose a solution that may help citizens living in remote areas with proper and secure healthcare facilities without moving to other places. The revolution in ICT technologies, especially IoT, 5G, and cloud computing, has made access to healthcare facilities easy and approachable. There is a need to benefit from these technologies so that everyone can get secure healthcare facilities from anywhere. This research proposes a framework that will ensure 24/7 accessibility of healthcare facilities by anyone from anywhere, especially in rural areas with fewer healthcare facilities. In the proposed approach, the patients will receive doorstep treatment from the remote doctor in rural areas or the nearby local clinic. Healthcare resources (doctor, treatment, patient counseling, diagnosis, etc.) will be shared remotely with people far from these facilities. The proposed approach is tested using mathematical modeling and a case study, and the findings confirm that the proposed approach helps improve healthcare facilities for remote patients.

Keywords: healthcare; pandemic; remote areas; IoT; 5G; cloud computing



Citation: Humayun, M.; Almufareh, M.F.; Al-Quayed, F.; Alateyah, S.A.; Alatiyyah, M. Improving Healthcare Facilities in Remote Areas Using Cutting-Edge Technologies. *Appl. Sci.* **2023**, *13*, 6479. <https://doi.org/10.3390/app13116479>

Academic Editor: Dimitris Mourtzis

Received: 8 April 2023
Revised: 8 May 2023
Accepted: 23 May 2023
Published: 25 May 2023



Copyright: © 2023 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (<https://creativecommons.org/licenses/by/4.0/>).

1. Introduction

Access to healthcare facilities is challenging in rural areas of the country due to constraints such as long distances to care sites, lack of secure telehealth services, travel sites, staffing shortages, etc. According to [1–4], travel time to get specialist treatment for chronic illnesses, including cardiovascular disease, chronic kidney disease (CKD), and cancer, may increase morbidity and mortality in far-off places since it is a factor that can be changed to improve results [5,6]. Even within a relatively limited geographic area, increased healthcare consumption and superior outcomes are strongly correlated with shorter travel times to healthcare services and the availability of such services at the nearest location. To enhance service and healthcare outcomes for rural communities, careful planning is needed to optimally locate future healthcare facilities [7,8].

In recent years, the death toll from heart disease, cancer, and stroke has decreased in almost every country, but not uniformly between urban and rural regions, even in industrialized nations such as the United States [9,10]. The rural-urban health gap in the United States is widening as rural improvements slow or regress. As can be seen

in Figure 1, the discrepancy between rural and urban America's death rates has tripled over the previous 20 years. The reasons for this gap include a lack of healthcare facilities equipped to handle severe trauma emergencies in rural locations.

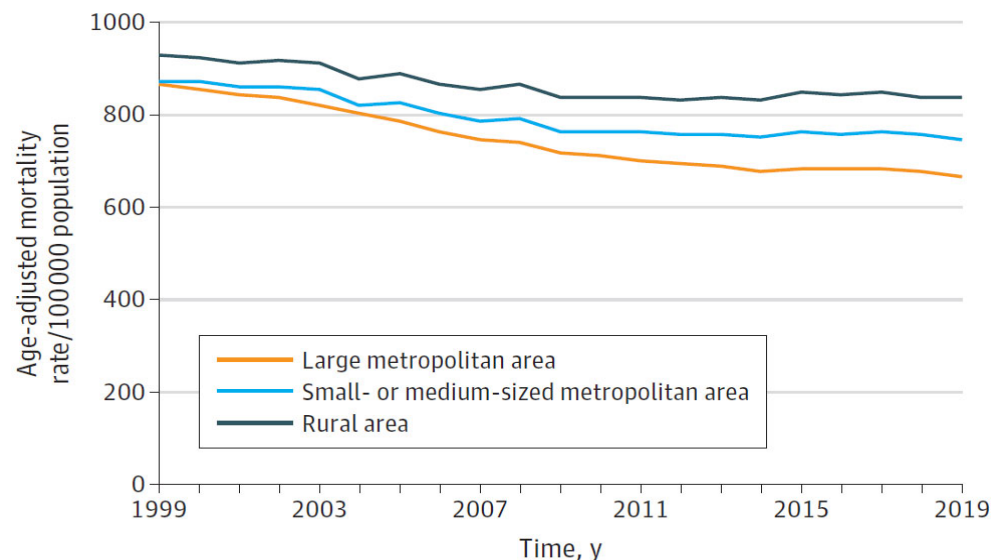


Figure 1. Death rate disparity between urban and rural areas in the US [11].

Healthcare problems, especially pandemic situations such as COVID-19, may emerge fortnightly without alarming and allowing time for preparation to fight against it globally [12]. These pandemics and other fatal healthcare problems always bring a higher level of community losses in several aspects until the world reaches some conclusion to defeat it. Emerging technologies, including 5G, the Internet of Things (IoT), cloud computing, and artificial intelligence (AI), can help the community fight and provide the right ways of treatment and timely availability of healthcare facilities [13]. This research plans to use the emerging power of the mentioned technologies to improve remote healthcare facilities. These technologies can benefit healthcare in the following way: improving healthcare facilities and reaching patients remotely require more internet speed and bandwidth, which has become possible with the emergence of 5G internet [14]. Furthermore, monitoring patients' health remotely is now possible with the help of the latest ICT, especially IoT devices [15]. The massive amount of patients' data generated by IoT devices can also be easily stored using cloud computing technology. This massive amount of data can be further reused for various predictions using AI techniques [16]. IoT, cloud computing, 5G, and AI have made healthcare more accessible and successful.

Considering the benefits of the above-mentioned technologies, this study leverages the potential benefits of these technologies and proposes a framework to bridge the gap between urban and rural areas. The explicit contribution of this research is as follows:

- Examine the use cases of IoT, 5G, cloud computing, and AI in healthcare
- Propose an approach to provide doorstep healthcare facilities to people living in remote areas.
- Design and develop a model based on IoT, cloud computing, 5G, and AI for the timely accessibility of healthcare facilities by anyone and anywhere
- Provide insight into making design strategies and policies to manage healthcare facilities

The above-stated points will be achieved by presenting an effective model using the IoT, cloud computing, 5G, and AI since these technologies have already proved their effectiveness in healthcare. The remaining paper is organized into five sections: Section 2 will provide the essential use cases of suggested cutting-edge technologies in healthcare and a brief overview of existing literature to provide the current state of the art. Section 3 will discuss the proposed methodology; Section 4 will evaluate the proposed methodology with

the help of mathematical modeling and a case study; and Section 5 will discuss our findings. Finally, the paper will conclude in Section 6 by providing insights into future work.

2. Background

This section will explore the relationship of suggested technologies with healthcare to better understand the proposed solution and the motivations behind it. Further, it will review rural communities' potential healthcare challenges and the existing solutions to find the current gaps and propose a solution based on the identified gaps.

2.1. 5G Use Cases in Healthcare

When it comes to digital healthcare transformation, 5G is at the forefront, and its potential applications in the healthcare sector are exciting. High-speed data transfers and real-time, high-quality internet access are made possible by 5G, allowing both local and distant authorities to link their medical equipment and workers on a centralized network [17–19]. Some critical use cases of 5G in healthcare include (a) telemedicine in which health-related information and services are sent remotely via data networks and telecommunications systems, (b) remote patient monitoring and surgery using wearables and eHealth devices, (c) real-time patient data/information (sensors and HD videos) flowing between the hospital and the ambulance to connect the ambulance service, etc. [20–23]. Some other use cases of 5G in healthcare are shown in Figure 2.

