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Abstract

Due to the COVID-19 pandemic, the world has faced a significant challenge in the increase of the rate of morbidity and mortality among people, particularly the elderly aged patients. The risk of acquiring infections may increase during the visit of patients to the hospitals. The utilisation of technology such as the 1cInternet of Things (IoT) 1d based on Fog Computing and Cloud Computing turned out to be efficient in enhancing the healthcare quality services for the patients. The present paper aims at gaining a better understanding and insights into the most effective and novel IoT-based applications such as Cloud Computing and Fog Computing and their implementations in the healthcare field. The research methodology employed the collection of the information from the databases such as PubMed, Google Scholar, MEDLINE, and Science Direct. There are five research articles selected after 2015 based on the inclusion and exclusion criteria set for the study. The findings of the studies included in this paper indicate that IoT-based Fog Computing and Cloud Computing increase the delivery of healthcare quality services to patients. The technology showed high efficiency in terms of convenience, reliability, safety, and cost-effectiveness. Future studies are required to incorporate the models that provided the best quality services using the Fog and Cloud Computation techniques for the different user requirements. Moreover, edge computing could be used to significantly enhance the provision of health services at home.

Integration and Applications of Fog Computing and Cloud Computing Based on the Internet of Things for Provision of Healthcare Services at Home

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Abstract: Due to the COVID-19 pandemic, the world has faced a significant challenge in the increase of the rate of morbidity and mortality among people, particularly the elderly aged patients. The risk of acquiring infections may increase during the visit of patients to the hospitals. The utilisation of technology such as the "Internet of Things (IoT)" based on Fog Computing and Cloud Computing turned out to be efficient in enhancing the healthcare quality services for the patients. The present paper aims at gaining a better understanding and insights into the most effective and novel IoT-based applications such as Cloud Computing and Fog Computing and their implementations in the healthcare field. The research methodology employed the collection of the information from the databases such as PubMed, Google Scholar, MEDLINE, and Science Direct. There are five research articles selected after 2015 based on the inclusion and exclusion criteria set for the study. The findings of the studies included in this paper indicate that IoT-based Fog Computing and Cloud Computing increase the delivery of healthcare quality services to patients. The technology showed high efficiency in terms of convenience, reliability, safety, and cost-effectiveness. Future studies are required to incorporate the models that provided the best quality services using the Fog and Cloud Computation techniques for the different user requirements. Moreover, edge computing could be used to significantly enhance the provision of health services at home.

Keywords: home hospitalization; internet of things; fog computing; cloud computing; health care; patients; healthcare staff

1. Introduction

The COVID-19 pandemic affected the entire world. On the one hand, it slowed down economic, educational and social activities, and on the other hand, it increased the morbidity and mortality among the people [1]. In the first wave, the highest number of deaths were recorded in Italy and Spain. It was noticed that the virus can spread rapidly through respiratory droplets via coughing and sneezing. It was also documented that the virus can cause more harm to the people involved in chronic diseases such as diabetes, cardiovascular disorders, and chronic respiratory infections. Elderly people turned out to be more suffered from the risk of infections and a higher number of deaths have been recorded among people with the age above 60 years old [2]. Home hospitalization is one of the alternatives that must be adopted by the government to limit the virus spread. Indeed, the COVID-19 spread is most often occurred due to people meeting. In this case, one of the

best procedures that must be adopted by individuals and governments is to remotely treat patients at their homes [3].

