A Study Enhancing IoT-Based Patient Data Processing Through Fog-Cloud Integration

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ABSTRACT

By facilitating continuous, real-time data collecting from a variety of medical devices, patient monitoring has been revolutionized with the integration of Internet of Things (IoT) technology in healthcare. In this research, we provide a fog-assisted information model that uses Internet of Things (IoT) devices to provide healthcare as a cloud service. In addition, the data of cardiac patients, which is obtained through their requests, is efficiently managed by the suggested approach. The suggested model's performance in a Fog-enabled cloud environment is examined using the iFogSim tools. When compared to cloud computing, the experimental findings show that the fog-based method performs better on all important parameters. In comparison to cloud settings, fog computing significantly decreases the average amount of time, latency, and energy used by the network. Additionally, by reducing latency, preserving energy, and improving network resource use, fog computing provides a more effective alternative for processing time-sensitive healthcare data, such that from heart patients.

Keywords: *Patient, Network usage, Latency, Energy consumption, Cloud*.

I. INTRODUCTION

There has been a dramatic shift in the healthcare industry due to the incorporation of cutting-edge technology like the IoT, AI, and big data analytics. While these technologies show promise, they also bring up further concerns around the transmission, processing, and storage of data. Healthcare gadgets, such as patient monitoring systems, medical imaging equipment, wearable health devices, and mobile health applications, generate massive amounts of diverse data at high speeds, necessitating solutions that are efficient, scalable, and safe. When it comes to healthcare applications, which demand real-time processing with low latency, high reliability, and privacy as crucial, typical cloud computing—with its centralized data centers—does not cut it. A hybrid paradigm known as fog-cloud integration is transforming the healthcare business by combining fog computing, also known as edge computing, with cloud technologies.

The Internet of Things (IoT) devices and other data sources can benefit from a dispersed computing system known as fog computing, which moves storage, compute, and networking closer to the source. Reducing latency and dependence on distant cloud servers, it enables data processing at the network's edge. For healthcare applications like patient monitoring, emergency response systems, and remote diagnostics, where quick judgments based on real-time data processing are critical, fog computing is a lifesaver. Fog computing enables decision-making and data analysis to happen almost instantly by reducing the time data must travel to and from the cloud. The technology enables data processing and analysis to take place locally at the network's edge, with only relevant or summarized data being sent to the cloud for further storage and further processing. As a result, patients are more likely to have positive outcomes as a result of doctors receiving fast and accurate insights to help them make better therapeutic decisions.

Cloud computing, on the other hand, offers plenty of storage space, processing power, and scalability. Important for healthcare applications like EHR, research, and training machine learning models, it allows for the aggregation and long-term storage of huge datasets. Healthcare organizations may take use of the cloud's centralized infrastructure to make massive amounts of patient data accessible at all times, from any place. Additionally, cloud computing facilitates global data interchange, which in turn supports distributed healthcare services such as telemedicine and collaborative research.

By combining fog and cloud computing, healthcare organizations may build dispersed systems in which each part serves a specific purpose. Patient monitoring and early detection systems are examples of time-sensitive, low-latency activities that fog computing can perform, in contrast to resource-intensive tasks like storing large medical databases, running complex AI algorithms, and supporting data analytics platforms. When combined, these technologies provide an intelligent, responsive, and scalable healthcare system that is both affordable and safe. Healthcare providers may make informed decisions in real time and take use of the cloud's storage and processing power for future insights with this hybrid strategy that assures data interoperability.

The ability to provide real-time health monitoring and remote treatment is one of the primary advantages of fog-cloud integration in healthcare, especially in telemedicine and patient management systems. To illustrate, fog computing allows for the real-time processing of data from wearable devices, such as activity trackers, glucose sensors, and heart rate monitors, even in remote or rural areas with limited access to healthcare services. Fog nodes may potentially analyze this data on the spot and relay the results to doctors for rapid treatment. However, more complex tasks, such as storing long-term health data or doing complex medical image analysis, can be handled by cloud servers with the computing power to handle such operations.

Concerns about patient data privacy and security are paramount in the healthcare industry, especially in light of the rapid expansion of electronic health records. Integrating fog with cloud computing enhances security by allowing sensitive health data to be processed locally before being transmitted to the cloud. Data anonymization and encryption are built into this localized processing to ensure that sensitive medical data and personally identifiable information (PII) are only sent to the cloud when absolutely necessary. Fog computing ensures the safety of patient data throughout the processing lifecycle by implementing additional security measures such as edge data encryption and access restriction.

