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Analytical Studies on the Effectiveness of IoMT for Healthcare Systems

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Abstract

The Internet of Things (IoT) has great importance in the medical industry. The creation of intelligent sensors, intelligent machines, and superior algorithms for lightweight communication made it feasible to connect medical equipment in order to monitor biomedical signals and also to detect illnesses in patients without human intervention. This new IoT and medical equipment connection is called IoMT. This IoMT model is most adapted to this pandemic since every human being has to be interconnected and monitored via a larger communication network. Hence, this article provides an overview of remote healthcare systems, monitoring ingestible sensors, mobile health, smart hospitals, and improved chronic disease management focused on the Internet of Medical Things. Finally, this paper proposes an IoMT architecture and platform to assist with persistent healthcare.

Keywords: m-Health, Internet of Medical Things, COVID - 19, Healthcare professional.

1. Introduction

The whole globe is devastated by the new virus (SARSCoV-2) outbreak that was discovered on December 31, 2019, in Wuhan, China. Now it is known as "COVID 19". It is a viral infection with the quickest circulation, leading to a new worldwide public health challenge. There are currently 183,368,584 instances of COVID-19 in the world, 3,975,503 of which are reported to be deaths. As of July 4th 2021, a total of 2,985,766,169 vaccine doses have been administered to prevent a virus outbreak[1].

The figures for viral infection are increasing significantly per hour. Today, medical professionals and experts are looking for emerging tools to track and manage the dissemination of the COVID-19 pandemic in this public health emergency. Rapid identification of a viral disease is essential, not only for doctors and nurses, but also to ensure adequate patient insulation from a wider public-health perspective in order to avoid viral infections [2][3]. In this case, innovative computing technologies such as IoT and AI are the latest emerging technologies that can be used to solve the main medical issues related to Corona viruses [4].

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The IoMT is the assortment of information from medical equipment and medical application software that is connected wirelessly with healthcare IT systems[5].

The goal is to integrate people, data, and methods via patient monitoring smart phone applications so that medical treatment can be improved. This has resulted in an ever-increasing number of uses and technologies to provide new and globally fast adoption in health services [6]. The Internet of Things (IoT) offers computing capabilities and Internet links to common things, enabling the data collected from the real world to be processed, communicated, and stored [7][8][9]. Most IoT applications are omnipresent.

Recently, IoT applications are playing a very important role in the healthcare sector in the form of the Internet of Medical Things (IoMT) [10]. In order to provide patients with medical information to healthcare professionals, the IoMT's potency provides better diagnostics, reduces errors, and has relatively low care costs via advanced technology. Because of the wireless connectivity, medical visits are not necessary to avoid COVID-19 from spreading. Patients may be empowered to feel self-confident about their health conditions via IoMT platforms [11]. In many situations, the intervention of medical experts is even avoided or minimized. The quantity of IoMT applications is forecast to significantly expand in the next year, and the connectivity and privacy-related problems will be caused by the heterogeneity of various IoMT elements.

A decent healthcare system must, in this respect, be sufficiently adaptable to accommodate all these notions. Thus, it becomes important to integrate IoMT technologies into an interoperable environment and to build mechanisms for storing, analyzing, and extensive distribution of IoMT data. They also have to overcome technological hurdles to the development of new systems[12]. The IoMT is a special case of the Internet of Things where the IoMT is specially developed to help individuals and medical professionals with medical software and facilities. IoMT will help patients, nurses, health officials, and physicians monitor, identify, educate, and guide them to appropriate health services, as well as ensure timely and accurate information delivery and control of concerns until they become serious [11] [12].
Our contribution to this work is summarized as follows:

1. The literature review provides a detailed explanation of different IoMT-enabled working applications.
2. We are also suggesting this system for remote monitoring of patients all the time using advanced techniques of IoT.
3. Finally, we proposed different IoMT models for improving healthcare, like:

i. Continuous monitoring of the patient’s blood pressure, heartbeat, and oxygen level using wearable sensors attached devices.
ii. All the data will be monitored by a health supervisor or doctor to avoid any emergency.
iii. All the data will be sent to the fog server for storage and to be forwarded to the hospital data repository.