Home hospitalisation is one of the smart models in the healthcare practices that facilitate the people by providing the care treatment processes at home (Figure 1). This method is considered to be efficient in reducing the patient's suffers and continuous care can be provided to the patients by reducing the risk of infections [4]. It was documented that the method of home hospitalisation showed high efficiency for the patients as well as for the staff of healthcare centres as it permits to decrease the disease burden by two means.
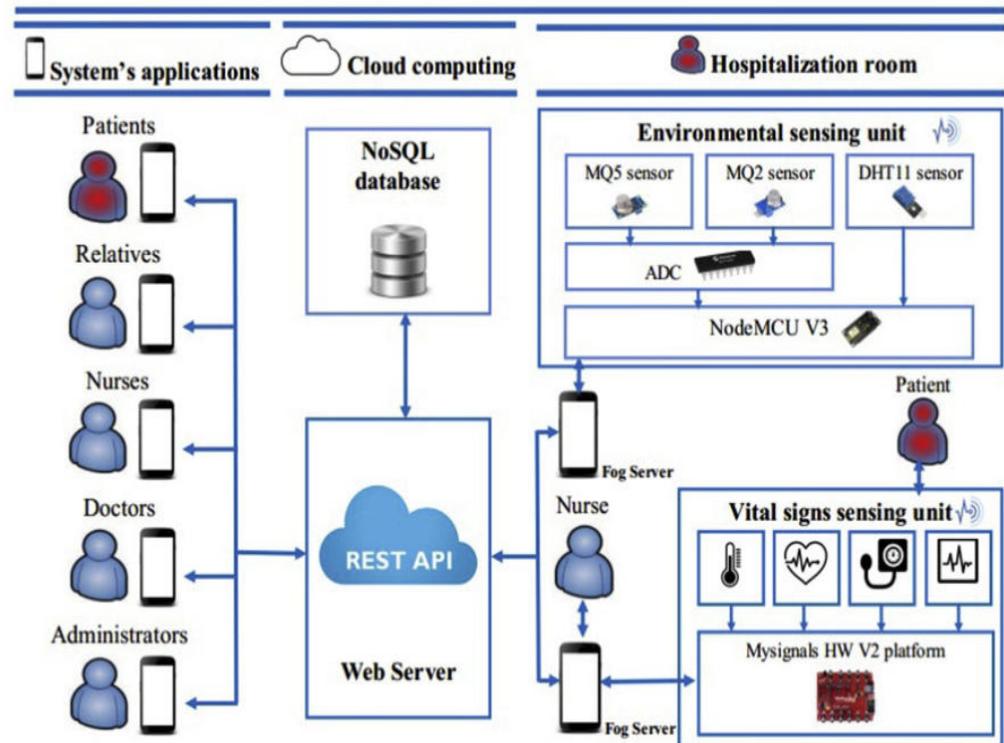

Figure 1. General layout of the home hospitalisation system proposed in the previous research study14. (Source: Hassen et al., 2020).

Firstly, home hospitalisation allows the medical treatment to be in the home environment. This treatment in the family environment has positive impacts on human health, and consequently results in the fast recovery of patients and increases their satisfaction. Secondly, home hospitalisation is also efficient in terms of economic aspects as it decreases the treatment cost.

However, for the success of home hospitalisation, the environmental factors must be maintained and monitored by the healthcare staff as they can affect patients' health and recovery [5].

In recent years, advanced technologies such as the Internet of Things (IoT) permit to easily monitor the environment surrounding patients with the help of smart objects and devices [6]. It provides the ability to collect and share information. The applications of IoT took place in the field of healthcare and more extensive advantages were associated with the assessment of the patient's condition and environment remotely (Figure 2). The use of this technology improved the healthcare quality services and the health conditions and well-being of the patients [7].
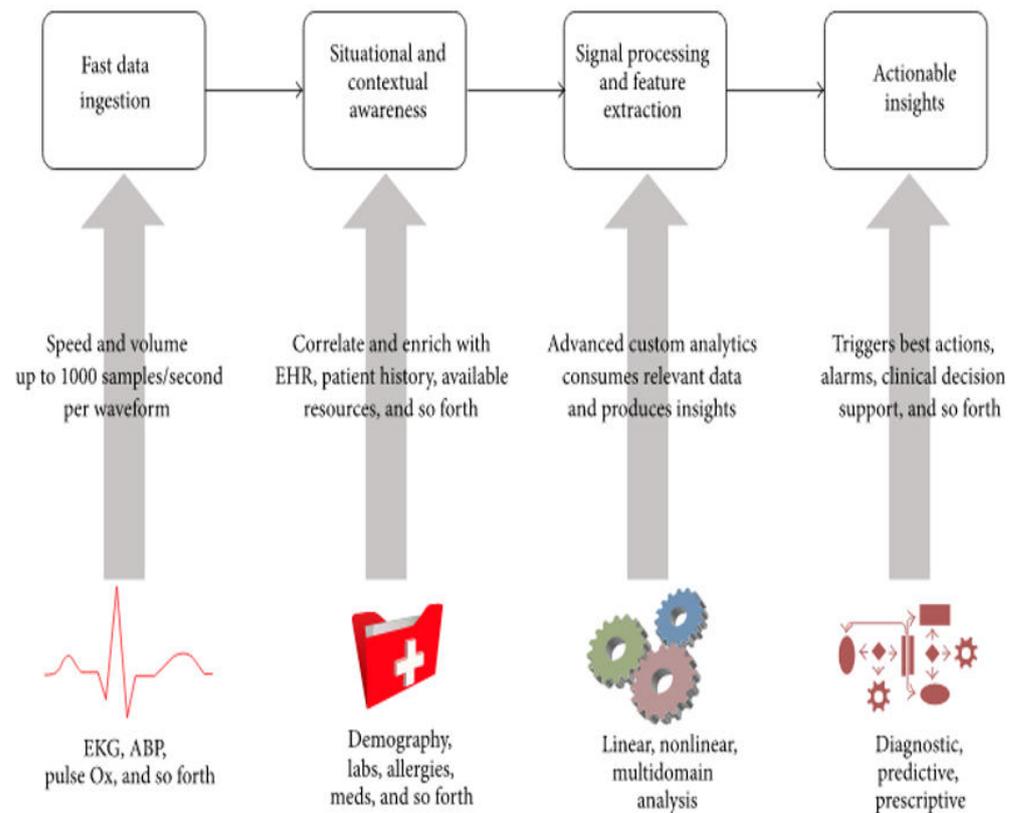
Figure 2. Cloud Computing and its applications in health care. (Source: Rajabion et al., 2019).