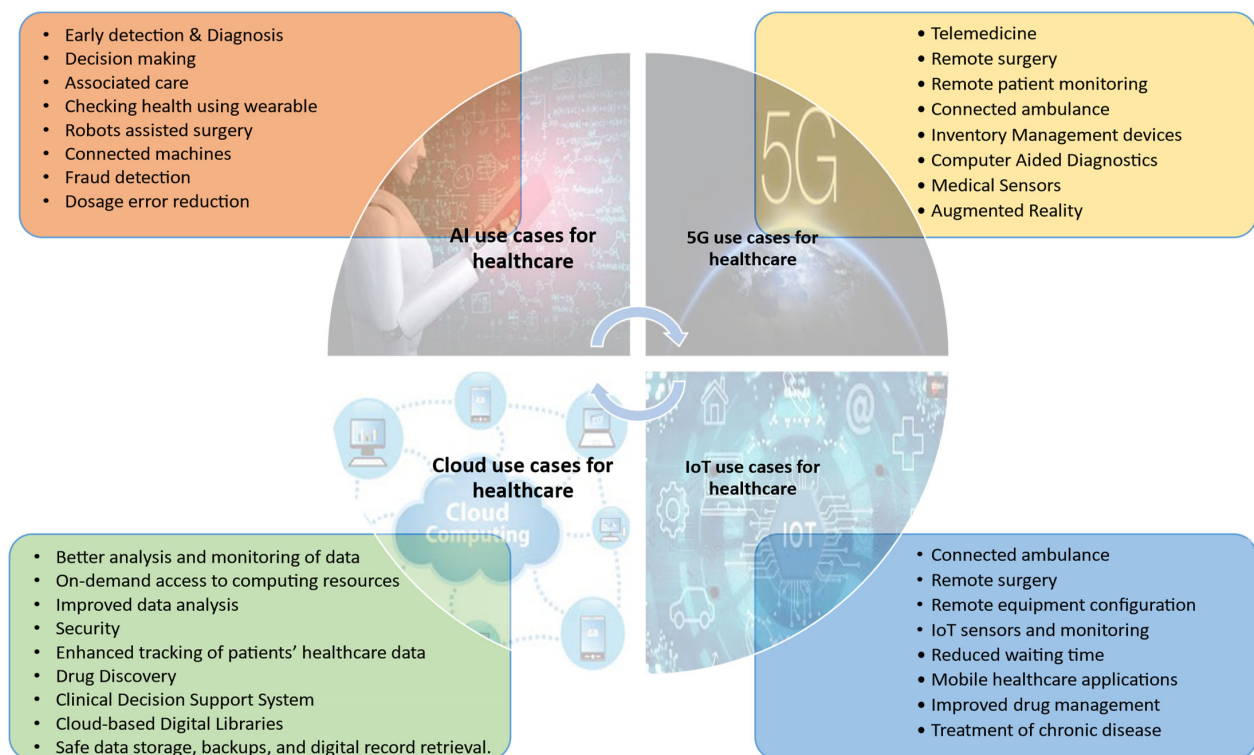


Figure 2. 5G, IoT, cloud, and AI use cases for healthcare.

2.2. IoT Use Cases in Healthcare

We often think of intelligent sensors and connected hospitals when considering the IoT in the healthcare sector. However, the answers go beyond this. Spending on IoT solutions in healthcare is expected to reach USD 1 trillion by 2025 [24]. The IoT has the potential to assist healthcare providers in offering high-quality, cost-effective, and individually tailored healthcare services to a broader population. Several applications exist for healthcare IoT, such as remote health monitoring and transmitting real-time alarms [25]. Some compelling use cases of IoT in healthcare are remote patient monitoring, emergency care, staff monitoring, inventory tracking, and virtual monitoring, etc. [20,26–29].

2.3. Cloud Computing Use Cases in Healthcare

Since the COVID-19 pandemic, cloud computing in healthcare has become more prevalent. With a predicted global market size of \$25.54 billion by 2024, the importance of cloud computing in the healthcare industry cannot be overstated. Undoubtedly, cloud computing is an essential tool for the healthcare business to provide a first-rate, person-centered service to its patients [30]. Among the crucial applications of cloud computing in healthcare are the following [31–35]:

- Improved analysis and monitoring of data pertaining to the diagnosis and treatment of various illnesses
- Massive storage capacity for huge electronic health record (EHR) and radiological imaging files
- Capability to offer access to computer resources on-demand
- Sharing EHR with only authorized physicians, doctors, and hospitals in various parts of the globe allows rapid access to life-saving information and decreases the need for redundant testing
- Better data analysis
- Enhanced monitoring of patients' health information

2.4. AI Use Cases in Healthcare

AI can automate operations and analyze large patient data sets to provide better healthcare sooner and at lower costs. Insider Intelligence estimates that 30% of healthcare budgets are spent on administration. Time and resources spent by healthcare workers on administrative tasks such as insurance pre-authorization and billing follow-up may be saved if AI were to automate these tasks [27,33,36–38]. According to research compiled by Insider Intelligence, 30% of healthcare budgets are spent on administrative costs [39]. AI has the potential to save healthcare providers' time and money by automating tasks such as insurance pre-authorization, invoice follow-up, and record keeping. AI is being integrated into wearable medical equipment to serve patients better. FitBits and smartwatches driven by AI might analyze data to warn users and physicians about potential health risks. One may lessen the load on doctors and avoid unnecessary hospitalizations and readmissions by using health monitoring technologies [40–42].

2.5. Literature Review

The applicability of 5G wireless transmission technologies in healthcare was reviewed in a paper by Li [14]. It underlines the possible obstacles to 5G technology availability. According to this study, there are still considerable obstacles to providing healthcare services to a population growing older. Recent observations have prompted concerns about the rising expenses of healthcare, the imbalance of medical resources, the ineffective management of the healthcare system, and uncomfortable medical encounters. To meet these challenges, however, cutting-edge technologies, such as the IoT, big data, AI, and 5G wireless transmission technology, are being developed to improve the efficacy of healthcare services while lowering the overall cost of healthcare. According to the conclusions of the research, these new technologies are starting to influence and transform healthcare substantially. A survey was performed by Jenesn et al. [43], and the analyses found several conclusions that contributed to the following four major themes: rural communities have their own culture, rural mental health workers face particular problems, rural communities face barriers to mental healthcare, and new ideas are required to overcome these barriers. According to a study by Iglehart [44], there is a persistent shortage of physicians, dentists, pharmacists, and non-physician providers; a wave of hospital closures; and a deepening gap in life expectancy between urban and rural inhabitants. According to a study by Taqi et al. [45], planners, researchers, and healthcare providers should pay close attention to the accessibility and availability of health facilities and the delivery of high-quality services in rural areas. In this context, the current paper identifies and evaluates the inequalities in health infrastructure availability and accessibility in India's rural areas. According to Dassah et al. [46], access to primary healthcare is a fundamental

human right and a critical component of healthcare system performance; unfortunately, people with disabilities face more obstacles to PHC than the general population. According to Lanksono et al. [47], in Indonesia, there is a discrepancy in hospital utilization as an outpatient and as an outpatient-inpatient at the same time in urban and rural regions. Further, gender, marital status, education level, job type, socioeconomic status, insurance, travel time, and transportation expenses all contribute to the discrepancy in hospital utilization. The applicability of 5G wireless transmission technologies in healthcare is reviewed in Paper 15. It underlines the potential obstacles to 5G technology availability.

According to a study by Bhattacharya [48], 5G has exceptionally low latency and one hundred times faster data transmission than the current 4G network. In the field of healthcare, this characteristic of 5G will provide quicker internet connection for large items and medical equipment, as well as enhanced bandwidth, coverage, and accessibility. 5G is not a single technology or standard but rather an amalgamation of emerging technologies, including big data, cloud computing, AI, supercomputing, the IoT, and digital security capabilities such as blockchain. Together, they will create an ecosystem that will transform the fields of medical training and research, remote diagnosis and treatment, smart ambulance and emergency services, home care for the elderly and their recovery, and even remote surgery.

The research by Rahman et al. [49] examines the relationship between 5G technology and present healthcare concerns and identifies 5G-based solutions that can address COVID-19 issues in various settings. This study thoroughly analyzes 5G technology and the integration of other digital technologies in developing healthcare applications. The study's findings indicate that 5G's promising features have the potential to advance healthcare, and that the healthcare industry is currently adopting 5G-based technologies. These features include improved health services, enhanced quality of life, more effective medical research, and better experiences for medical professionals and patients. This study further highlights the growing role of 5G technology in addressing epidemiological concerns. The paper also covers a variety of technical obstacles and opportunities associated with the development of 5G-powered healthcare solutions.

