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Cloud Fog Edge Computing for Internet of Health Things

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***Abstract*— In India, 63% of the population resides in areas where access to healthcare is significantly restricted compared to urban locales, which have superior services offered by private healthcare centers primarily situated in cities. The nation experiences a shortage of staff, especially in rural regions, causing locals to journey considerable distances. The increasing incidence of diseases and fatalities within the population has created a problem during the COVID-19 crisis. The Internet of Health Things promises to revolutionize health systems by gathering and analyzing patient physiological information through wearable devices and sensor networks. These systems can provide realtime assisted living services and various multimedia health services. Thus, this research investigates the revolutionary power of cloud-fog edge computing for IoHT applications.**

***Index Terms*—Cloud computing, Fog computing, Edge computing, Internet of Health Things, Healthcare.**

I. INTRODUCTION

Healthcare is one of the many industries that have changed as a result of the Internet of Things' (IoT) real-time monitoring and data collecting capabilities. The application of IoT in the healthcare industry to enhance treatment quality and offer a more comprehensive picture of patient health is known as the Internet of Health Things, orIoHT. However, there are obstacles to overcome in the implementation of IoHT, such as worries about privacy and security of data, problems with interoperability, and the requirement for powerful data analytics tools. [1]

Technologies like cloud, fog, and edge computing might help with these issues. Using an internet-based network of distant computers for data processing, management, and storage is known as cloud computing. Fog computing is a decentralized computing architecture that effectively distributes data, compute, storage, and applications between the data source and the cloud. By bringing processing and data storage closer to the point of demand, edge computing speeds up reaction times and reduces bandwidth use.[5] The delivery of healthcare might be enhanced by the integration of these technologies with IoHT. By processing data closer to the source and cutting down on the time needed to transfer it to the cloud for processing, edge computing, for instance, can minimize latency.

By offering a decentralized architecture and minimizing the quantity of sensitive health data that has to be sent to the cloud, fog computing can help allay worries about data security and privacy. [8] The goal of this research is to look into the potential benefits and drawbacks of using Edge, Cloud, and Fog computing in IoHT.

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It will also investigate the outcomes of present IoHT deployments of these technologies. The findings of this study may assist shape future improvements in this field by providing politicians and healthcare practitioners with meaningful information.

II. Architecture of Healthcare IoT System

The Architecture of a Healthcare Internet of Things (IoT) System is a comprehensive model that describes the interactions and roles of all the various parts of an IoT system in the healthcare industry. It is a multi-layered system made to make it easier to gather, move, process, and use health data. The device layer, which includes various IoT devices such as wearables, sensors, and medical equipment, serves as the design’s base. These devices are responsible for collecting a wide range of health-related data in real time. This may include the patient’s physical location, glucose levels, heart rate, and blood pressure. These devices then use the network layer to communicate the data they’ve collected. To ensure dependable and secure data transmission, this layer uses a number of communication protocols and technologies, including as cellular networks, Bluetooth, and Wi-Fi.

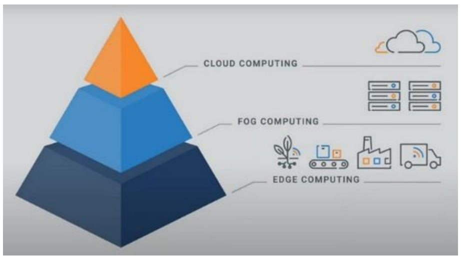

Figure 1 Layers of Cloud, Fog, and Edge Computing

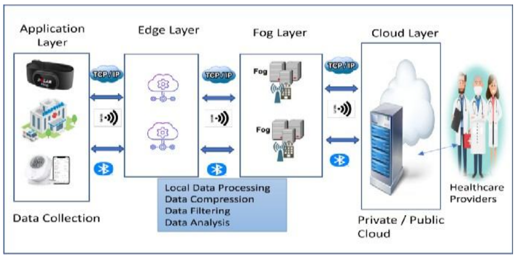

Figure2. Healthcare IoT System Architecture

Following transmission, the data arrives to the middleware layer. This layer serves as the central component of the IoT system. It manages device connectivity, ensuring that data flows seamlessly between the network and device layers. Additionally, it provides critical services like as data aggregation, device management, and storage.