The following part of this research paper is categorized as follows: Section 2 describes the related work that has been done by various researchers in this field. Section 3 explains the proposed IoMT-based clinics or hospitals for proper monitoring during this COVID-19 era. Section 4 discusses the facts and findings, and finally, Section 5 provides the conclusions about which protocols show better performance for IoMT devices and the future scope of IoMT-based hospitals.

2.Literature review

In [13], the authors conducted a survey on IoT healthcare from the perspective of wireless body area network (WBAN). Some healthcare applications of IoT have been discussed, for example, remote patient monitoring, clinical care, and context awareness. Boutros-Saikali et al. [14] proposed an environment for companies like Samsung, Microsoft, and Nokia, which incorporates several IoMT technologies. Connectors, which are numerous, have features for the collection of data from each source of acquired data. The AIDA platform, introduced by Cardoso et al. [15], is used to interact between agents and each medical device and transfer the acquired data acquired onto a major server. The JADE framework [16] was utilized by the authors, and the EHRs were based largely on FHIR.

Moreover, the study does not include a description of data processing and integration tools for different EHRs instead of IoMT instruments. In an IoMT architectural survey, Irfan and Ahmad [17] found that two to five layers were often employed. The authors have selected an IoMT framework of three facets consisting of stuff, intermediary, and merged application layers covering all IoMT needs. In [18], the authors propose an intermediary level between sensors and the cloud and show a prototype of a system that includes the proposed Smart e-Health gateway. Concept design evidence shows the dependability and effectiveness of the answer presented. The security portion is highly essential since patient records are personal.

The author, therefore, proposes in [19] a guideline for the development and design of intelligent and safe IoT healthcare systems using biometric data. This standard provides simple, high-capacity, and secured access to data. In [20], the author presented three layers of IoT architecture for a healthcare system. These layers are the cloud, fog, and medical device layers. In order to acquire, analyze, and transmit data in real-time, each layer is split into sub-layers. Fog nodes and gateways are also utilized to offer users health care services. In [21], the authors presented a framework and the IoT system of the healthcare system, which collects WBAN data and uses gateways to transmit online data. The system ensures safe data transfer based on the key distribution group concept. In [22], the author proposed an IoT–based alarming and real-time detection model for preventing COVID–19.

3.METHODOLOGY

3.1 IoMT Architecture Proposal and Platform to Assist Persistent Healthcare

This section outlines the proposed IoMT architecture that takes into account the difficulties raised above. The major elements of a cloud and IoMT-based integrated health system that were used to construct the platform are depicted in Figure 1. Data is acquired by diverse sensors or obtained from healthcare repositories and delivered to cloud gateways. Patients' smartphones are used as monitoring gateways in their settings. On the other hand, fog servers allow the system to be instantiated in hospitals or clinics, functioning as regional health information systems (HIS) and allowing the administration and viewing of digital medical documents.

Technologies based on Machine Learning, Big Data, and online analytics process the aggregated data on the cloud, anonymize it, and process it for knowledge extraction and statistical analysis. Furthermore, cloud-based sharing services are available for distributing data to third-party applications.

3.2 Working Principle of the proposed system

The following is the procedural flow of the IoMT-based e-health system that can be proven very helpful during the COVID-19 pandemic. As we know, social distancing is also required along with intense patient monitoring. Otherwise, the doctors and hospital staff can also suffer

from infection by coronaviruses [23]. So, the following are processes and uses of sensors that can be implemented in this adverse time.

- In the given IoMT-based health care system, the hospital or clinic is embedded with numerous heterogeneous sensors from which data is continuously scanned, read, and sent to a fog server or cloud gateway.
- This scanned data can be regarding the heart rate, blood pressure, body temperature, or oxygen level of the patient, along with surrounding humidity and temperature.
- Patient health conditions are monitored by measuring these parameters. Various apps are installed on a patient's smartphone, and data is fetched by smart watches and various sensors and IoMT devices attached to the patient.
- Then healthcare professionals monitor the patients by directly analyzing the health data received from them.
- As we know, in the case of COVID-19, many patients suffer from a deficiency in oxygen levels. Even patients themselves remain unaware of the lack of oxygen in their bodies. In this situation, 24x7 monitoring is done through these IoMT-based systems.