Hameed et al. [50] presented an IoT with a cloud-based clinical decision support system for illness prediction and severity level monitoring by integrating 5G services and blockchain technology. The proposed framework gathers patient data through medical devices linked to the patient, which are kept on a cloud server with pertinent medical documents. Blockchain and 5G technology enable the secure transfer of patient data at a rapid transmission rate with an adequate reaction time. In addition, a neural network (NN) classifier is used to forecast illnesses and their severity, and different classifiers are used to validate the proposed model.

The above discussion highlights the importance of the latest ICT technologies in improving the healthcare sector; however, we did not find any study that explicitly uses these technologies to provide 24/7 healthcare facilities to patients living in remote/rural areas with fewer healthcare facilities. Table 1 provides a comparison of existing studies to better understand the current state of the art.

Table 1. Comparison of existing studies.

Paper	Problem Discussed	Solution Proposed	Research Methodology Used	Gaps
[14]	Improving digital healthcare	Explore the applications of 5G wireless transmission technology in healthcare	Review of existing studies	Validation is missing
[43]	This investigation sought to better understand the barriers to mental health care for rural individuals	Understand the barriers rural residents face in obtaining mental healthcare	Semi-structured interviews	The sample size (8) is very small for generalizing results

Table 1. Cont.

Paper	Problem Discussed	Solution Proposed	Research Methodology Used	Gaps
[44]	Rural issues such as life expectancy gaps, the ACA, rural health workforce expansion, and rural hospital closures are discussed in this report	Provide the list of efforts needed to expand the rural health workforce, and the pace of rural hospital closures	Review for comparing the major issues between rural and urban areas	Validation is missing
[45]	Inadequate healthcare infrastructure in rural areas	Examine the disparities in the availability and accessibility of health infrastructure in rural India	Review of current healthcare facilities in rural areas of India	Findings are based on secondary data
[46]	This study explored the factors affecting access to PHC for PWDs in rural areas globally	Modify the access framework to better understand PHC access challenges and opportunities in rural settings	Review of existing studies	The number of studies used for evaluation was not sufficient for generalization
[47]	The disparity in hospital utilization between urban-rural areas in Indonesia	Illustrate the differences between hospital utilization in urban and rural areas	Data analysis based on data collected in 2013	Validation is missing
[48]	The benefits of using 5G technologies in healthcare	Highlight the role of cutting-edge technologies in healthcare	Review of existing studies	Findings are not validated
[49]	Role of cutting-edge technologies in improving healthcare	A thorough analysis of 5G technology and its integration with other digital technologies	Review of existing studies	Validation is missing
[50]	Integrating 5G services and blockchain technologies with IoT and a cloud-based CDSS framework for the prediction of disease and its severity level through the use of 5G services	Propose a framework to collect patients' data to predict diseases and their severity level using blockchain and 5G technology with a neural network (NN) classifier	Employing different classifiers	Using one algorithm instead of examining the data by using different algorithms

3. Proposed Framework

The above discussion shows that the key reason behind the death rate disparity between urban and rural areas is the lack of healthcare facilities in both areas. Although the mortality rate in rural areas is decreasing with time, there is still a need to provide 24/7 healthcare facilities and access to remote areas. A framework is proposed to address this need, as shown in Figure 3. The proposed framework leverages the potential benefits of modern cutting-edge technologies and provides healthcare facilities to patients living in remote areas. According to the proposed framework, healthcare centers in remote areas are connected with the healthcare professionals of urban areas, e.g., doctors, nurses, ambulances, pharmacists, etc., through the 5G internet. In urban areas, the healthcare system is fully automated, and the overall data of the hospital are transferred to the cloud through the 5G internet; these big data are stored in the cloud and are mined using AI techniques to extract useful information. Healthcare centers in remote areas are connected to the cloud to get information about healthcare professionals. Thus, timely remote medical care is provided to patients who cannot reach the city healthcare center due to the limitations of time and money.

In the proposed framework, the remote patient request for healthcare facilities is handled using the process mentioned in Algorithm 1.

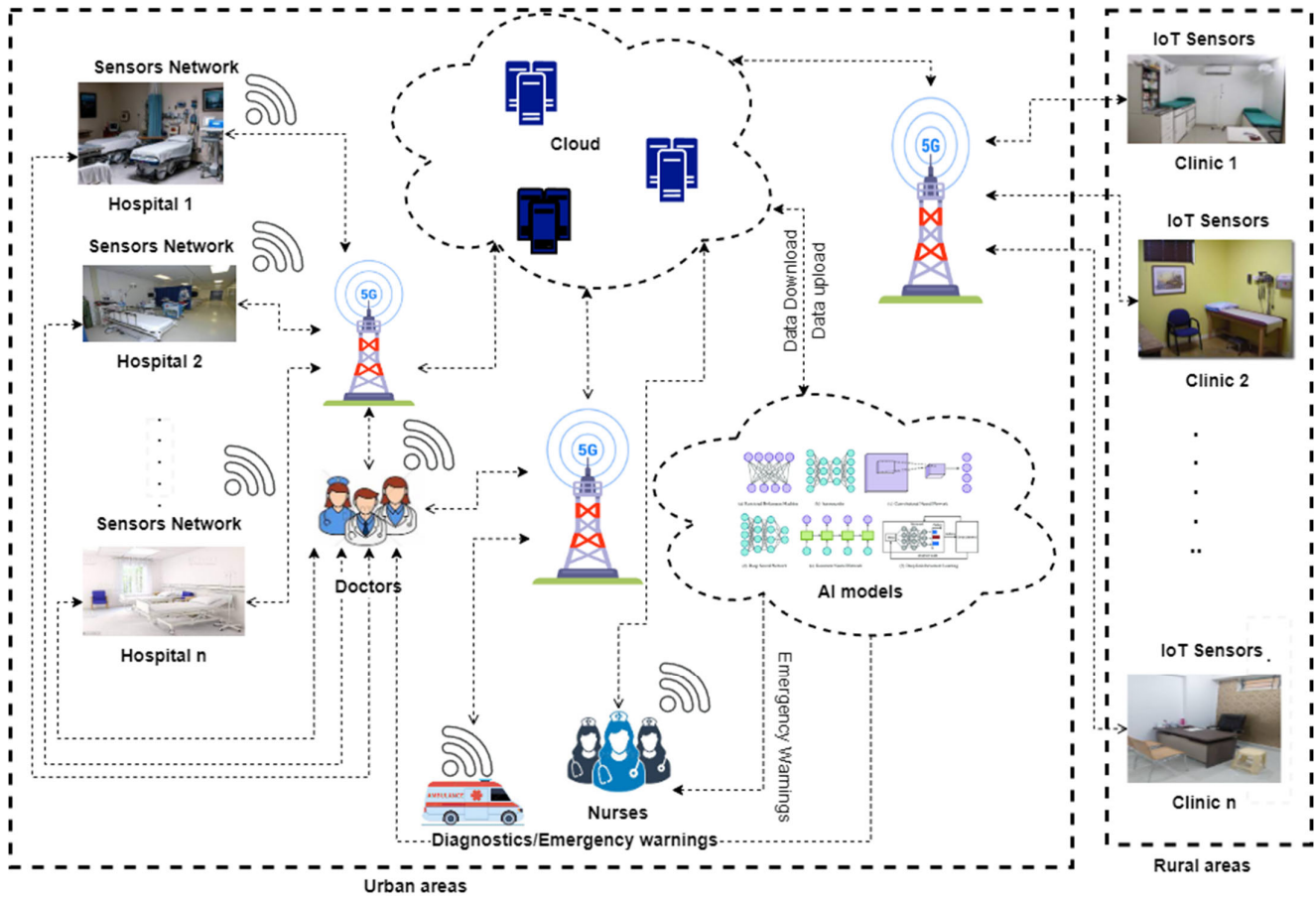


Figure 3. Proposed methodology.

