Implementing Architecture of Fog Computing for Healthcare Systems based on IoT

Mayank Singh, Viranjay M. Srivastava

Abstract— ***Healthcare has been highly benefited with the technology advancement. Technology-based new solutions, methods, applications, and systems completely revolutionize the healthcare industry. Earlier the decision making of doctor entirely depends on the experience, domain knowledge, laboratory reports, diagnostics and patient's symptoms. With the advancement of technology in healthcare, the decision-making will be highly advanced and add wisdom to it. The patient's care and regular monitoring have been vastly improved at low cost with the appearance of the Internet of things based healthcare systems. There are a lot of Internet of Things (IoT) based healthcare devices that produces enormous of data and transfer to the cloud for analysing and sharing with other stakeholders. Cloud computing is the backbone for such devices to collect, analyse and share the data or result with all the concern persons. Data are increasing day by day as the user base of IoT based healthcare devices has also been increased in folds. Due to such high volume of data, the latency rate, security issues and quality of analysed data has been decreased on the cloud. To overcome such limitation of cloud, a new paradigm called Fog computing has appeared. Fog computing is the intermediate layer between sensors and cloud servers. It facilitates the data gathering from various nearby sensors, analyses the data and provides the result to the sensor, cloud servers and other concerns locally. Deploying such computing infrastructure locally reduces the cost and increase the quality of analysis and alerting in real time. It also adds the security to the data as it is processed locally. This paper proposed an architecture to implement the fog computing between IoT sensors and cloud to handle the medical data.***

Index Terms — Fog computing, healthcare systems, IoT based healthcare applications

I. Introduction

The healthcare industry is entirely revolutionized with the advancement of information communication and technologies. The Internet of Things (IoT) evolved an ecosystem for smart devices with various sensor to collect and exchange the information between sensors or IoT devices [1]. The IoT incorporates in the healthcare industry with several types of devices to radically improve the patient monitoring, effective medication and making healthcare affordable for everyone [2]. With the help of IoT, the healthcare industry is evolving new service areas in lowest cost [3,4]. IoT devices help the practitioners to monitor the patient's activities and health remotely and enhanced the alert system in case of any abnormality in patient's health-related data [5,6,7]. It is a prediction that the most of the medical care will be balanced in home-based monitoring and assisting with hospitals by 2020 [8].

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The current scenario is the integration between cloud services and IoT sensors or devices. These IoT sensors or devices are directly transmitting the data to the cloud for analysis. These devices or sensors generate an exceptional amount of health-related data on a daily basis. It is a prediction that by 2020, the IoT devices will produce 25000 Petabyte of healthcare-related data on a daily basis [9]. Due to the resource constraints, it will be a challenging situation to gather and analyse such massive amount of data. The analysis will take much time to get the result and notify the user, patients or practitioner. In case of healthcare, the latency in analysing and responding is not tolerable at all.

To overcome this situation, we need to modify the current architecture that requires an intermediate computing layer. Fog or edge computing will work as intermediate computing layer [10,11]. The fog centric modified architecture will provide services to enhance the performance, usability, scalability, security, and reliability. It divides the big data into sub data for processing on time and producing the result [12,13].

This paper presents the study of benefits and challenges of fog centric, IoT based healthcare system. A modified architecture is also presented to handle the healthcare data at the intermediate layer. Section II describes the previous research work. IoT based smart healthcare system are explained in section III. Section IV explain the basics of fog implementation in IoT based healthcare systems. An architecture is proposed for implementing the fog computing in IoT based healthcare system in section V. A fog server architecture is proposed in section VI. The last section describes the conclusion and future scope of the work.

II. Related Work

The technology development in intelligent systems enables the well-being devices to help the patients in self-managing and monitoring. Much research is going on in the development of IoT and cloud-based systems and applications [14,15]. Various Sensors are used to monitor and measure the patient's activities in real time.

This information is transmitted to the cloud servers for processing and getting results about the health record of a patient. Based on the analysed data, the system also predicts the health-related issues which can occur shortly.

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A diabetes management system was proposed by Jara et al. [16]. The proposed system monitor the glucose level in the blood and provide the feedback for insulin therapy. Gupta et al. [17] proposed a cloud and IoT based physical activity monitoring system. The primary concern of this proposed model is to securely transmit the data from sensors to cloud servers and analyse the physical activity performed by the patient.

A cloud-centric online data management prototype for IoT based healthcare devices was proposed by Doukas et al. [18]. All the patients' data is directly transmitted for processing to the cloud servers. Data handling and security issues are detected because of much communication involved between sensors or IoT devices and cloud servers. Chen et al. [19] proposed the security trust model for medical data sharing over the cloud. The author uses the data segmentation and encryption-decryption technique to secure the medical data over the communication channel.