The technique of Cloud Computing can be employed with respect to processing, computation, storage and sharing of resources in a convenient manner (Figure 3) [8]. Furthermore, another advanced technique, referred to as Fog Computing, brings the computing and storing resources closer to users [9]. Cloud Computing and Fog Computing are two methods that facilitate access to IoT-based applications in healthcare [10].
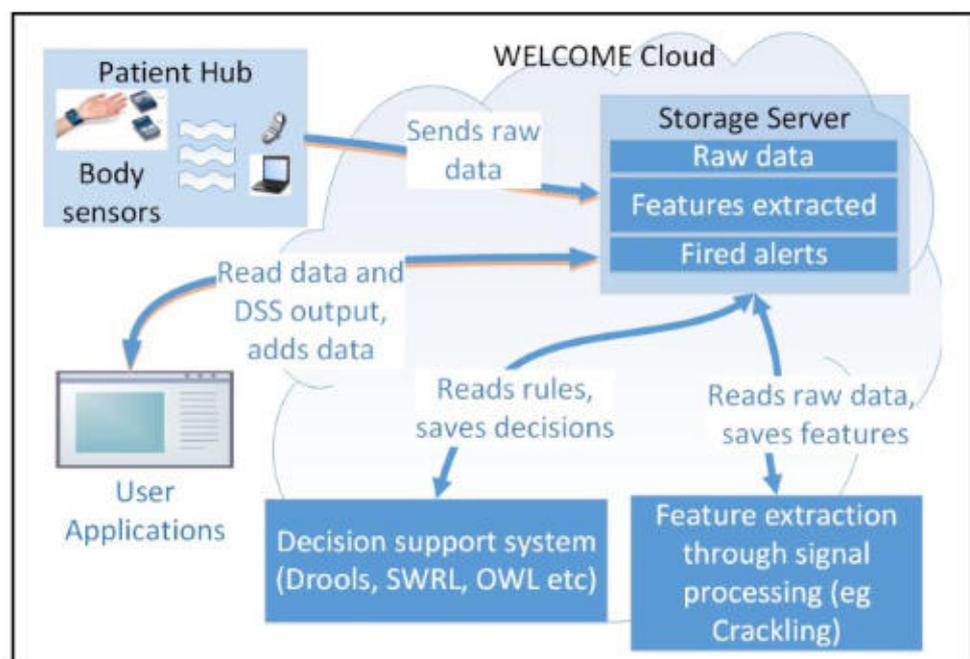

Figure 3. Cloud Computing integration in the healthcare system [6] (Source: Chouvarda et al., 2014).

This paper aimed at exploring the efficiency of adopting the home hospitalization system by the application of IoT, Fog Computing, and Cloud computing. This study was conducted to gain a better understanding and insights into the most effective and novel applications of IoT, Cloud computing, and Fog Computing in the healthcare field.

Recently, it has been observed that technical challenges associated with the applications of IoT-based Cloud Computing and Fog Computing in healthcare showed unpredicted performance distortions, resource exhaustion as well as distribution of large-scale cloud systems. Thus, these challenges need to be addressed to improve the implementation of such technologies in the healthcare field and to support the healthcare professionals during treating the patient's treatment. Furthermore, the current study mainly focused on the significance of these technological tools. The present research is intended to give significant emphasis to the associated challenges and to provide recommendations for the integration of better technology to further enhance the delivery of healthcare services at home.