The ever-changing healthcare industry places a premium on scalability, and fog-cloud integration offers it. As more and more devices and sensors are being integrated into healthcare systems, the data load is constantly growing. When needed, healthcare providers may scale up their infrastructure with the help of the hybrid fog-cloud approach. The fog layer can expand with the addition of more edge devices, and the cloud can handle the increased demand for processing power and storage. Healthcare systems can easily adapt to new technologies and increasing data demands thanks to their versatility, which ensures that performance and security are not compromised.

Other significant benefits of fog-cloud interaction include improved reliability and fault tolerance. If a cloud server goes down, it might lead to downtime or data loss for systems that rely only on the cloud. However, by using distributed processing and storage, fog computing reduces the likelihood of a complete system failure. As a result, fog nodes ensure that healthcare activities will continue even if the cloud service is briefly offline. More system availability is assured by this distributed technique, which is an essential requirement in healthcare where downtime can have substantial implications.

II. REVIEW OF LITERATURE

Nandankar, Praful et al., (2021) A combination of factors, including an aging population and a lack of medical professionals, has increased the demand for smart healthcare systems globally. Advancements in big data, machine learning, and the Internet of Things (IoT) have lately aided these systems. The processing of health data is a significant challenge, too, because these advancements produce enormous amounts of data. It is challenging to impose effective processing on this data because of its dynamic features, which include high dimensionality, irregularity, and sparsity. These difficulties are addressed by big data analysis. We propose a novel method for analyzing massive amounts of healthcare data collected from wearable IoT devices or historical medical images in this article. The data heterogeneity issue might be efficiently addressed by the suggested method by utilizing middleware between Map Reduce Hadoop clusters and diverse data sources. To address issues with online and offline data processing, storage, and categorization, the suggested architecture also allows for the usage of cloud systems and fog computing. Additionally, it guarantees that patients have full and safe access to their medical records.

Vu Khanh, Quy et al., (2021) Medical and healthcare applications for humans have consistently been the primary motivator for scientific and technological advancements throughout human history. With the initial wave of cloud computing, new business models including software as a service, platform as a service, and infrastructure as a service became possible. Healthcare information systems have been dominated by cloud technology for decades. One drawback of apps hosted in the cloud is the lengthy time it takes for service to respond. Controlling and monitoring patient status, making decisions with connected resources (e.g., a doctor, an ambulance, and medical conditions) in a matter of seconds can have a direct influence on patients' lives in some emergency circumstances. Proposed optimum computing solutions, including cloud, edge, and fog computing, aim to address these issues. Various forms of computer technology are compared in this article. Next, we provide a fog computing-based common architectural framework for Fog-IoHT applications. Furthermore, we emphasize the possible benefits and challenges of fog computing in healthcare IoT applications. The research found that IoHT applications based on fog computing are very promising. Our study is based on the idea that healthcare IoT applications built on fog technology may be a good starting point for how these technologies develop in the future.

Awaisi, Kamran et al., (2020) The Internet of Things (IoT) is enabling the enhancement of people's quality of life by connecting billions of devices worldwide. Innovations in the IoT have paved the way for new approaches to healthcare data analysis. Although there are now cloud-based and IoT solutions that can analyze and process patient data, cloud computing causes major end-to-end latency and network usage issues when processing enormous amounts of data. Internet of Things (IoT) healthcare systems continue to face efficiency and security issues. The limitations of cloud computing inspired the development of fog computing, which moves data storage and processing nodes to the network's peripheral. This article begins by presenting an efficient architecture for healthcare systems that depend on the Internet of Things, which is built on fog. Then, we'll demonstrate how to utilize identity management to authenticate users and prevent security breaches. The user authentication technique uses Elliptic Curve Cryptography to produce tokens.

Saha, Rahul et al., (2019) Modern conveniences for a simpler human existence are a result of developments in network technology and hardware that operate in tandem with the Internet of Things (IoT). In addition to so-called "smart" surroundings like smart homes, cities, and farms, the Internet of Things (IoT) has now found its way into e-healthcare systems for the purpose of real-time diagnosis and medical consulting. By delivering low latency and quick reaction time, fog layers have shown their utility in enhancing the capabilities of healthcare systems based on the Internet of Things. Nevertheless, this trend is making it much more difficult to protect users' privacy, which adds to the security and privacy concerns. Such technology has naturally encountered less privacy regulations due to its infancy. Consequently, the focus of our current effort is on a privacy-preserving e-healthcare framework for EMRs. We have also compared the suggested work to other recent efforts and conducted experiments to determine its reaction time and latency. The results demonstrate the efficacy of the suggested approach in offering privacy in addition to conventional network settings.