Algorithm 1 Working of Proposed Methodology

Let ρ denote remote patient; $\gamma\rho$ = physician in remote areas with limited healthcare facilities; Γ = telehealth system; θ = patients' vital signs; ∂ = doctor; $\mathbb{C}$ = cloud; I = IoT sensors; $\mathfrak{H}$ = laboratory; $\wp$ = pharmacist; $\mathbb{F}$ = 5G; $\mathcal{T}$ = treatment

1. **Begin**
2. $\rho \rightarrow \text{register}(\Gamma)$ // remote patient is registered to telehealth system
3. $I \rightarrow \text{Collect}(\theta)$ // patient's vital signs are collected through IoT sensors
4. $\text{Transmit}(\theta) \rightarrow \mathbb{C} \rightarrow \mathbb{F}$ // patient's vital signs are transmitted to the cloud using 5G
5. $\gamma\rho \rightarrow \text{Receive}(\theta) \rightarrow \mathbb{C}$ // remote physician receives vital signs through cloud
- If handling(θ) $\rightarrow \gamma\rho = \text{true}$ // remote physician will first try to handle the patient if he can
 - Then send $\mathcal{T} \rightarrow \rho$ // remote physician will suggest treatment for the remote patient
 - Else forward(θ) $\rightarrow \Gamma \rightarrow (\mathbb{F}, \mathbb{C})$ // remote physician will forward vital signs to telehealth system through cloud & 5G
6. $\Gamma \rightarrow \text{Observe}(\theta)$ // telehealth system observes vitals
 - If $\theta \rightarrow \partial$ // if vitals show that remote patient needs consultation
 - Send(θ) $\rightarrow \partial$ // telehealth system forwards vitals to the doctor
 - Else if $\theta \rightarrow \mathfrak{H}$ // if vitals show that remote patient needs consultation Send
 - (θ) $\rightarrow \mathfrak{H}$ // telehealth system forward vitals to the lab
 - Else if $\theta \rightarrow \wp$ // if vitals show that remote patient needs medicines
 - Send(θ) $\rightarrow \wp$ // telehealth system forward vitals to the pharmacy
7. $\Gamma \rightarrow \text{Receive}(\mathcal{T})$ // treatment is received by the telehealth system
8. $\Gamma \rightarrow \text{Forward}(\mathcal{T}) \rightarrow \gamma\rho \rightarrow (\mathbb{F}, \mathbb{C})$ // telehealth system forward the treatment details to a remote physician
9. $\gamma\rho \rightarrow \text{Prescribe}(\mathcal{T}) \rightarrow \rho$ // remote physician prescribes treatment to the remote patient
10. **End**

4. Mathematical Modeling

This section will evaluate the proposed approach mathematically; our objective function is to optimize healthcare facilities in remote areas under the constraints of limited healthcare facilities. Equation (1) models our objective function

$$\Theta F = \max f(\mathcal{T}||[d_i]) \text{ s.t } \partial \in \Omega \quad (1)$$

where $f(\mathcal{T}||[d_i])$ is the objective function, $\mathcal{T}$ is the treatment provided to the remote patient, $[d_i]$ is the set of decision variables, and Ω is the constraint set (or feasible set). Minimize and subject to are shortened to min. and s.t., respectively. The $[d_i]$ include four variables as shown in Equation (2):

$$d_i = \{\vartheta, \Gamma, S, \mathcal{G}\} \quad (2)$$

$$\text{While } \Omega \in \{I, \mathbb{C}, \mathbb{F}, A\} \quad (3)$$

According to Equation (2), correct vitals, a working telehealth system, accurate patient status, and proper clinical guidelines are the key decision variables to facilitate healthcare facilities in remote areas. Equation (3) describes the constraints that are necessary for optimizing decision variables. These constraints include the proper working of IoT sensors to collect vitals, full-time 5G internet availability to transmit patient vitals to the cloud, and AI algorithms applied to the data fetched through the cloud to get useful information.

The remote patient participating in a treatment process according to a clinical guideline $\mathcal{G}$ often follows a cyclical procedure. In this loop, the patient is in constant contact with his physician. Data on his health are gathered automatically through IoT sensors and uploaded to the cloud, where a treating physician may keep a close eye on things from afar. Different status S is proposed related to the proper therapy or diagnostic approach depending on the more adequate clinical guideline $\mathcal{G}$ and the vitals of the patient ϑ . Depending on the patient's condition and the established therapeutic criteria, a remote physician may alter the course of therapy. Therapy outcomes are affected by a patient's response to the treatment, which might vary based on the patient's disease and other personal factors. These findings will be included as new iteration entries in the subsequent cycle. The therapy in this approach is the conversation system's response to the patient's symptoms. A physician's daily procedure includes iterative analyses of patient data, current status S , and applicable clinical guidelines $\mathcal{G}$ to bring the patient's condition into compliance with the guidelines. The doctor can change the patient's status if they see fit. That is, using therapy or a diagnostic approach that goes beyond the recommendations of established practice standards. Suppose a doctor thinks the patient's severity is low, while the evidence suggests it is high, for instance. In that case, he may downgrade the patient's status and use the therapies recommended by the clinical guidelines for low severity cases. If he thinks the patient's condition is dire, he may consult an expert panel through the telehealth system.

$$\tilde{S} = \max_s \rho(S|\mathcal{G}, S^\emptyset) \quad (4)$$

$$= \max_s \rho(\mathcal{G}|S) \rho(S|S^\emptyset) \quad (5)$$

In order to prescribe the proper treatment to the patient, the status of the patient should be best represented by $\tilde{S}$ in Equations (4) and (5), where the status can be maximized based on clinical guidelines followed by the patient and the previous status of the patient such that vitals are correct.

$$\tilde{\mathcal{G}} = \max_{\mathcal{G}} \rho(\mathcal{G}|\vartheta, S, \vartheta^\emptyset, \Gamma) \quad (6)$$

$$= \max_{\mathcal{G}} \rho(\vartheta, S|\mathcal{G}, \vartheta^\emptyset, \Gamma) \rho(\mathcal{G}|\Gamma, \vartheta^\emptyset) \quad (7)$$

According to Equations (6) and (7), clinical guidelines need to be maximized to get proper treatment, which is only possible when the patient's vitals are captured accurately, and the patient's status is best. Furthermore, the previous vitals record is also there, and the telehealth system is working correctly.

$$\tilde{\Gamma} = \max_{\Gamma} \rho(I|\vartheta, \mathbb{F}, \mathbb{C}, S, \vartheta^{\check{}}) \quad (8)$$

$$= \max_{\Gamma} \rho(\vartheta|I) \max_{\Gamma} \rho(I|\mathbb{F}, \mathbb{C}, S, \vartheta^{\check{}}) \quad (9)$$

According to Equations (8) and (9), the telehealth system should be working and available all the time to remote physicians to provide proper treatment. It is only possible when IoT sensors are working correctly so that patients' vitals can be collected in a timely manner, IoT data are transferred to the cloud using 5G, and previous status and vitals are available.

$$\tilde{\vartheta} = \max_{\vartheta} \rho(I|\vartheta, \vartheta^{\check{}}) \quad (10)$$

$$= \max_{\vartheta} \rho(g|I) \max_{\vartheta} \rho(I|\vartheta^{\check{}}) \quad (11)$$

According to Equations (10) and (11), vital signs must be correct, which is only possible if the remote patient follows the clinical guidelines and the IoT sensors are working correctly to capture vitals. Furthermore, the previous vitals collected through IoT sensors are also available and correct.