Renta et al. [20] present a model for fast data analysis on the cloud for user's critical medical data. The author also presents the faster processing and response or alert system in real time based on the predictive rules of health and user's activity plan. Specifically for cardiac patients, a new fog based approach was proposed by Gia et al. [21]. Various sensors are used in the proposed system to collect the cardiac related data and send for the analysis and notification on the fog nodes.

From the previous work, we observed that there is a requirement for a generic fog centric IoT based framework for healthcare that follows the cloud-like structure and provides efficient and on time result. The framework should enhance the interoperability and integration to enhance the services.

III. SMART HEALTHCARE SYSTEM BASED ON IOT

Smart devices opened a new way of the healthcare industry to deliver the services and improving the well-being and health of human being. Smart devices provide freedom to access the data anytime from anywhere and availability. The personal, high-quality healthcare related data will be accessed using smart devices for processing and analysing the health of a person. Hence, smart devices which are based on IoT are considered as favourable solutions for the healthcare industry. With such devices and sensors, the medical practitioners can monitor their patient on a regular basis without any personal interaction.

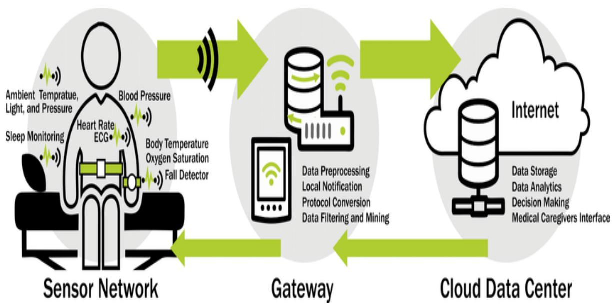

Figure 1: IoT and Cloud based Healthcare system [9]

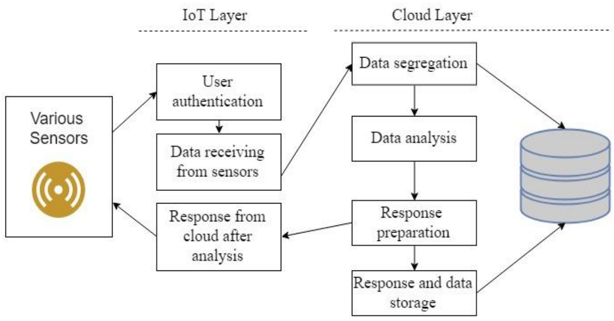

Figure 2: IoT and Cloud based Healthcare application model

They can also analyse the track of health record to prescribe the medication or support. These smart IoT based healthcare devices directly communicate with the cloud to provide data in real time for processing and to get the response for any alert or issue. Figure 1 shows the IoT and cloud based healthcare system.

These IoT based smart healthcare devices work on the three-layer architecture. The first layer belongs to the sensors of these devices that collect the health-related data of a person and controlling actions. Next is network layer which enables the communication between the sensors of IoT devices and cloud servers. The last layer is the application layer that facilitates the user by analysing the collected data using computation methods over cloud servers. This architecture also allows sharing the analysed data with an adequate person for timely feedback. IoT and cloud-based healthcare model is represented in figure 2.

This architecture has a limitation because the massive amount of data has been gathered from smart healthcare devices for processing at the cloud. Only cloud transferring of data is not the appropriate solutions because of latency in the response and heavy data traffic. Security will also be a concern if all the data is directly transferred to the cloud from sensors. To successfully deal with such substantial medical or health-related data for gathering and processing a novel approach is required or addition of a layer is a necessity. Fog computing will work as this fourth layer that revolutionizes the healthcare industry.

IV. IOT BASED - FOG CENTRIC SMART HEALTHCARE SYSTEM

Cisco devised the new term Fog computing to make the cloud computing closer to the user [22]. Fog computing enables the deploying of applications closer to the user's propinquity for advances in the reduction of processing time, cost, network bandwidth, communication and enhancing of security and privacy [23].

Fog computing extends the capabilities to cloud computing and omits the limitation. It is not the replacement of cloud instead it extends the computation capabilities by reducing the computation only at cloud end. It has the similar characteristics of cloud-like on-demand storage, network resources, and computing.

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The three main characteristics differ the fog from cloud i.e.

- Deployment at closest to the user
- Provide flexibility to the user
- Its wide geographical distribution

V. PROPOSED ARCHITECTURE FOR IMPLEMENTATION OF FOG COMPUTING

This paper presents a modified three-layer architecture with the integration of Fog, IoT and cloud to provide reliable healthcare services. With this architecture, the intelligence is transferred toward the closer to the user on the edge network. These nodes work as a bridge between various sensors or IoT devices and the cloud for providing better and efficient healthcare services to the end user. The proposed architectural model is presented in figure 3 to explain how this integration can achieve the objective.