The processed data is utilized at the application layer. It consists of numerous healthcare apps that exploit IoT device data. These apps, all designed to improve patient care and outcomes, could range from telemedicine platforms to patient monitoring systems. Data is handled, processed, and analysed at the cloud layer. It uses cloud computing technologies to provide powerful data processing and scalable storage. Big data analytics, machine learning, and other cutting-edge data-driven healthcare applications rely on this layer. Finally, patients and medical professionals interact with the system at the end user level.[4] Users can access real-time health data and insights via its user interfaces, dashboards, and alerting systems. Finally, the Healthcare IoT System Architecture is a complex yet necessary framework for modern healthcare systems. It enables the efficient and effective use of IoT in healthcare, paving the way for improved patient care, health outcomes, and healthcare systems. It also comes with obstacles, like as privacy, interoperability, and data security, which all have to be handled for successful deployment. To figure axis labels, use words rather than symbols. Do not label axes only with units. Do not label axes with a ratio of quantities and units. Figure labels should be legible, about 9-point type.

Color figures will be appearing only in online publication. All figures will be black and white graphs in print publication.

Screenshot, programs, and other junk images etc must be removed; instead block diagrams, algorithm, flowchart, circuit diagram, state diagram, UML designs, etc may be introduced.

The paper must have proposed system, results, discussion to infer the quality of the research paper. All the figures, equations and etc must be in high resolution and in good quality.

A. Benefits

- Cloud Computing: Cloud computing provides cost savings, scalability, and accessibility. Large amounts of data generated by various health monitoring devices can be kept and analysed by healthcare providers.
- Fog Computing: Fog computing provides enhanced security, privacy, and faster response times. It supports a wide range of Internet of Things applications and services, including increased communication and real-time services.
- Edge Computing: Edge computing reduces bandwidth uti- lization, improves real time decision-making, and minimizes latency. It can encourage innovation to increase value and quality. [7]

III. RESEARCH METHODOLOGY

The use of cloud domain and IoHT domain in a remote patient monitoring system is examined in this study. The approach uses iFogSim to model a three-layered architecture at the fog layer. [10] Wearable sensors that gather physiological data make up the patient-side edge layer, and a mobile device that serves as a gateway and user interface is optional. Basic data processing is carried out by an application module on the edge, after which it is safely sent to the fog layer.[6] Individualized care may be provided to every patient through context-sensitive health monitoring. There are two types of contexts: intrinsic and extrinsic. When it comes to healthcare, extrinsic context is impacted by outside variables such as the patient's surroundings. Biosensors can extract the intrinsic context of a user, whereas environmental sensors can retrieve the person's extrinsic characteristics. Relevant data from extrinsic and intrinsic sensors can be utilized to track patients' health. However, the kind of information that is pertinent varies based on the patient's illness. Thus, the fog layer must also retain context-sensitive data processing. A fog computing toolkit called iFogSim is used to model the fog layer. This enables the features of the fog network to be tested and optimized prior to actual deployment. Another application module operates under the simulated fog layer, combining data from several patients, pre-processing, and doing real- time analysis according to pre established guidelines. [4] High processing and storage capacity are offered by the cloud layer for long-term data storage, intricate analytics, and EHR system integration. Healthcare professionals may set up monitoring settings, view historical data, and generate analytics reports using a management dashboard located in the cloud layer. Real-time patient health monitoring is visualized based on data from the fog layer. This technique makes it easier to assess how well the Cloud-Fog-Edge architecture performs in terms of efficient data processing via fog layer analysis, real- time patient monitoring, and overall scalability 37 to handle an increasing number of patients. Additional advantages of using iFogSim for fog layer modeling include the ability to optimize and assess fog network performance prior to real- world deployment. [2]

An architecture, in Figure 3, with three layers that we have provided as part of our study. The first layer, referred to as the cloud layer, is made up of a cloud where a cloud provider maintains servers and data centres and offers on-demand services. The fog layer, which is positioned in the centre of the architecture, allows for the use of fog computing features such network setup, local storage, cloud traffic management, and redundant data filtering. Most of the computing takes place at the lowest layer, known as the edge layer. The amount of computing that must be done on the cloud is decreased when data is gathered from several IoHT sensors and processed locally at the user's end.