Based on Equations (4)–(11), our objective function can be modeled as

$$\Theta F = \max f(\mathcal{T}[d_i]) \triangleright \max(\tilde{S}, \tilde{\vartheta}, \tilde{\Gamma}, \tilde{\vartheta}) \iff \Omega(I, \mathbb{C}, \mathbb{F}, A) \quad (12)$$

$$\begin{aligned} \max_{S, \rho}(S|\vartheta, S^{\check{}}) \cap \max_{\vartheta, \rho}(\vartheta|S, S, \vartheta^{\check{}}, \Gamma) \cap \max_{\Gamma, \rho}(I|\vartheta, \mathbb{F}, \mathbb{C}, S, \vartheta^{\check{}}) \\ \cap \max_{\vartheta, \rho}(I|\vartheta, \vartheta^{\check{}}) \Omega(I, \mathbb{C}, \mathbb{F}, A) \end{aligned} \quad (13)$$

Thus

$$\Theta F = \bigcup_{i=1}^4 d_i \doteq f(\tilde{S}, \tilde{\vartheta}, \tilde{\Gamma}, \tilde{\vartheta}) \Vdash \Omega(I, \mathbb{C}, \mathbb{F}, A) \quad (14)$$

The individual impact of every decision variable on objective function can be evaluated using partial derivatives of Equation (14) as shown in Equations (15)–(18):

$$f_{\Theta F_{\tilde{S}}} = \frac{\partial d}{\partial \tilde{S}}(\Theta F) = \frac{\partial d}{\partial \tilde{S}}(\tilde{S}) + \frac{\partial d}{\partial \tilde{S}}(\tilde{\vartheta}) + \frac{\partial d}{\partial \tilde{S}}(\tilde{\Gamma}) + \frac{\partial d}{\partial \tilde{S}}(\tilde{\vartheta}) + \varepsilon \quad (15)$$

$$f_{\Theta F_{\tilde{\vartheta}}} = \frac{\partial d}{\partial \tilde{\vartheta}}(\Theta F) = \frac{\partial d}{\partial \tilde{\vartheta}}(\tilde{S}) + \frac{\partial d}{\partial \tilde{\vartheta}}(\tilde{\vartheta}) + \frac{\partial d}{\partial \tilde{\vartheta}}(\tilde{\Gamma}) + \frac{\partial d}{\partial \tilde{\vartheta}}(\tilde{\vartheta}) + \varepsilon \quad (16)$$

$$f_{\Theta F_{\tilde{\Gamma}}} = \frac{\partial d}{\partial \tilde{\Gamma}}(\Theta F) = \frac{\partial d}{\partial \tilde{\Gamma}}(\tilde{S}) + \frac{\partial d}{\partial \tilde{\Gamma}}(\tilde{\vartheta}) + \frac{\partial d}{\partial \tilde{\Gamma}}(\tilde{\Gamma}) + \frac{\partial d}{\partial \tilde{\Gamma}}(\tilde{\vartheta}) + \varepsilon \quad (17)$$

$$f_{\Theta F_{\tilde{\vartheta}}} = \frac{\partial d}{\partial \tilde{\vartheta}}(\Theta F) = \frac{\partial d}{\partial \tilde{\vartheta}}(\tilde{S}) + \frac{\partial d}{\partial \tilde{\vartheta}}(\tilde{\vartheta}) + \frac{\partial d}{\partial \tilde{\vartheta}}(\tilde{\Gamma}) + \frac{\partial d}{\partial \tilde{\vartheta}}(\tilde{\vartheta}) + \varepsilon \quad (18)$$

For optimization, we need a threshold value to determine whether the optimization is achieved or not. Let τ_1, τ_2, τ_3 , and τ_4 be the preferences/threshold values set for

$\tilde{S}$, $\tilde{\vartheta}$, $\tilde{\Gamma}$, and $\tilde{\vartheta}$ respectively. Then, the comfort index C_i will be calculated using the formula mentioned in Equation (19):

$$C_i = \tau_1 - \left(\frac{e_1}{\tilde{S}} \right)^2 + \tau_2 - \left(\frac{e_2}{\tilde{\vartheta}} \right)^2 + \tau_3 - \left(\frac{e_3}{\tilde{\Gamma}} \right)^2 + \tau_4 - \left(\frac{e_4}{\tilde{\vartheta}} \right)^2 \quad (19)$$

where $\tau_1 + \tau_2 + \tau_3 + \tau_4 = 1$ and e_1, e_2, e_3 , and e_4 represent differences between actual values and estimated values.

Let $T(n_1), T(n_2), T(n_3), \dots$ be the execution time taken to transfer vitals between various components of the proposed methodology and $P(n_1), P(n_2), P(n_3), \dots$ be the probability that a particular transfer will be done successfully. Then, the average case time complexity of the proposed model will be calculated using the formula given in Equation (20):

$$T(n_1)P(n_1) + T(n_2)P(n_2) + T(n_3)P(n_3), \dots, T(n_n)P(n_n) \quad (20)$$

The suggested framework's throughput varies in various places. The quantity of data transmitted successfully from one location to another in a certain time period is measured in bits per second (bps). When data from various sources are stored in the cloud, the storage throughput is estimated based on the quantity of data that can be received and written to the storage medium. Thus, the throughput of the proposed model will be calculated using the formula mentioned below:

$$TH = \frac{N}{T} + \frac{S}{T} \quad (21)$$

where N refers to the number of requests and T refers to the time in which certain transmission or storage requests are received, while S refers to the number of storage requests in a particular amount of time.

In the proposed system, quick information transmission is required since healthcare data are particularly sensitive and require fast delivery and reaction. As a result, the delay should be as short as possible. The proposed framework's delay will be determined using the methodology shown below.

$$Delay = \frac{P}{T} + \frac{D}{S} \quad (22)$$

where P is the packet size, T is the time taken to transmit a packet, D is the distance between the sender and the receiver, and S is the speed of the link.

Now, we evaluate the proposed model using a case study. The description of the case study is as follows:

Case Study

Bob is a cardiac patient who uses wearable sensors to monitor his vital signs. He lives in a rural region with few medical services. In his neighborhood, 5G internet service is available, and Bob is using his smartphone to take advantage of it. Bob's vital signs are recorded by wearable sensors and assessed using threshold vital sign values. If the vital signs are aberrant, they are transmitted immediately through 5G to the cloud, where AI algorithms operate to predict abnormal vital signs. AI algorithms evaluate vital signs and classify them into normal and abnormal vital signs. The abnormal vital signs are then accessed by the doctor from the cloud. The doctor determines the severity of Bob's vitals by evaluating his vitals following clinical standards and his prior health. He sends the patient's vitals to the telehealth system if he determines they are of high severity. The telehealth system monitors Bob's vitals and then selects from the three available alternatives. (1) If it considers that vitals severity is high and an expert panel needs to be contacted, then it transmits vitals to the expert panel. The expert panel evaluates vitals and sends prescriptions back to the telehealth system using 5G and the cloud. The telehealth

system sends this prescription to the remote physician via the cloud. The remote physician accesses the prescription and sends it to Bob through a smartphone app installed on Bob's smartphone. (2) If the telehealth system considers that vitals need lab examinations, then it transmits the vitals to the lab experts. The lab experts evaluate the vitals and send the required diagnostics using 5G and the cloud to the telehealth system. The telehealth system sends these diagnostic details to the remote physician via the cloud. The remote physician accesses the diagnostic information and sends it to Bob through a smartphone app installed on Bob's smartphone. (3) If the telehealth system considers that vitals need medicines based on the prescriptions received by the doctor, then it transmits vitals to the pharmacy. The pharmacist evaluates vitals and dispatches the required medicines to the telehealth system using 5G and the cloud. The telehealth system sends medicine details to the remote physician via the cloud. Remote physicians access the medicine details and send them to Bob through a smartphone app installed on Bob's smartphone.

The detailed working of the case study is shown in the sequence diagram in Figure 4. The aforementioned case study scenario is a success if all the requirements (IoT sensors are operational, the patient follows clinical recommendations, 5G is operational, healthcare data are stored and retrieved through the cloud, the telehealth system is operational, etc.) listed in the objective function are met. The timely accessibility of a healthcare facility to a remote patient will be impacted, nevertheless, if any of the aforementioned constraints are not present.