Nandyala, Sukanya & Kim, Haeng-Kon. (2016) Medical professionals used to depend only on their own expertise, the patient's symptoms, and the results of diagnostic tests when making decisions about treatment. The advent of new gadgets, objects, and technologies, on the other hand, has played a pivotal role in assisting medical professionals in making more informed decisions on patient monitoring. Fog (a substantial extension of cloud) overcomes the drawbacks of the cloud paradigm, which is the foundation of U-healthcare monitoring system architectures and allows for the on-demand utilization of a shared pool of configurable computing resources. C2F computing, which interacts more by serving closer to the edge (end points) at smart homes and hospitals, is a motive and benefit in this paper's suggested architecture for Internet of Things (IoT) based u-healthcare monitoring.

III. EXPERIMENTAL SETUP

This study implements the features of the iFogSim architecture by utilizing the fundamental event simulation capabilities of CloudSim. "Entities" in CloudSim include datacenters and the message-sending procedures that allow them to communicate with one another. Hence, the main CloudSim layer of iFogSim handles events between the Fog computing components. In iFogSim, the primary CloudSim layer is responsible for coordinating the several Fog computing components' operations. Virtual services and entities lay the groundwork for an iFogSim deployment. Figure 1 shows the setup (CPU GHz, RAM size, and Power) of several fog devices.

Device type	CPU GHz	RAM (GB)	Power (W)
ISP Gateway	4.0	6	117.445
Smartphone	2.6	2	88.64
Wi-Fi Gateway	4.0	6	117.445
Cloud VM (Virtual Machine)	4.0	6	117.445

Figure 1: Setup of Several Fog Devices

In addition, we modeled patient data using VM in a cloud simulation environment that relies on an expanded datacenter class for fog device implementation. Furthermore, Cloudlets were enhanced to facilitate the realization of patient data, which is used to undertake user demands. Each fog node is only designated to run one host in order to execute the fog applications. In a fog-assisted cloud environment, data pertaining to cardiac patients is processed by fog nodes that are geographically close to the Internet of Things (IoT) devices. This helps to save network bandwidth, reduce reactions time, and increase responsiveness.

IV. RESULTS AND DISCUSSION

In Figure 2, we can see the estimated amount of time spent on the network for different amounts of user requests made by cardiac patients in a cloud and fog-based setting. Since fewer user requests are directed to the cloud in a fog-based environment, the calculated value is lower in the fog-based environment than in a cloud-based environment. Using fog instead of cloud reduces the average time a network is used by 22.63 to 26.80%.

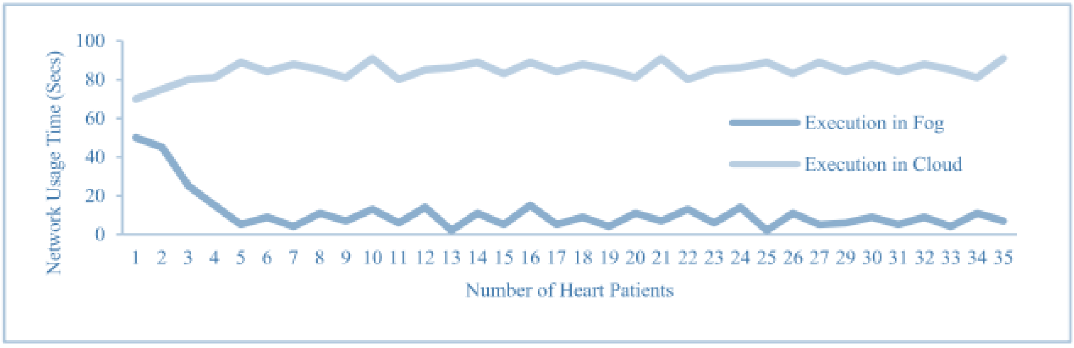

Figure 2: Comparing Network Usage Time of The Fog and Cloud Systems Exposed to Number of Heart Patients

Figure 3 compares the latency of the Fog and Cloud systems when exposed to varying numbers of user requests initiated by cardiac patients. In comparison to cloud, fog has lower latency. When compared to cloud, fog lowers latency by an average of 19.54 to 29.42%.