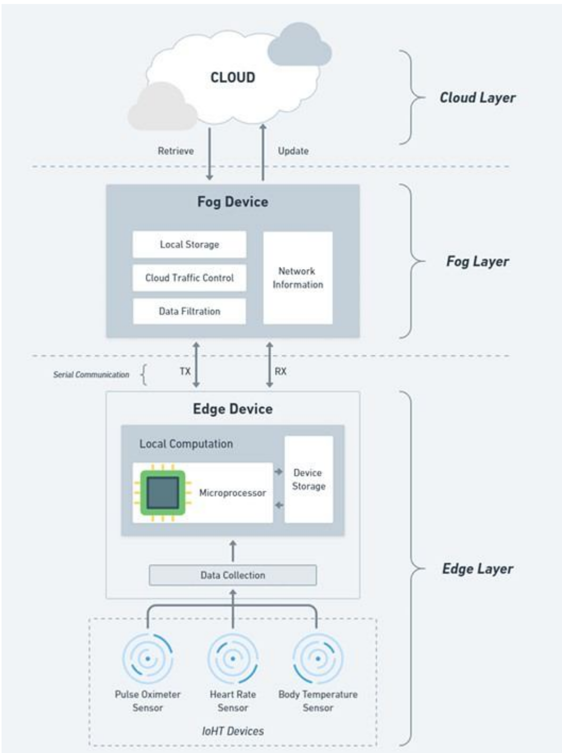

Figure 3. Schematic Diagram of proposed Architecture

- Data Processing: IoHT devices serve as the main data collectors in remote patient monitoring systems, gathering a variety of physiological data to evaluate a patient's condition from a distance. Critical indicators like heart rate, blood pressure, blood oxygen saturation, and breathing rate make up the bulk of the data. The gadget may also record biometric information, such as electrocardiogram (ECG) or electroen- cephalogram (EEG) measurements, depending on how com- plicated it is.[9]
- At the Edge Tier: wearable sensors, or the mobile device execute basic data cleaning activities such as filtering out noise or missing values. This first processing minimizes data volume before transmission, hence reducing bandwidth use and network strain.
- At Fog Tier: Fog nodes collect data from numerous patients. Here, more complex processing techniques are used. Normalization techniques may be used to guarantee that data from different sensor types are on a consistent scale. The fog layer is vital in real-time analysis. An abrupt increase in heart rate, for example, might signal a problem with the heart. This real-time analysis enables faster reaction times and potential intervention as needed.
- At the Cloud Tier: the platform archives previous data acquired from the fog layer. More complicated data processing techniques can be applied to the massive amount of acquired data. This enables more in-depth insights into patient health patterns as well as the early detection of potential health problems.

A. Data Analysis

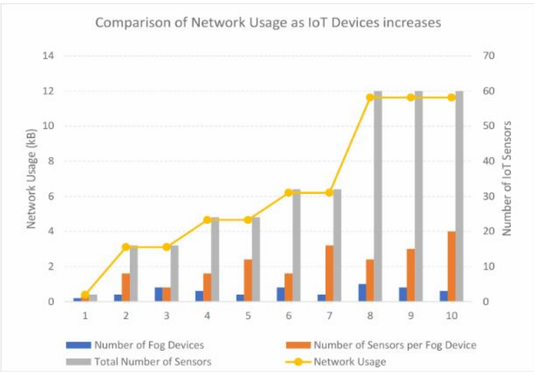

Figure 4 Graph of Network Usage & Number of IoT Device

S. No.	Number of Fog Devices	Number of Sensors per Fog Device	Total Number of Sensors	Network Usage (kB)	Latency (ms)
1	1	2	2	0.388	5.4703
2	2	8	16	3.104	6.5814
3	4	4	16	3.104	5.8407
4	3	8	24	4.656	6.5814
5	2	12	24	4.656	7.3222
6	4	8	32	6.208	6.5814
7	2	16	32	6.208	8.0629
8	5	12	60	11.64	7.3222
9	4	15	60	11.64	7.8777
10	3	20	60	11.64	8.8037

Figure 5 Simulation Outcomes

- Latency Analysis: In place where mighty performance is required in real-time then the latency should be minimized. Therefore, fog computing has the advantage for avoiding reg- ular cloud requests and it does so by performing computations at the network's edge and providing a prompt response to the client device. The formula for calculating latency is,

$$\text{Latency} = \alpha + \mu + \phi \qquad (1)$$

where μ is the amount of time to upload data for processing and storing in the fog node, α is the execution delay of CPU, and ϕ represents the amount of time needed to.
show the information to the patient or clinician via an alert or message.

- Network Usage Analysis: Cloud resources are only used when there is an increase in traffic to the cloud server. increasing network use is the result of increasing traffic on the cloud server. As a result, increasing the network congestion will drops the network's data rates. [7] When servers are dispersed globally, a single fog node is designated to handle requests from a certain region. As a result, in that scenario, the transmission rate for the remaining traffic increases while the network consumption falls. [8],

$$\text{Network Usage} = \text{Latency} \times \partial \qquad (2)$$

where ∂ represents the tuple network size.
The simulation in iFogSim will help in obtaining the values and then we will obtain the result using these formulas during implementation.