This study is different from previously existing literature since it provides knowledge and understanding of three computing technologies, including IoT, Cloud Computing and Fog Computing. Additionally, this study also discusses edge computing which helps the healthcare industry to implement remote patient monitoring as well as telehealth. Moreover, edge computing could assist healthcare professionals to communicate with patients. As a consequence, the data of those patients' data could be transmitted to patient management systems to assist the diagnosis and provision of treatment. The present work is also different from other research studies since it helps understand the applications of Fog Computing and Cloud Computing in detail with respect to the home-based hospitalisation system. Our study is beneficial in terms of providing knowledge and developing awareness among the people about the use of IoT devices and their applications in the healthcare field.

A complete description of the remaining parts of the paper is here. as stated in Section 2, we introduce a "Research Methodology" from previously linked literature. Sections 3 and 4 explain the "Results" and "Discussion". Sections 5 and 6 are described the "Recommendations for Future Study" and "Conclusions" of the paper.

2. Research Methodology

A research question was formulated to be answered by reviewing previously available literature. The purpose underpinning the formulation of a question is to clearly outline appropriate and specific search strategies and set out inclusion and exclusion criteria to collect relevant information efficiently. Following is the research question.

RQ: How do the integration and application of Cloud Computing and Fog Computing with the "Internet of Things" promote healthcare services at home?

Based on this research question, this paper applied the methodology by collecting information from the different secondary sources and databases such as PubMed, Science Direct, Google Scholar and MEDLINE. These databases were used because it provides access to the authentic and reliable published research articles to collect the scientific information [11]. The search key terms were home hospitalisation, IoT, COVID-19, cloud computing, Fog Computing, health care, patients. Boolean operators such as AND, OR were used to specify the search of the literature in the different databases. The methods of searching by using the Boolean operators were found effective in providing useful outcomes for the relevant research articles [12]. The inclusion criteria for the research papers in this review were those research articles published after 2015. Those research articles which provided detailed information about the application of Cloud Computing and Fog Computing in the field of healthcare particularly during the provision of home hospitalisation services to the patients were included. The research articles whose full texts available were included.

The exclusion criteria were those research articles published before 2015. The research articles that did not specifically provide information about the applications of Cloud Computing along with Fog Computing in the field of healthcare were excluded. The research articles whose full texts were not available were also excluded. PRISMA diagram