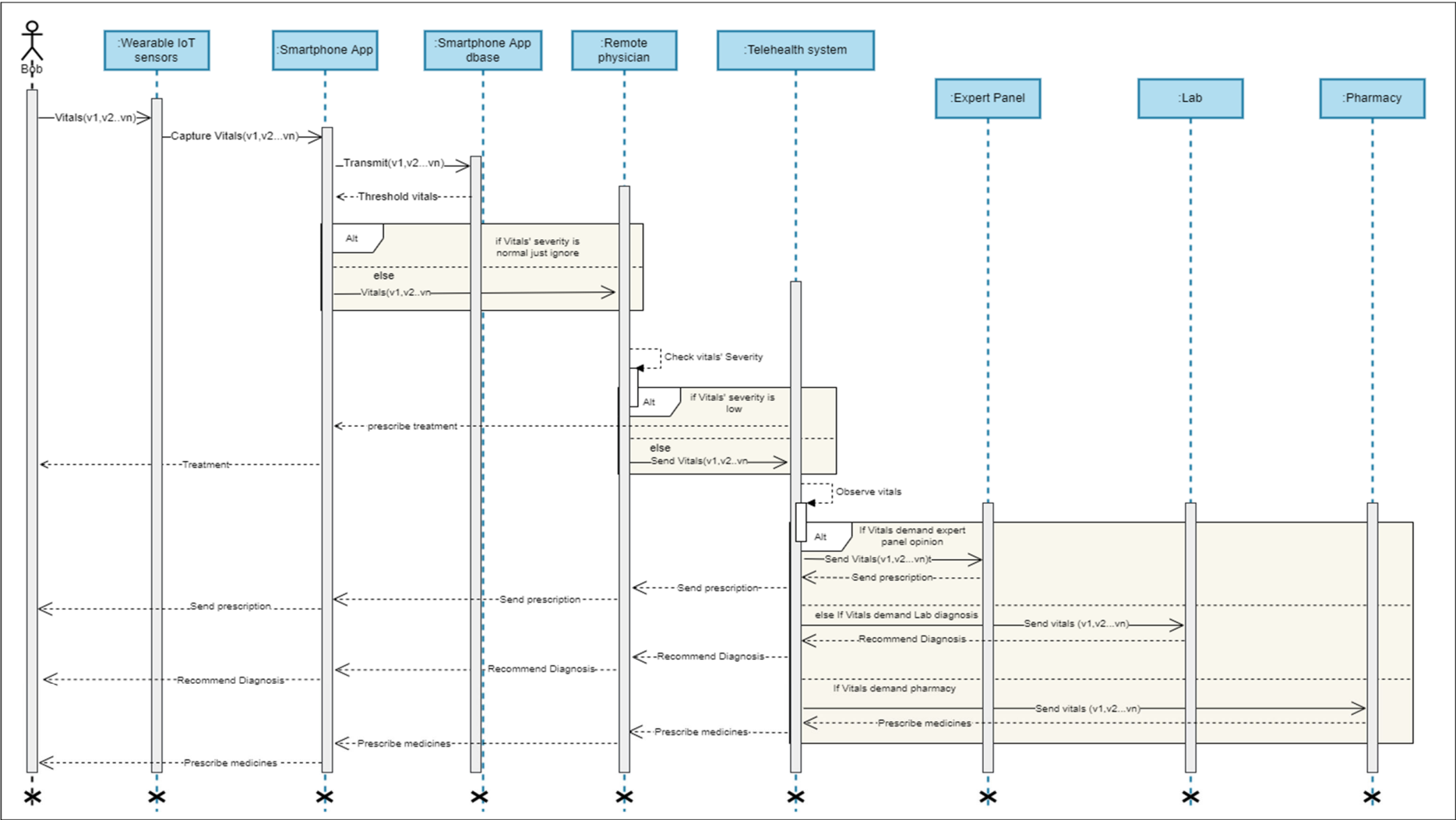


Figure 4. Detailed working of the case study.

5. Discussion

High regional inequalities are often brought about by concentrated economic activity and growth in one specific area. Urban regions are often where economic activity is concentrated. In the end, inequities develop in every subject, including the realm of health. The hospital is often constructed in metropolitan areas as a basic health treatment facility. It seems understandable that a hospital would be built in this metropolitan location. The main motivation is to guarantee that community access is made simpler due to the availability of improved mobility options, including infrastructure and public transit. Every healthcare system has adopted equal access to hospitals, patient happiness, and respect for patient wishes as fundamental principles. Health planners and policymakers primarily focus on disentangling or downgrading inequities in healthcare consumption. This has to be done as part of the endeavor to raise the performance indicator for the healthcare system [47,51].

Further, the COVID-19 pandemic gave us a peek at how the healthcare business will continue to grow using cutting-edge technologies. It also highlighted the significance of remotely monitoring and treating patients. It is anticipated that IoT, 5G, and cloud computing will play a crucial role in the future of healthcare by linking everything from wearables to emergency services, medical campuses, and hospitals [52]. By lowering latency, enhancing dependability, and boosting security, new healthcare use cases will be enabled and will profit from the availability of these innovative technologies.

This study makes use of IoT, 5G, cloud, and AI technologies, which have the potential to be very beneficial. After examining how these technologies are used and how they enhance healthcare, this article offers patients, particularly those who reside in rural locations with few healthcare options, a remote healthcare alternative. The study aims to provide distant patients with the best care possible while adhering to specific limitations. The suggested strategy assumes that the patient and doctor are in constant communication. IoT sensors affixed to the patient's body gather his vital signs. If there is any irregularity in the vitals, the smart application on the patient's smartphone quickly sends data through 5G to the cloud [53,54]. The doctor accesses patients' information from the cloud and evaluates their vitals. If the vital signs are somewhat out of the ordinary, the doctor will prescribe medicine and deliver it to the patient through the cloud, 5G, and a smartphone app. If the doctor determines that the severity of the vitals is high, he connects to the healthcare facilities using telehealth technology and sends the vitals to the appropriate healthcare division. In this manner, patients get prompt medical attention, even in rural areas. A real-life case study and mathematical modeling were used to assess the proposed system. The findings imply that cutting-edge contemporary technologies help enhance healthcare facilities.

Constraint and Limitation

The study proposed the use of cutting-edge technologies to provide remote access to healthcare facilities. However, a few implementation details mentioned in the proposed methodology are generic to make it more flexible. Further, 5G is provided as a means of communication between various healthcare entities, while 5G is not implemented completely yet, especially in remote areas. How the organization will use cloud computing facilities and in which capacity, what ML algorithms and techniques will be used for prediction and detection of vitals is also mentioned generically so that healthcare organizations may tailor it according to their needs.

6. Conclusions and Future Work

Healthcare is one of the most significant fields of study and the nation's top priority. However, even in industrialized nations, individuals living in distant places cannot access timely and adequate healthcare services. Many deaths occurred during the recent COVID-19 outbreak due to the inaccessibility of healthcare services. Therefore, this study suggests a strategy that might provide residents in distant locations with adequate and safe healthcare services without requiring them to relocate. The suggested solution uses new, creative technology and proposes a strategy that would make healthcare facilities accessible 24/7,

and from any place, particularly in rural regions where healthcare facilities are few. In the proposed method, patients would receive care at their homes from a remote doctor in rural regions or a nearby local clinic. Remotely accessible healthcare resources (physician, treatment, patient counseling, diagnosis, etc.) would be made available to those who live far away from healthcare facilities. The suggested method is evaluated using mathematical modeling and a case study; the results confirm that the technique is beneficial for enhancing healthcare services for distant patients.

In the future, we plan to augment the suggested framework with other novel technologies, such as big data and edge computing. In addition, we want to confirm our results by applying the proposed paradigm to a real-world scenario.

Author Contributions: Conceptualization, M.H., M.A. and F.A.-Q.; methodology, M.H. and M.F.A.; validation, M.H., M.A. and F.A.-Q.; formal analysis, S.A.A. and M.A.; investigation, M.A. and M.F.A.; writing—original draft preparation, M.H.; writing—review and editing, S.A.A., M.F.A. and M.A.; visualization, M.A.; funding acquisition, M.A. and S.A.A. All authors have read and agreed to the published version of the manuscript.