IV. Future Research and Discussions

The use of cloud domain and IoHT domain in a remote patient monitoring system is examined in this study. The approach uses iFogSim to model a three-layered architecture at the fog layer. [10] Wearable sensors that gather physiological data make up the patient-side edge layer, and a mobile device that serves as a gateway and user interface is optional. 6]

There are Biosensors can extract the intrinsic context of a user, whereas environmental sensors can retrieve the person's extrinsic characteristics. A fog computing toolkit called iFogSim is used to model the fog layer. This enables the features of the fog network to be tested and optimized prior to actual deployment. [4] High processing and storage capacity are offered by the cloud layer for long-term data storage, intricate analytics, and EHR system integration. Healthcare professionals may set up monitoring settings, view historical data, and generate analytics reports using a management dashboard located in the cloud layer. Real-time patient health monitoring is visualized based on data from the fog layer. This technique makes it easier to assess how well the Cloud-Fog-Edge architecture performs in terms of efficient data processing via fog layer analysis, real- time patient monitoring, and overall scalability to handle an increasing number of patients. Additional advantages of using iFogSim for fog layer modeling include the ability to optimize and assess fog network performance prior to real- world deployment.

V. Result and Findings

The parameters that were considered previously are implemented in the simulator, with respect to that we obtained different values of Network Usage and Latency for different values of variable names numOfFogDevices and numOfSenorsPerFogDevice, note that we have obtained these values when SENSOR TRANSMISSION TIME was set to 10 seconds.

After applying the parameters in iFogSim, we acquired varied values for network use and latency, as shown in Table 4 Simulation Outcomes. The values obtained are monitored and displayed on a graph.

Figure5 depicts a clear pattern: as the number of IoT sensors grows, so does network usage. However, the number of fog devices and sensors per fog device has no effect on network utilization, which is constant in all setups.

Figure 6 shows that there is an increase in delay when there are fewer fog devices and more sensors per fog device. This means that more fog devices should be installed to minimize latency. Also, when the number of sensors increases, network latency does not always rise. [3] Figures 7 and 8 compare the outcomes of our system with findings from previous research. This comparison reveals that our system performs favorably compared to prior approaches. [7]

VI. Conclusion

In our study project, we discovered that transferring the majority of the work to the user-end greatly decreases the strain on the cloud. The Fog layer handled the majority of the calculations, including data filtering. This strategy resulted in lower network utilization and better latency. Additionally, the Edge layer maintains constant connection with sensors, regulates noisy sensor data, and handles inconsistent sensor readings. The best effectiveness of an IoT network using fog computing is dependent on a well balanced ratio of fog devices and sensors. Too few fog devices and data from several sensors clog the network, but too many fog devices can be expensive and energy intensive. Maintaining the appropriate ratio allows fog devices to process data more efficiently closer to the source, reducing data traffic and latency for real-time applications. This balance is critical for a high-performance and cost-effective IoT network.

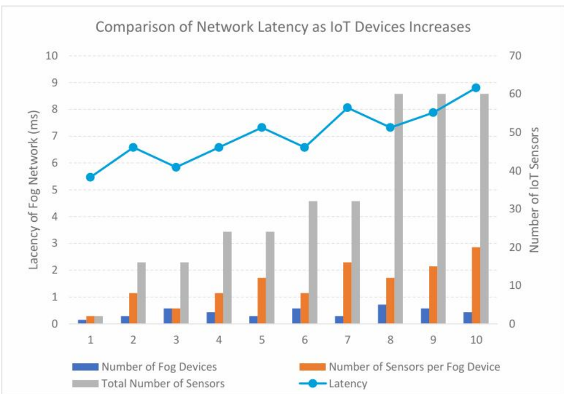

Fig. 6. Graph of Latency & Number of IoT Devices in Network

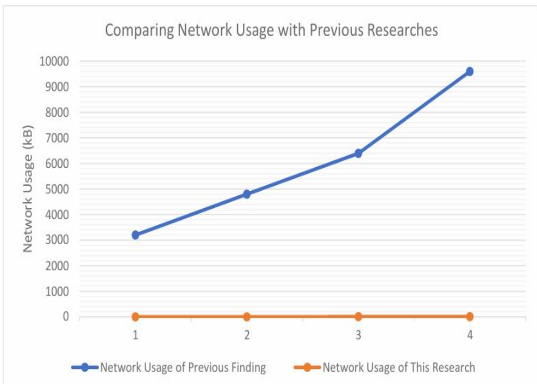

Fig. 7. Network Usage Comparison with Previous Research

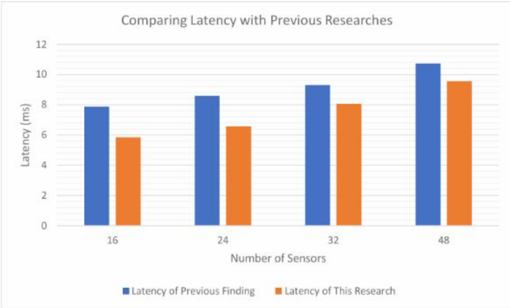

Fig. 8. Latency Comparison with Previous Research

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