was used to explain and report the method employed for the selection of the most relevant research studies. The utility of the PRISMA diagram is considered significant for reporting the search strategy and associated outcomes in the systematic reviews [13]. It also assists in writing and explaining the selection process of the research articles more appropriately and efficiently (Figure 4: PRISMA FLOW diagram). The duplicates retrieved from different databases during data collection were removed based on similar title, similar results and similar authors. A total of five research articles were shortlisted for this review article. The ethical considerations were maintained while writing the present review article. All the information included in this article was appropriately cited with the sources. The included research articles were assessed for ethical approval from the Ethical review committee and consent form from the studied participants prior to selection for the present review study. The quality of the research articles included in the review was assessed by checking the consistency of the outcomes obtained in the different research studies.
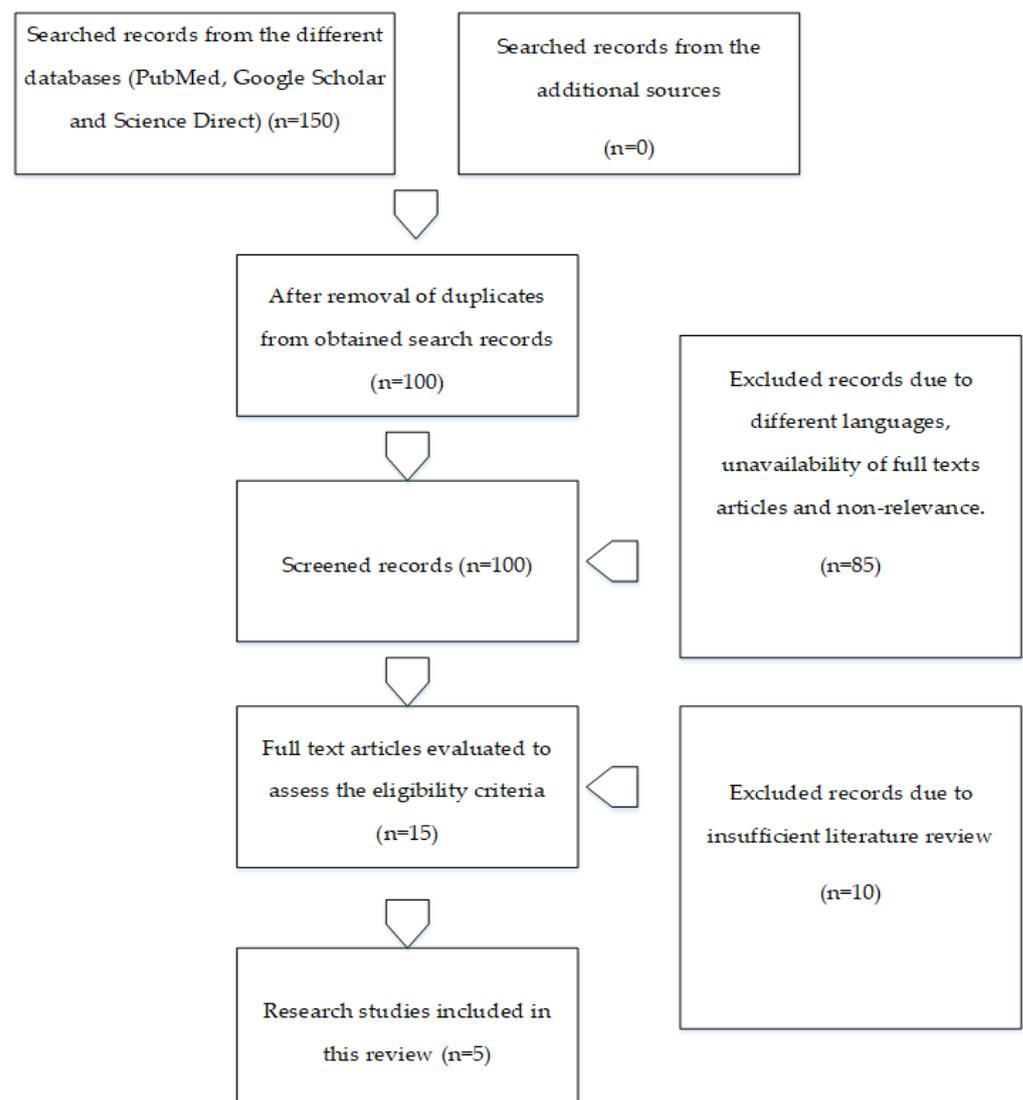

Figure 4. Prisma flow diagram.

3. Results

The findings of the five research studies based on the integration of IoT technology such as Cloud Computing and Fog Computing were employed in the present review (Table 1). The study carried out by Hassen et al. [14] aimed to propose the home hospitalisation system by integrating the applications of IoT such as Fog Computing and

Cloud Computing. The study was focused on proposing the smart-based model for the application in the healthcare system during the pandemic of coronavirus. It was mentioned that the pandemic that occurred due to the coronavirus increased the problems for the healthcare staff in the hospitals by increasing the burden, workload, and chances of infections. The chances of the infections spread are increased for the medical staff and the paramedical team which poses a significant health risk for the staff and the patients. Therefore, the study aimed to propose a model that can be helpful to monitor the conditions of the patients by providing those services at home. These models include the efficient monitoring system that delivers the services via software.

The paper discussed the efficiency of using the applications of IoT such as Fog Computing and techniques of Cloud Computing considered as the important technologies for the development of the model and framework in the field of health care. The research proposed the architecture of framework that can be used for home hospitalisation and the development of the architecture was based on utilising the techniques of Cloud Computing and Fog Computing. The research provided comprehensive information about the environment sensing system and the android applications for the settings and displaying measurements. The scale of system suitability (SUS) was employed to check the opinion of the healthcare staff members and patients about the use of the proposed framework.

The components of the system include the NodeMCU, a detection module of temperature and humidity, a detection system for smoking, a detection module for the gas leak, a digital converter and power supply. The outcomes of the research study indicated that the system was found efficient for the doctors as well as the patients in the increase of time of recovery period in their homes. The proposed system was also found cost-effective, reliable, safe and reduced the burden on the staff in the hospital due to COVID-19 and was accepted by the doctors and patients.