Funding: This study is supported by funding from Prince Sattam bin Abdulaziz University project number (PSAU/2023/R/1444).

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Acknowledgments: This study is supported by funding from Prince Sattam bin Abdulaziz University project number (PSAU/2023/R/1444).

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Darkwa, E.K.; Newman, M.S.; Kawkab, M.; Chowdhury, M.E. A Qualitative Study of Factors Influencing Retention of Doctors and Nurses at Rural Healthcare Facilities in Bangladesh. *BMC Health Serv. Res.* **2015**, *15*, 344. [CrossRef] [PubMed]
2. Olatomiwa, L.; Blanchard, R.; Mekhilef, S.; Akinyele, D. Hybrid Renewable Energy Supply for Rural Healthcare Facilities: An Approach to Quality Healthcare Delivery. *Sustain. Energy Technol. Assess.* **2018**, *30*, 121–138. [CrossRef]
3. Weiss, D.J.; Nelson, A.; Vargas-Ruiz, C.A.; Gligorić, K.; Bavadekar, S.; Gabrilovich, E.; Bertozzi-Villa, A.; Rozier, J.; Gibson, H.S.; Shekel, T.; et al. Global Maps of Travel Time to Healthcare Facilities. *Nat. Med.* **2020**, *26*, 1835–1838. [CrossRef] [PubMed]
4. Wilson, N.; Couper, I.; De Vries, E.; Reid, S.; Fish, T.; Marais, B. A Critical Review of Interventions to Redress the Inequitable Distribution of Healthcare Professionals to Rural and Remote Areas. *Rural Remote Health* **2009**, *9*, 1060. [CrossRef] [PubMed]
5. Dadkhah, M.; Mehraeen, M.; Rahimnia, F.; Kimiafar, K. Use of Internet of Things for Chronic Disease Management: An Overview. *J. Med. Signals Sens.* **2021**, *11*, 138–157. [CrossRef]
6. Raji, A.; Jeyasheeli, P.G.; Jenitha, T. IoT Based Classification of Vital Signs Data for Chronic Disease Monitoring. In Proceedings of the 2016 10th International Conference on Intelligent Systems and Control (ISCO), Tamilnadu, India, 7–8 January 2016; IEEE: Coimbatore, India, 2016; pp. 1–5. [CrossRef]
7. Wang, F. Measurement, Optimization, and Impact of Health Care Accessibility: A Methodological Review. *Ann. Assoc. Am. Geogr.* **2012**, *102*, 1104–1112. [CrossRef]
8. Ayyalasomayajula, B.; Wiebe, N.; Hemmelgarn, B.R.; Bello, A.; Manns, B.; Klarenbach, S.; Tonelli, M. A Novel Technique to Optimize Facility Locations of New Nephrology Services for Remote Areas. *Clin. J. Am. Soc. Nephrol.* **2011**, *6*, 2157–2164. [CrossRef]
9. Spencer, J.C.; Wheeler, S.B.; Rotter, J.S.; Holmes, G.M. Decomposing Mortality Disparities in Urban and Rural U.S. Counties. *Health Serv. Res.* **2018**, *53*, 4310–4331. [CrossRef]
10. Liu, Q.; Zhang, L.; Li, J.; Zuo, D.; Kong, D.; Shen, X.; Guo, Y.; Zhang, Q. The Gap in Injury Mortality Rates between Urban and Rural Residents of Hubei Province, China. *BMC Public Health* **2012**, *12*, 180. [CrossRef]
11. Sound Health and Lasting Wealth-Health Is Wealth. Available online: <https://www.soundhealthandlastingwealth.com/> (accessed on 3 May 2023).
12. Ogunkola, I.O.; Adebisi, Y.A.; Imo, U.F.; Odey, G.O.; Esu, E.; Lucero-Prisno, D.E. Rural Communities in Africa Should Not Be Forgotten in Responses to COVID-19. *Int. J. Health Plan. Manag.* **2020**, *35*, 1302–1305. [CrossRef]
13. Ye, J. The Role of Health Technology and Informatics in a Global Public Health Emergency: Practices and Implications from the COVID-19 Pandemic. *JMIR Med. Inform.* **2020**, *8*, e19866. [CrossRef] [PubMed]