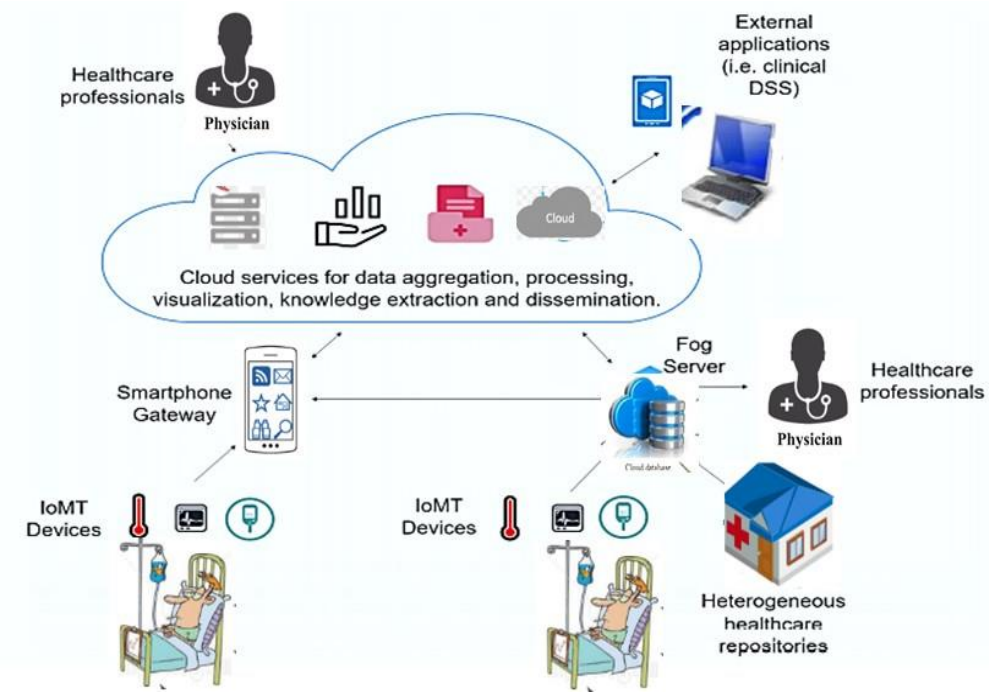

Figure 1: A Typical IoMT-based e-healthcare system

4. Hardware Requirements and Methods

4.1 IoMT Devices Development Framework

We deliver a development framework designed in C++ that facilitates the creation of the AE (Application Entity) and BPs (Binding Protocol) because the IoMT devices follow the OneM2M standard. The main classes are depicted in Figure 2.