Another research study carried out by Pham et al. [15] aimed to develop the "Cloud-based smart home environment (CoSHE)" that assisted in the health assessment and monitoring of the patients for providing them healthcare at home. The methodology of the study included the proposed architecture of CoSHE for the provision of contextual information for the patients. In addition, sensor data were processed by using the gateway of the smart home. The information from the gateway was further processed to the private cloud that provided access of the caregivers to the recorded data. The six subjects were included in the study and the age range of the subjects was from 25 to 35 years. The proposed architecture was incorporated into four components named home setup, the infrastructure of private cloud, wearable unit, and home service robot. The applications of the proposed model (CoSHE) were checked and evaluated for the monitoring of the health conditions of the patients. The findings of the study documented that the framework provided solutions and comprehensive information to the caretakers about the movement of the patients along with the health data. The study concluded that CoSHE employed a robot that helped aid the patients at home. The infrastructure was based on the cloud system and helpful in the efficient delivery of services at home.

The research did by Tuli et al. [16] aimed to explore the utility of Fog Computing systems for the development of a framework named Health fog for deep learning along with the real-time application of the analysis of cardiac diseases. The study was successful in the development of the system's architecture of the Health Fog model associated with the IoT system. There were different sets of components included to develop the model and the performance evaluation was done by setting the experimental data. The applicability of the "Health Fog model" was examined for the cardiac patients with the age ranged from 37 to 63 years. The model covered of components includes sensor network, gateway, modules of fog bus such as broker node, worker node and cloud data centre. The components of software consist of filtering of the data and pre-processing, resource manager, a module of deep learning and assembling module. The outcomes of the study supported the use of the "Health Fog model" as the findings indicated the efficiency of the system in the diagnosis of cardiovascular diseases among the patients by using the IoT fog-based devices.

Table 1. Summary of research studies related to the utilization of IoT-based Fog and Cloud Computing in the field of health care.

Research Study	Aim of the Study	Research Methodology	Components of the Proposed Framework	Research Outcomes
Hassen et al. [14]	To propose the home hospitalisation system focused on the integration of IoT, Fog Computing, and Cloud Computing.	The research study proposed the architecture of home hospitalisation by using the techniques of Cloud Computing and Fog Computing. The study proposed the environment sensing system and the android applications for the settings and displaying measurements. The scale of system suitability (SUS) was also employed in the study.	NodeMCU, Detection module of temperature and humidity, a Detection system for smoking, Detection module for the gas leak, Digital converter, power supply	The system was found efficient for doctors as well as patients in the increase of the time of recovery period in their homes. The proposed system was also found cost-effective, reliable, safe and reduces the burden on the staff in the hospital due to COVID-19.
Pham et al. [15]	To develop the cloud-based smart home environment (CoSHE) that assists in the health assessment of the patients for providing them healthcare at home.	The study proposed the architecture of CoSHE for the provision of contextual information. The processing of sensor data was done in a gateway of smart home and processed to the private cloud that provided real-time access to the data by the caregivers. The six subjects were included with age ranged from 25 to 25 to test the experimental procedures.	The system consists of four components named smart home setup, the infrastructure of private cloud, wearable unit, and home service robot.	The outcomes of the study indicated that CoSHE provides comprehensive information to the caretakers about the movement of the patients along with the health data. Moreover, the CoSHE employed the robot services at home and the infrastructure that was based on the cloud system and provided efficient services to increase the efficiency of healthcare services at home.
Tuli et al. [16]	To develop and propose the framework named Health fog for deep learning in the computing devices and real-time application of the analysis of cardiac diseases.	The study developed the architecture of the Health fog model based on an IoT system. The different sets of components employed which were implemented and performance were evaluated by setting the experiment. The data of the cardiac patients have included whose ages ranged from 37 to 63 years.	The model includes sensor network, gateway, modules of fog bus such as broker node, worker node and cloud data centre. The components of software include filtering of the data and pre-processing, resource manager, a module of deep learning and assembling module.	The research study proposed the novel model of a smart healthcare system based on the fog system. This system was found efficient in the diagnosis of cardiovascular diseases among the patients by using the IoT fog-based devices.
Debauche et al. [17]	To develop and propose the Fog IoT Cloud-based health monitoring system by using the different signals such as physiological and environment for the provision of contextual information in daily life activities.	The system architecture was proposed based on the Fog-cloud based health monitoring system and the experiment was done on the patients at home. There were three layers, sensors layer, Fog layer and Cloud layer in the proposed system.	The architecture consists of sensor network, smart gateway, cloud processing and behaviour detection.	The findings of the study suggested that the Fog-Cloud-based IoT system was efficient in the health monitoring of the patients. The privacy of the patient's data was protected using the system and the proposed system provided smart and systematic methods for the monitoring and assessment of the health data of the patients by using the new technology.
George et al. [18]	To propose a framework of Fog Computing and the use of smartphones in the form of sensors for the monitoring of patients health conditions and records.	The methodology includes the development of the architecture for the smart system by including the fog-based applications for the doctors, nurses and other healthcare staff. The network layer is covered by a cloud layer and router. The data were processed to the fog network by using the sensors. The sensors were used in the smartphone of the patients to collect and record the data.	The components of the proposed smart framework include services layer, network layer (cloud-based), fog layer or networks and sensors.	The findings of the study suggested that the proposed system based on Fog Computing technology was effective in the health monitoring of the data among the insured patients, general hospitalised patients and patients who need monitoring in the future at home.