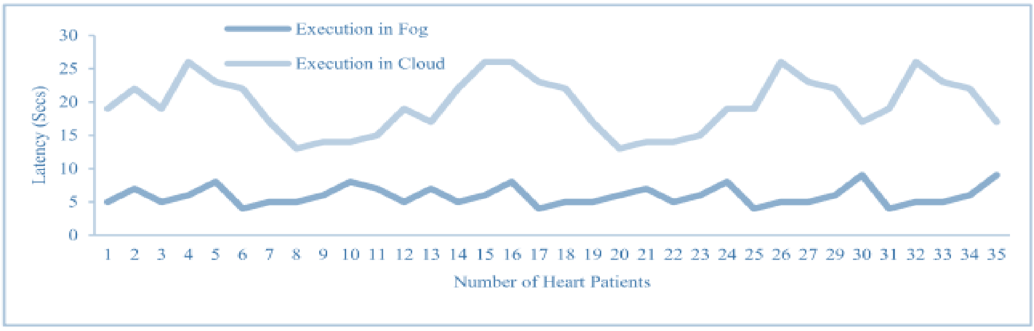

Figure 3: Latency of the Fog and Cloud Systems Exposed to Number of Heart Patients

Figure 4 shows the energy usage of both the fog and cloud environments while processing varying numbers of user requests initiated by heart patients; for the same number of requests, the cloud environment uses more energy than the fog environment. For 33 user requests, fog's energy usage is 33.45% lower than cloud's, while for 20 user requests, it's 8.25% lower in cloud. Comparing fog to cloud, the average energy usage decreases by 23.56%.

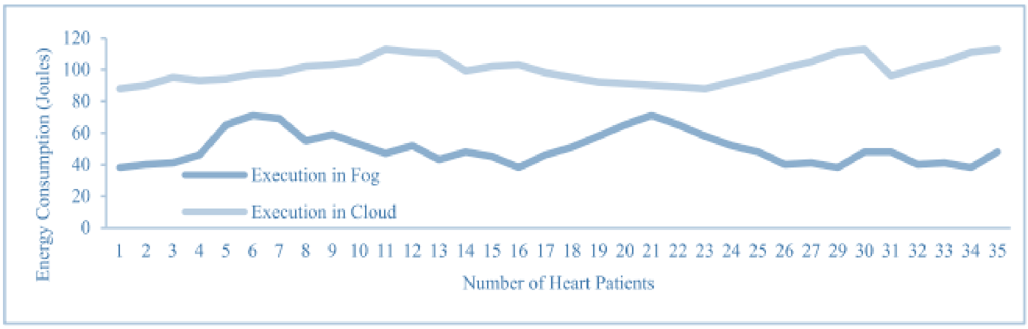

Figure 4: Energy Consumption of The Fog and Cloud Systems Exposed to Number of Heart Patients

Cloud and fog computing are two distinct environments that are compared in Table 1 using three metrics: latency, energy consumption, and overall network use time.

Table 1: Comparison of Performance Parameters Across Cloud and Fog Computing Environments

Environment	Processing Layer	Network Usage (s)	Energy Consumption (J)	Latency (s)
Cloud computing	IoT to Cloud	84.61	101.28	24.35
Fog computing	IoT to Fog	11.15	34.45	3.28
	Fog to Cloud	12.20	16.68	5.07
	Total	23.37	51.09	8.27

On average, the network use time, energy consumption, and latency for IoT to cloud communication in a cloud computing environment is 84.61 seconds, 101.28 joules, and 24.35 seconds, respectively. In comparison to fog computing, cloud computing is more energy intensive, takes longer to process data, and has longer latency. In contrast, the IoT to Fog communication in a fog computing environment demonstrates a lot less energy consumption (34.45 Joules), latency (3.28 seconds), and network usage (11.15 seconds) on average, indicating a more efficient process.

Transferring data from the fog to the cloud does raise latency to 5.07 ms, energy consumption to 16.68 joules, and average network use time to 12.20 s, but it's still far better than cloud computing. In comparison to cloud computing, overall performance metrics are considerably improved by integrating both communication lines in fog computing (IoT to Fog and Fog to Cloud). Total average network use duration is 23.37 seconds, with an average of 8.27 seconds of delay and 51.09 Joules of energy consumption.

V. CONCLUSION

This study's results show that, as compared to conventional cloud computing, fog computing processes time-sensitive healthcare data far more efficiently, especially in cases when cardiac patient monitoring is involved. Users' requests are handled closer to the edge via fog nodes, which significantly improves critical performance metrics including energy consumption, latency, and network use time. Internet of Things (IoT) applications in healthcare may greatly benefit from fog computing, which not only provides quicker reaction times and more energy-efficient data processing but also decreases the pressure on central cloud servers. This research highlights the possibility of improving system responsiveness, lowering operating costs, and improving overall service quality for important applications via the integration of fog computing in real-world settings.

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