The critical components of the architecture are

- Sensors or IoT devices
- Fog nodes
- Fog servers
- Cloud servers

Only cloud servers are centrally located at the healthcare provider's location while other components, i.e., sensors or IoT devices and fog servers are distributed according to their geographical locations.

In this architectural model, various sensors are available for end-user to record the medical data such as wearable devices, environmental sensors, motion sensors and several others. Different communication channels like ZigBee, Wifi, LTE or 3G, are used by these IoT devices to interact with each other. These devices are directly connected with the fog nodes that act as intermediate data collection and processing point. It has the limited computation processing capabilities for necessary information processing. For further detailed processing, it will transmit the data to fog servers. Fog server performs complete processing to gather information for feedback and responses. It works as lightweight cloud server in the proximity of end user.

Due to its infrastructural limitations, it can perform all the computation functionalities but lacking in predictive computation that can only be done by cloud servers because it required big data analysis which is not possible at the fog servers. In this way, we can provide the quality of service to the end user in appropriate time with low cost. Data collected and processed by the fog servers can be removed without uploading to the cloud. In case of further processing is required, then only the collected data will be transferred to cloud otherwise merely processed information will be stored in the cloud.

Furthermore, the fog server can works as a backup to the cloud servers in case of communication failure. Hence, Cloud computing layer aggregates data summaries from multiple Fog nodes/servers, performed more in-depth analysis and based on achieved insights performs rule and pattern updates at the Fog level.

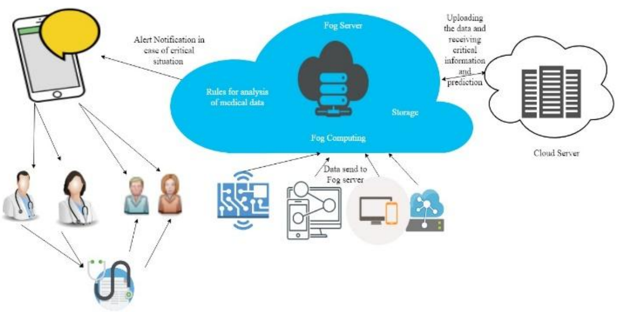

Figure 3. Proposed architecture for implementing fog computing layers in an IoT based healthcare system

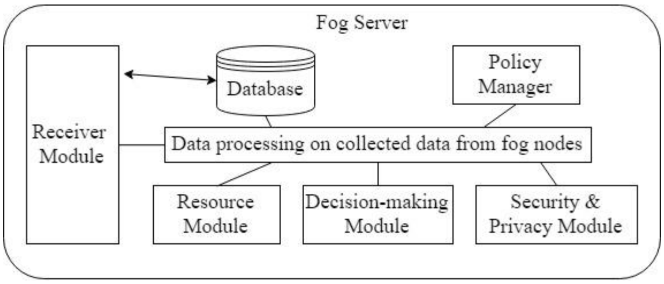

Figure 4. Proposed architecture for fog server

VI. PROPOSED ARCHITECTURE FOR FOG SERVER

Fog servers are the lightweight cloud servers that are capable of storing, processing, analysing, filtering of data and providing responses to the end user in real time. To perform the above-mentioned functionalities, the fog servers should be composed of the following components shown in the figure 4.

- Receiver module works permanently to receive or send messages from the fog node for processing. It will check the correctness of the message and after ensuring send for the authentication check. If message is not authenticated the sender will be notify by the receiver.
- Security and Privacy module check the authenticity of the message sender and cloud providers to prevent the unauthorized access. This module is entirely responsible for the security of fog servers from viruses, malware or intrusions.
- Storage module stores all the valid messages for further use in processing.
- Decision-making module performs all the computation processing to analyses the data for feedback and responses to the user. It also decides for instant communication or sending alerts to the concerns in case of any variation found in the health record of the end user.
- Policy manager module handles and maintains the local policies of communication with cloud and fog nodes.
- Resource module handles the nearby available resources to utilize effectively in data gathering and processing. Furthermore, it stores the details of fog nodes that are managed by the fog server for easy access to other fog nodes.

VII. PERFORMANCE EVALUATION

The performance of our proposed architecture is evaluated and compared with the cloud-IoT based healthcare architecture. Both the environment is simulated to check the network delay for the result analysis, cost incurred in the data processing and to check the number of sensors required to perform the certain number of services for both the architectures.

Figure 5 shows the network delay by the applications in both the environment. Cloud based architecture takes higher data transmitting and analysis time in compare to the fog based architecture. The data is availability time is less in fog based architecture because of multiple communication links between data source and computation components.