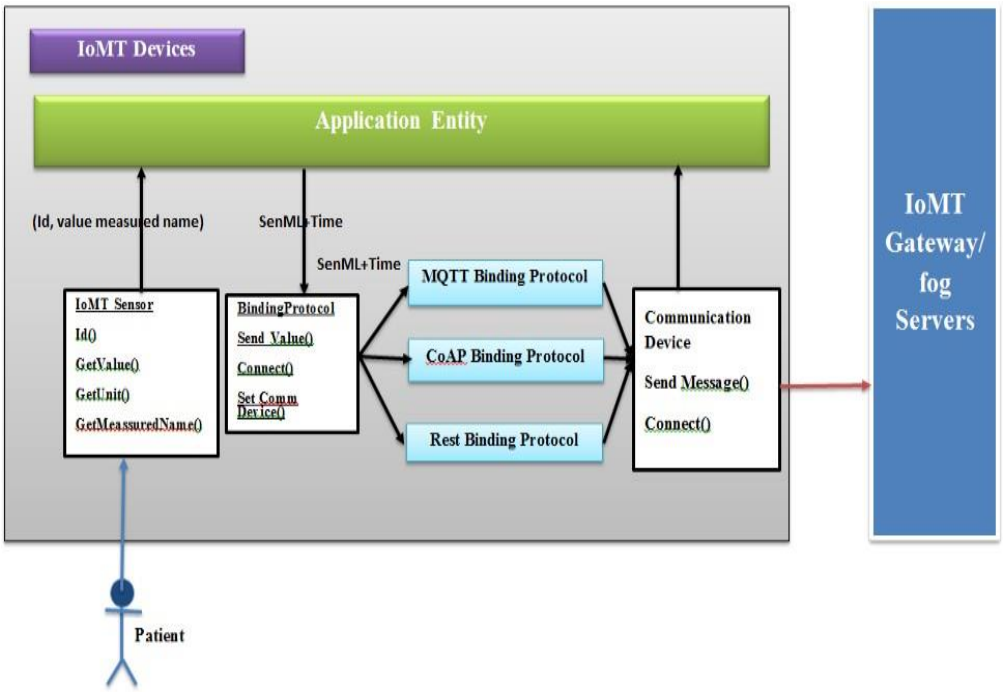

Figure 2: Development Framework for an IoMT Device

In order to represent physical sensors, the IoMT sensor abstract class has to be extended, and functions are implemented to obtain the sensor identifier, read the observation value, get the measurement unit related to the observations, and make an effective measurement. To depict innovative or bespoke OneM2M binding protocols, the Binding Protocol abstract class must be extended, redefining the Send Value, Connect, and Set Communication Devices. This class has extensions for MQTT, CoAP, and REST BPs in the development framework. Communication must be established to have physical network access, and this structure allows for Wireless Fidelity, Global System for Mobile Communication, and Ethernet module implementations. The main work of the Application Entity (AE) is to link and manage the monitoring process. It also converts the sensor observation to the SenML(Sensor Markup Language) data format and tracks the time via the Universal Time Standard.