The research did by Debauche et al. [17] proposed the system based on the development of the fog IoT Cloud-based health monitoring system. This method was employed for increasing the efficiency of the healthcare quality services for the patients. The study used different signals such as physiological and environment for the provision of contextual information in daily life activities. Both Fog and Cloud-based devices were used in the health monitoring system to provide services to the patients at home. There were three layers, sensors layer, fog layer and cloud layer in the proposed system. The architecture was based on the components such as sensors network, smart gateway, and cloud processing and behaviour detection. The outcomes of the research study presented that the Fog-Cloud-based IoT system was efficient in effective health monitoring of the patients. The privacy of the patient's data was protected using the system and the proposed system provided smart and systematic methods for the monitoring and assessment of the health data of the patients by using the new technology.

On the other hand, the research study of George et al. [18] proposed the framework of Fog Computing and the utilization of smartphones in the form of sensors for tracking the health conditions and record of the patients. The efficacy of a Fog Computing system was assessed in this study containing the development of the architecture for the smart system. The model was developed for the convenience and safety of healthcare staff members such as doctors, nurses, and other members. The network layer is included of a cloud layer and router. The data were processed to the fog networks by using the sensors. These sensors were used in the smartphone of the patients to collect and record the data all the time. The components included services layer, network layer (cloud-based), fog layer or networks and sensors. The results of the study suggested that the proposed system was based on Fog Computing technology and effective in the health monitoring of the data among the injured and general hospitalized patients. The Fog-based computing framework was found efficient in health monitoring of the patients in the future at home.

4. Discussion

The present study proposed an efficient smart healthcare model for the patients to adopt the healthcare services at home, especially in the time of pandemic due to coronavirus. The study discussed the findings of five research papers and displayed the paradigm shifts in the implementation of the smart healthcare system. It was observed that the proposed systems in the reviewed research studies were effective in the fast recovery of the patients as they received the healthcare services at home and close to their family members [19]. Another point that supported the findings of the present study is that patients are often afraid to go to the hospitals because this might increase the risk of infections acquiring. Therefore, the smart-based healthcare system was effective to be employed in the time of COVID-19 [20].

The research study supported the idea that due to the COVID-19, the elderly patients were most commonly affected and therefore, they benefit most from the positive impacts of the IoT technology [21]. The IoT system based on Fog Computing and Cloud Computing solves the problems of congestion in the hospitals that are most often encountered by the patients. Furthermore, the research study demonstrated that the problem of lack of resources in the hospitals can be solved by adopting the model of IoT based on Fog Computing or Cloud Computing [4]. It was noted that by using the IoT system, the health conditions, as well as the environmental conditions of the patients at home, were monitored on the regular basis [22]. The applications of Fog Computing were found as more advanced in comparison with Cloud Computing and comprising of both systems contributed towards the enhancement of the healthcare services for the patients.

The study reported that fog and cloud-based computing system was found convenient by the patients due to its cost-effectiveness, reliability, and safety. The doctors used to assess, monitor, examine and prescribe the treatment using the IoT reduces the chances of congestion and reduces the spread of infections among the patients [23]. The IoT-based fog and Cloud Computing system include the advanced sensors and tools that enhanced the

efficiency and advantages of the system was observed in the developed countries as well as in developing countries [24].

Other research studies that were in line with the findings of the present review study displayed the easy implementation of the IoT system in developed and developing countries with low cost [25]. The utilisation of mobile applications via fog and cloud servers plays an important role in analysing and measuring the vital signs of the patients. The medical reports can be prepared using the information gathered through these smart applications. Few studies also revealed that the advancement of the IoT system involved the advanced tools and sensors that contributed towards the increase of the cost that might bring the financial issues for the healthcare system of the developing countries [26–30]. It was also noticed that due to the COVID-19 pandemic, elderly people were found to be more suffered from the risk of infections and a higher number of deaths were observed among people with the age above 60 years old. The study presented the strong collaboration between COVID-19 researchers, especially between the United States and China [31,32]. The common COVID-19 risk factors were smoking, obesity, inflammation, exercise, and other factors associated with the prevalence of COVID-19. On the other hand, one of the research studies explored the emerging risks by the integration of the low-memory and low-cost devices in critical care units.