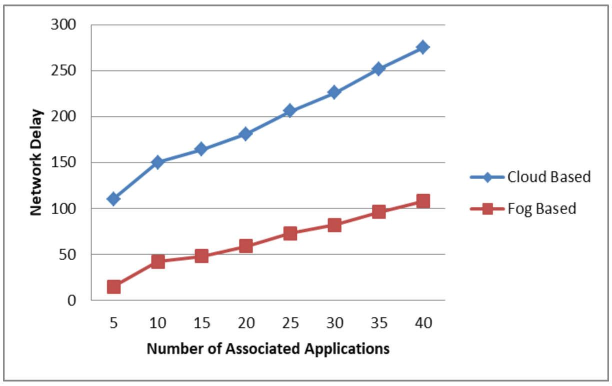

Figure 5. Network delay in Cloud and Fog based architecture

In fog based architecture, the application requires less number of resources for the computation in comparison to cloud based architecture because the service charges has to pay for the each virtual machine required to analyse the data which is shown in the figure 6.

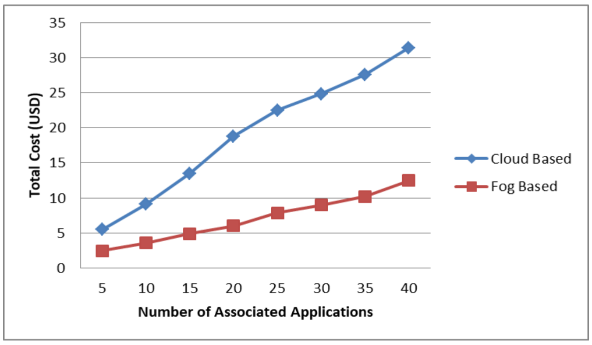

Figure 6. Virtual machine cost in Cloud and Fog based architecture

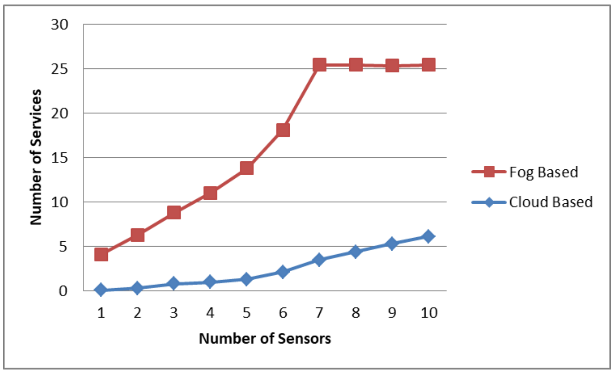

Figure 7. Variation in number of sensors for Cloud and Fog based architecture

Figure 7 shows the number of services accumulated with the increase of sensors for both types of architecture. Fog architecture can handle the associated applications in increasing manner for a certain level of increment in sensors because of less computation power. Post that level, services cannot be increased in fog architecture. Whereas in cloud architecture, the services can be increased with the increase of sensors.

VIII. ADVANTAGES OF FOG INTEGRATION

As discussed earlier, the fog computing extends the services of cloud computing for on-time processing, reduced latency, better utilization of network resources and fast response. The real-time analysis will be easy and effective according to the user's nearby available network resources and local policies for a vast amount of medical data.

The immediate processing of data is done in the proximity of the end user without any network constraints. Without any latency in the processing, the response action time will be decreased with improved quality of healthcare services.

Fog computing provides the mobility facility to its users. There are no constraints of fixed resources. The user can use the services wherever the nearby network resources are located from dense geographical distributed fog nodes. It will reduce the communication between sensors and cloud that result in reducing the bandwidth usage, fast processing of data, real-time alert or response system and provide quality healthcare services.

IX. CONCLUSION AND FUTURE SCOPE

A drastic change occurs in our life with current IoT based smart devices. Healthcare is the most impacted sector of these devices with full potential. With these devices, the availability, mobility, accessibility, effective healthcare delivery, quality services are possible for the end user. However, many challenges occur in the form of data storage, data accessibility in real time, interoperability, privacy, and security.

Fog computing comes into existence to overcome the challenges of IoT devices and cloud that integrate with IoT devices and cloud computing for efficient, faster and secure data gathering and computation. It is perfect for real-time processing of data and monitoring which is the primary requirement of any healthcare system or application. In this paper, a modified three-layer architecture for implementing the fog computing between IoT devices and cloud servers. The proposed architecture will reduce the burden of data computation on cloud and overcome the limitation of IoT devices and cloud servers. By the implementation of this framework, patients, medical practitioners, hospitals and other concerns will get benefited to monitor the health status and get the feedback in real time.

Advantages of implementing the fog computing also explained in the paper. In future, we will implement this architecture on the various specific medical disease to monitor, analyze and predict the health status of a patient.

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