14. Li, D. 5G and Intelligence Medicine—How the next Generation of Wireless Technology Will Reconstruct Healthcare? *Precis. Clin. Med.* **2019**, *2*, 205–208. [CrossRef]
15. Tiwari, S.; Dhanda, D.N.; Dev, D.H.; Pandey, D. A Hybrid Framework Based on IoT and Blockchain Network to Store the Patient Health Data. *Math. Stat. Eng. Appl.* **2022**, *71*, 330–339. [CrossRef]
16. Humayun, M. Role of Emerging IoT Big Data and Cloud Computing for Real Time Application. *Int. J. Adv. Comput. Sci. Appl.* **2020**, *11*, 110466. [CrossRef]
17. Qureshi, H.N.; Manalastas, M.; Ijaz, A.; Imran, A.; Liu, Y.; Al Kalaa, M.O. Communication Requirements in 5G-Enabled Healthcare Applications: Review and Considerations. *Healthcare* **2022**, *10*, 293. [CrossRef]
18. Sodhro, A.H.; Awad, A.I.; Beek, J.V.D.; Nikolakopoulos, G. Intelligent Authentication of 5G Healthcare Devices: A Survey. *Internet Things* **2022**, *20*, 100610. [CrossRef]
19. Moglia, A.; Georgiou, K.; Marinov, B.; Georgiou, E.; Berchiolli, R.N.; Satava, R.M.; Cuschieri, A. 5G in Healthcare: From COVID-19 to Future Challenges. *IEEE J. Biomed. Health Inform.* **2022**, *26*, 4187–4196. [CrossRef]
20. Gupta, M.; Chaudhary, G.; De Albuquerque, V.H.C. (Eds.) *Smart Healthcare Monitoring Using IoT with 5G: Challenges, Directions, and Future Predictions*, 1st ed.; Internet of Everything (IoE): Security and Privacy Paradigm; CRC Press: Boca Raton, FL, USA, 2022.
21. Tarikere, S.; Donner, I.; Woods, D. Diagnosing a Healthcare Cybersecurity Crisis: The Impact of IoMT Advancements and 5G. *Bus. Horiz.* **2021**, *64*, 799–807. [CrossRef]
22. Paramita, S.; Bebartta, H.N.D.; Pattanayak, P. IoT Based Healthcare Monitoring System Using 5G Communication and Machine Learning Models. In *Health Informatics: A Computational Perspective in Healthcare*; Patgiri, R., Biswas, A., Roy, P., Eds.; Springer: Singapore, 2021; Volume 932, pp. 159–182. [CrossRef]
23. Siriwardhana, Y.; Gür, G.; Ylianttila, M.; Liyanage, M. The Role of 5G for Digital Healthcare against COVID-19 Pandemic: Opportunities and Challenges. *ICT Express* **2021**, *7*, 244–252. [CrossRef]
24. Pratiti Technologies. Available online: <https://www.pratititech.com/7-amazing-use-cases-of-iot-in-healthcare/> (accessed on 3 May 2023).
25. Ullah, A.; Azeem, M.; Ashraf, H.; Alaboudi, A.A.; Humayun, M.; Jhanjhi, N. Secure Healthcare Data Aggregation and Transmission in IoT—A Survey. *IEEE Access* **2021**, *9*, 16849–16865. [CrossRef]
26. Sharma, A.; Kaur, S.; Singh, M. A Comprehensive Review on Blockchain and Internet of Things in Healthcare. *Trans. Emerg. Telecommun. Technol.* **2021**, *32*, e4333. [CrossRef]
27. Alshamrani, M. IoT and Artificial Intelligence Implementations for Remote Healthcare Monitoring Systems: A Survey. *J. King Saud Univ.-Comput. Inf. Sci.* **2022**, *34*, 4687–4701. [CrossRef]
28. Ahmad, M.O.; Siddiqui, S.T. The Internet of Things for Healthcare: Benefits, Applications, Challenges, Use Cases and Future Directions. In *Advances in Data and Information Sciences*; Tiwari, S., Trivedi, M.C., Kolhe, M.L., Mishra, K.K., Singh, B.K., Eds.; Springer: Singapore, 2022; Volume 318, pp. 527–537. [CrossRef]
29. Azbeg, K.; Ouchetto, O.; Andaloussi, S.J.; Fetjah, L. A Taxonomic Review of the Use of IoT and Blockchain in Healthcare Applications. *IRBM* **2022**, *43*, 511–519. [CrossRef]
30. Kleinerman, K. Applications of Cloud Computing in Healthcare. Ridge Cloud. Available online: <https://www.ridge.co/blog/cloud-computing-in-healthcare/> (accessed on 3 May 2023).
31. Pareek, K.; Tiwari, P.K.; Bhatnagar, V. Fog Computing in Healthcare: A Review. *IOP Conf. Ser. Mater. Sci. Eng.* **2021**, *1099*, 012025. [CrossRef]
32. Farid, F.; Elkhodr, M.; Sabrina, F.; Ahamed, F.; Gide, E. A Smart Biometric Identity Management Framework for Personalised IoT and Cloud Computing-Based Healthcare Services. *Sensors* **2021**, *21*, 552. [CrossRef] [PubMed]
33. Yadav, S.; Kaushik, A.; Sharma, S. Simplify the Difficult: Artificial Intelligence and Cloud Computing in Healthcare. In *IoT and Cloud Computing for Societal Good*; Verma, J.K., Saxena, D., González-Prida, V., Eds.; Springer International Publishing: Cham, Switzerland, 2022; pp. 101–124. [CrossRef]
34. Ijaz, M.; Li, G.; Lin, L.; Cheikhrouhou, O.; Hamam, H.; Noor, A. Integration and Applications of Fog Computing and Cloud Computing Based on the Internet of Things for Provision of Healthcare Services at Home. *Electronics* **2021**, *10*, 1077. [CrossRef]
35. Ali, S.; Hafeez, Y.; Jhanjhi, N.Z.; Humayun, M.; Imran, M.; Nayyar, A.; Singh, S.; Ra, I.-H. Towards Pattern-Based Change Verification Framework for Cloud-Enabled Healthcare Component-Based. *IEEE Access* **2020**, *8*, 148007–148020. [CrossRef]
36. Secinaro, S.; Calandra, D.; Secinaro, A.; Muthurangu, V.; Biancone, P. The Role of Artificial Intelligence in Healthcare: A Structured Literature Review. *BMC Med. Inform. Decis. Mak.* **2021**, *21*, 125. [CrossRef]
37. Jiang, F.; Jiang, Y.; Zhi, H.; Dong, Y.; Li, H.; Ma, S.; Wang, Y.; Dong, Q.; Shen, H.; Wang, Y. Artificial Intelligence in Healthcare: Past, Present and Future. *Stroke Vasc. Neurol.* **2017**, *2*, 230–243. [CrossRef]
38. Yu, K.-H.; Beam, A.L.; Kohane, I.S. Artificial Intelligence in Healthcare. *Nat. Biomed. Eng.* **2018**, *2*, 719–731. [CrossRef]
39. US Healthcare Industry in 2023: Analysis of the Health Sector, Healthcare Trends, & Future of Digital Health. Insider Intelligence. Available online: <https://www.insiderintelligence.com/insights/healthcare-industry/> (accessed on 3 May 2023).
40. Turner, D.; Pera, A. Wearable Internet of Medical Things Sensor Devices, Big Healthcare Data, and Artificial Intelligence-Based Diagnostic Algorithms in Real-Time COVID-19 Detection and Monitoring Systems. *Am. J. Med. Res.* **2021**, *8*, 132. [CrossRef]
41. Barnes, R.; Zvarikova, K. Artificial Intelligence-Enabled Wearable Medical Devices, Clinical and Diagnostic Decision Support Systems, and Internet of Things-Based Healthcare Applications in COVID-19 Prevention, Screening, and Treatment. *Am. J. Med. Res.* **2021**, *8*, 9. [CrossRef]

42. Nahavandi, D.; Alizadehsani, R.; Khosravi, A.; Acharya, U.R. Application of Artificial Intelligence in Wearable Devices: Opportunities and Challenges. *Comput. Methods Programs Biomed.* **2022**, *213*, 106541. [[CrossRef](#)] [[PubMed](#)]
43. Jensen, E.J.; Wieling, E.; Mendenhall, T. A Phenomenological Study of Clinicians' Perspectives on Barriers to Rural Mental Health Care. *J. Rural Ment. Health* **2020**, *44*, 51–61. [[CrossRef](#)]
44. Iglehart, J.K. The Challenging Quest to Improve Rural Health Care. *N. Engl. J. Med.* **2018**, *378*, 473–479. [[CrossRef](#)] [[PubMed](#)]
45. Taqi, M.; Bidhuri, S.; Sarkar, S.; Ahmad, W.S.; Wangchok, P. Rural Healthcare Infrastructural Disparities in India: A Critical Analysis of Availability and Accessibility. *J. Multidiscip. Res. Healthc.* **2017**, *3*, 125–149. [[CrossRef](#)]
46. Dassah, E.; Aldersey, H.; McColl, M.A.; Davison, C. Factors Affecting Access to Primary Health Care Services for Persons with Disabilities in Rural Areas: A “Best-Fit” Framework Synthesis. *Glob. Health Res. Policy* **2018**, *3*, 36. [[CrossRef](#)] [[PubMed](#)]
47. Laksono, A.D.; Dwi Wulandari, R.; Soedirham, O. Urban and Rural Disparities in Hospital Utilization among Indonesian Adults. *Iran. J. Public Health* **2019**, *48*, 247–255. [[CrossRef](#)]
48. Bhattacharya, S. The Impact of 5G Technologies on Healthcare. *Indian J. Surg.* **2022**. [[CrossRef](#)]
49. Rahman, M.M.; Khatun, F.; Sami, S.I.; Uzzaman, A. The Evolving Roles and Impacts of 5G Enabled Technologies in Healthcare: The World Epidemic COVID-19 Issues. *Array* **2022**, *14*, 100178. [[CrossRef](#)]
50. Hameed, K.; Bajwa, I.S.; Sarwar, N.; Anwar, W.; Mushtaq, Z.; Rashid, T. Integration of 5G and Block-Chain Technologies in Smart Telemedicine Using IoT. *J. Healthc. Eng.* **2021**, *2021*, 1–18. [[CrossRef](#)] [[PubMed](#)]
51. Song, Y.; Tan, Y.; Song, Y.; Wu, P.; Cheng, J.C.P.; Kim, M.J.; Wang, X. Spatial and Temporal Variations of Spatial Population Accessibility to Public Hospitals: A Case Study of Rural–Urban Comparison. *GIScience Remote Sens.* **2018**, *55*, 718–744. [[CrossRef](#)]
52. Humayun, M.; Jhanjhi, N.Z.; Almotilag, A. Real-Time Security Health and Privacy Monitoring for Saudi Highways Using Cutting-Edge Technologies. *Appl. Sci.* **2022**, *12*, 2177. [[CrossRef](#)]
53. Capolongo, S.; Gola, M.; Brambilla, A.; Morganti, A.; Mosca, E.I.; Barach, P. COVID-19 and healthcare facilities: A decalogue of design strategies for resilient hospitals. *Acta Bio Med. Atenei Parm.* **2020**, *91*, 50. [[CrossRef](#)]
54. Brambilla, A.; Sun, T.Z.; Elshazly, W.; Ghazy, A.; Barach, P.; Lindahl, G.; Capolongo, S. Flexibility during the COVID-19 pandemic response: Healthcare facility assessment tools for resilient evaluation. *Int. J. Environ. Res. Public Health* **2021**, *18*, 11478. [[CrossRef](#)]

Disclaimer/Publisher’s Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.