4.2 Work Flow Diagram and Coding for IoMT Devices

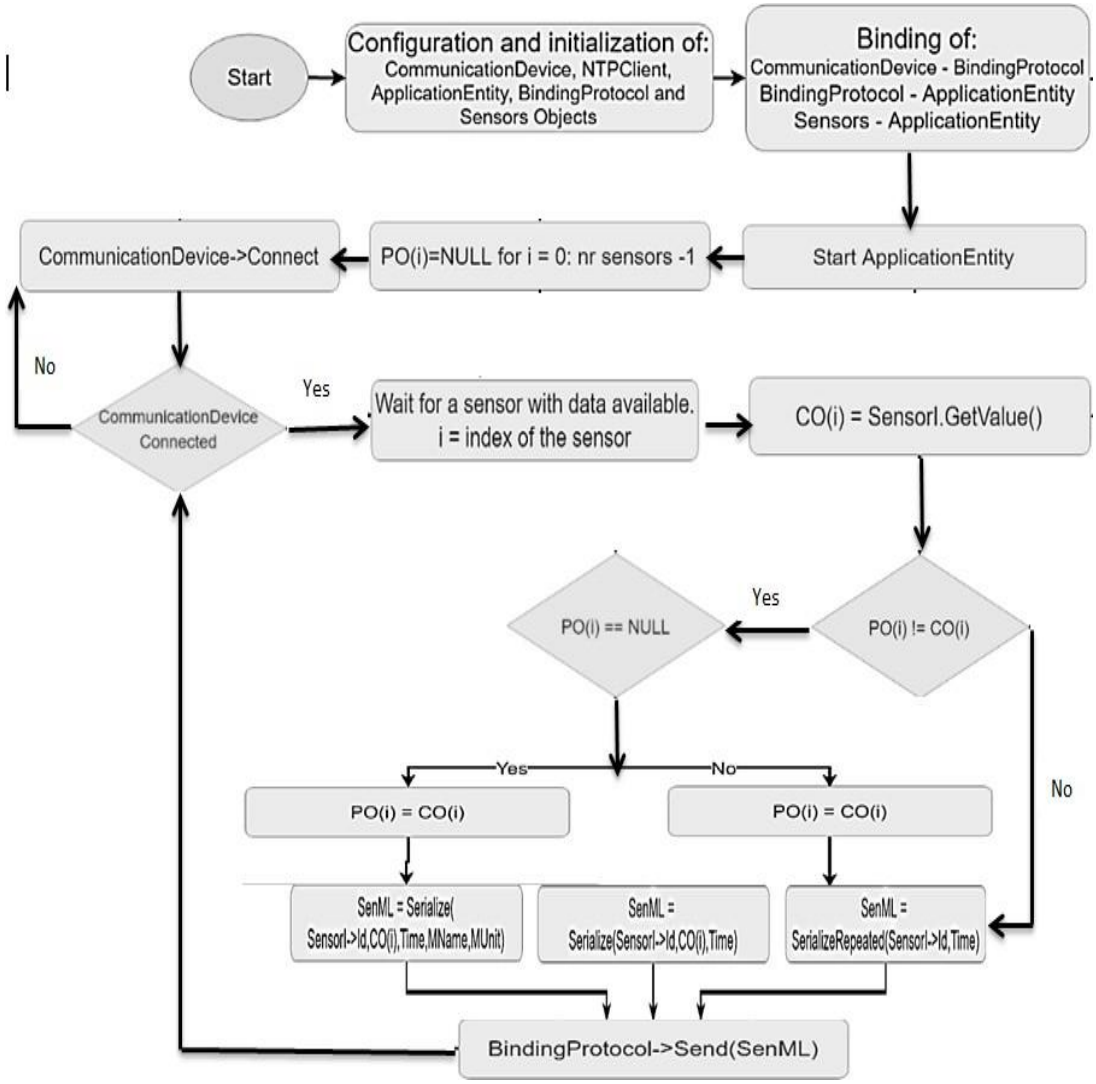

Figure 3: Flow Chart of Message Handling in IoMT Devices Development Framework.

Figure 3 illustrates how an IoMT device's development framework works. The process starts with the creation of the communication device (NTP client, AE, BP, and sensors); the AE executes; and these devices are attached to the physical network. The IoMT system is a base that can hold a number of sensors, and each has its own unique ID field. AE keeps an eye on the sensors until the ith-sensor has a CO(i) observation. CO(i), a recent observation, is then episodic as a SenML message and delivered via the binding protocol to either the gateway or the fog server.

5. Facts and Findings

This analysis covers numerous innovative IoMT applications to combat the current health problem of COVID-19. In order to reduce the workload for infection control practices in the healthcare industry, the IoMT platform allows real-time reporting, remote health monitoring, fast case recognition, early detection, cluster analysis, filtering, and monitoring.

This research is to find out the most suitable binding protocol to be used in the IoMT devices to transfer data for the hospital as well as personal healthcare.

The network described in Figure 4 above was used to send nearly a hundred body temperature data points to the fog server with the help of IoMT devices, permitting an analysis of the latency of the 3 binding protocols given in the architecture. Figure 5 shows this comparison of latencies. The latency test here is done to check which binding protocol can more efficiently transfer the data without much delay because in the COVIDIEN period, real-time monitoring of the patient is required. The CoAP BP had the lowest latency, so the CoAP BP had the best outcomes, whereas the "REST" and "MQTT BPs" had more latency but similar results.