There were IoT risks associated with the dynamic and self-adapting predictive cyber risk analytics focused on artificial intelligence and the applications of machine learning and real-time intelligence. These techniques will bring multiple benefits to the healthcare system [33]. On the contrary, a research study reported the challenges associated with the use of IoT-based devices and their applications for the healthcare system. It was mentioned that the hospitalization of patients at home is an extremely relevant option that technologies such as IoT system can be provided at the time of the COVID-19 pandemic, but the design of such a kind of applications cannot take place outside the legal frameworks that require the risk management and the integration of these tools and applications to enhance the safety of the patients and the healthcare staff [21,34–39].

5. Recommendations for Future Study

The architecture and specialized frameworks proposed in the selected research studies are presented and discussed. Moreover, some limitations in these previous works are identified and can be overcome in future work.

One challenge of home hospitalisation systems is cost. Therefore, it is recommended for future studies to focus on architectures with reduced cost and ensuring reliability and safety, so that low-income patients can acquire such systems. Most of the proposed frameworks for IoT-based systems, discussed in this study, used expensive sensing units that must be replaced with cost-effective units. In future research studies, the acceptance of the system for the patients and doctors must be analyzed to examine usability and efficiency. In addition, new features need to be added to the previous system due to the COVID-19 characteristics and therefore, specialized systems are required to be introduced for corona virus-infected patients. There is a great need to monitor the corona virus-infected patients using the computer-based system and IoT devices. Future studies must take into consideration these facts and efficient ways of monitoring the patients must be identified such as video communication and more.

It is also recommended to develop the bracelet measurement system through which patients' vital signs including the temperature and pulse rate can be monitored. The efficiency of this system can be analyzed by doing primary-based research studies on the patients. Furthermore, the efficiency of using the cloud-based and fog-based system for the analysis and storage of the patient's data must be comprehensively studied in the future based on the primary data collection methods. There are also limited research studies on exploring the use of the IoT-based system, particularly in developing countries. The research studies are required to explore the impacts and efficacy of using these strategies in the healthcare system of developing countries. There is also needed to introduce an

effective education-based program to enhance the knowledge and awareness of the doctors and patients regarding the efficiency of IoT systems based on the integration of Cloud Computing and Fog Computing.

In future studies, it is required to propose the IoT system-based devices in the healthcare system in the countries like Pakistan as it is also the need of time and COVID-19 prevalence can be reduced. Furthermore, people must be more educated about the use of IoT-based systems and this can be done by providing them with more information through the workshops and seminars about the applicability of IoT-based systems comprised of Cloud Computing and Fog Computing in the healthcare system. However, there are some challenges involved in the applicability of the IoT system in healthcare due to the higher finance included in the system along with the training and services provided to the doctors, nurses, and patients about the use of hospitalization system at home. There is a need to integrate and use the technology of edge computing that has made telehealth services more available for patients. Additionally, the patients can be monitored and assessed at home and provided with care facilities.

6. Conclusions

The findings of this study concluded that the use of a home hospitalization system based on IoT, cloud and Fog Computing was efficient in the increase of the healthcare quality services for the patients. This system brought significant improvement in the healthcare field by enhancing the recovery of patients, particularly for the older ages. The system of home hospitalization received good acceptance from the patients, doctors and the associated family members for the management and hospitalization operations in the COVID-19 situations. In the future, more detailed studies are required to bring awareness and education among the people about the utility of mobile applications and IoT-based systems for enhancing the communication between doctors and patients particularly in developing countries.

The present study also concluded that there is a great use of IoT-based systems by integrating Cloud Computing and Fog Computing for the patients particularly in the time of COVID-19. The patients can get accurate health monitoring by accessing the data from the home. The doctors and nurses can also guide the patients by accessing them from the hospitals and clinics. The approach is considered promising and helpful to be utilized in healthcare centers. Furthermore, edge computing could be integrated as one of the most efficient technology in comparison to cloud and Fog Computing to further enhance the provision of healthcare services at home as it has the potential to develop efficient coordination between patients and doctors. Along with this, it would help in early and appropriate diagnosis as well as treatment of patients at home via advanced telehealth services.

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