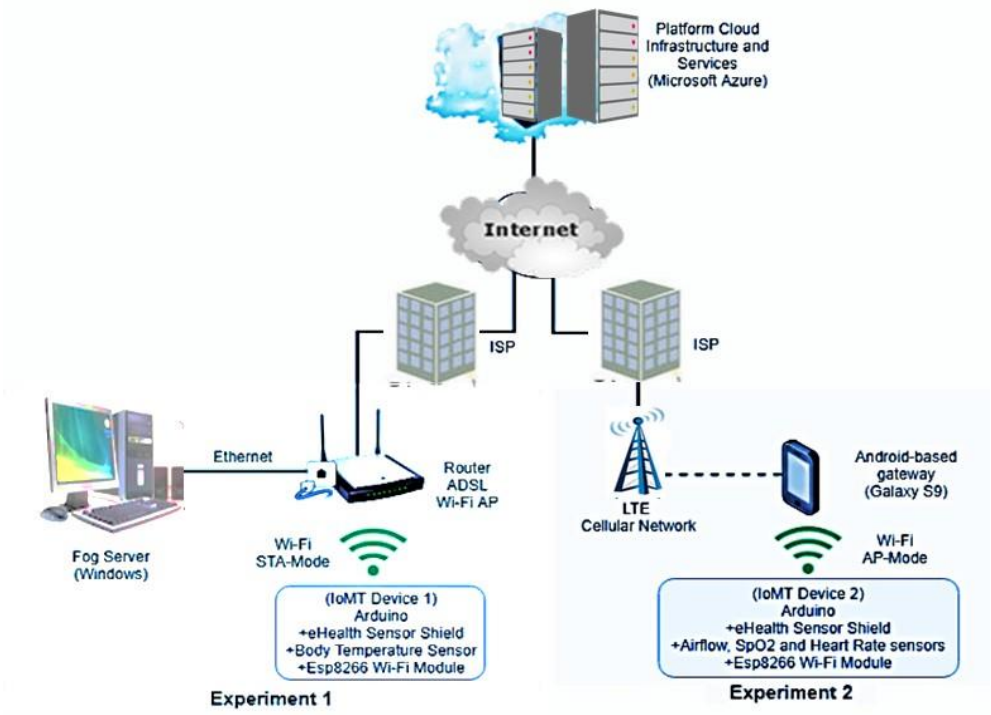

Figure 4: Network Topology for testing

Table 1 indicates the highest RAM memory consumed by each BP in the IoMT device. The superior results were once again supplied by CoAP. The CoAP BP consumed less memory than the other two BPs, so it showed better results.

Table 1: Memory (RAM) used by IoMT devices of each Binding Protocol

Binding Protocol	MQTT	CoAP BP	REST
Memory Used	**1697 kb**	**1139 kb**	**1452 kb**

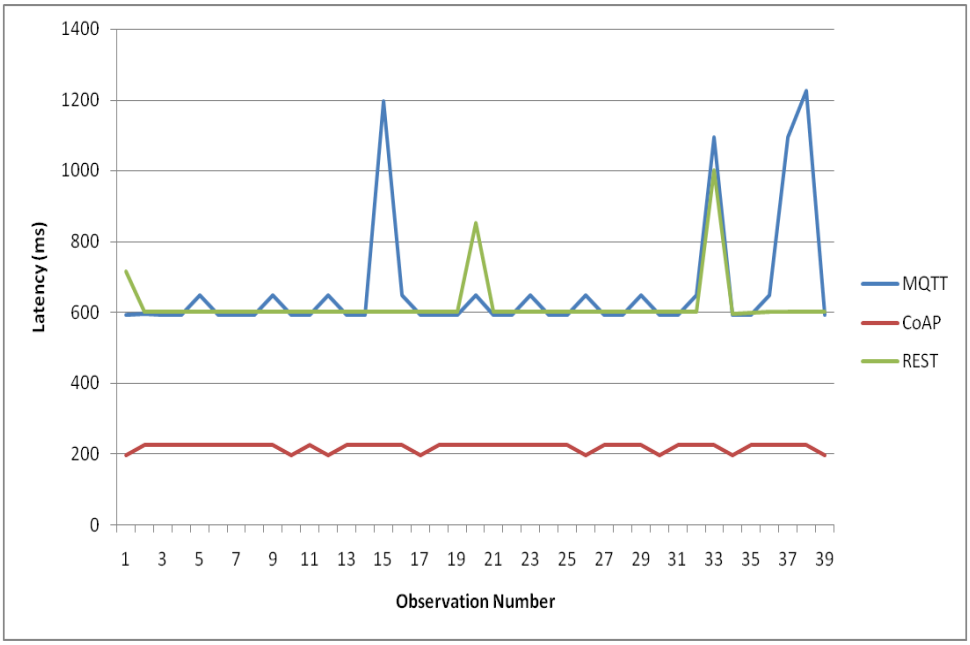

Figure 5: Binding Protocol (BP) Latency over Wi-Fi

6. The Social Implications of the Proposed Model

This proposed model has a great noble cause and role in society. During the time of the pandemic and its aftereffects, intensive healthcare and monitoring are essential for patients. Many people survived on oxygen in the ICU. Proper monitoring and accurate data transfer can be assured using the given proposed model to ascertain which binding protocol is fastest for these critical data transfers of patients. It can be used in hospitals as well as for personal health monitoring and in the isolation of patients.

7. Results and Conclusion

Finally, the performance tests produced positive results, validating the platform in the scenarios under consideration. The BP based on CoAP has the shortest delay. Latency was found to be acceptable for MQTT and REST BPs, and given the functional advantages of MQTT and the ease of REST, they can both be deemed ideal protocols.

So, we can conclude that IoMT is a capable technology for fast detection, dynamic surveillance, and tracking without spreading the virus to others, enhancing care and management. The CoAP binding protocol should be given preference over other protocols used by IoMT devices. This paper also shows that the scope of IoMT-based hospitals has a good future and will show great results for contagious diseases such as COVID-19.

This research paper's outcome can be considered one of the best outcomes for current and future healthcare in the country. In the future, work will involve the analysis of other healthcare scenarios like smart cities (SC).

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