

Platform Independent Approach for IoT based Secure Smart Healthcare System

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Abstract: IoT has emerged as a technology that can assist in numerous fields ranging from agriculture to education to healthcare. This technology provides a structural and competent approach to handle various aspects of service and delivery in remote monitoring and smart health by generating a lot of sensitive medical data. Computing is the basis of providing these services which may be based on either cloud or fog or edge. But cloud, fog or edge dependent computing requires processing of utmost sensitive health data on servers. The literatures present for platform based healthcare systems lacks in the security and privacy concerns of highly sensitive medical data. Also these platforms introduce latency in the response of healthcare systems. So to remove dependency of healthcare architectures on platforms and to make sensitive medical data more secure, a high level platform independent architecture is proposed in this paper. This architecture takes the advantages of internetworking by deploying local servers at the nodes and deploys the networking as per requirement and suitability.

Keywords: Internet of Things, healthcare system, cloud computing, fog computing.

Introduction:

People, all around the world, now a days have become very busy due to their working lifestyle. This busy schedule affects the health of a person directly. Due to shortage of time, people ignore their health, scheduled visits to doctors and regular checkups resulting in health problems. With passage of time, people recognize the importance of health for their growth and development and demand for healthcare services that too consuming less time (probably avoiding travel time to doctors). Traditional medical services require frequent visits to hospitals. Also, the world is facing a pandemic created by COVID 19. People are in fear. They try to ignore outside visits to hospitals and doctors for regular checkups. So smart healthcare system is the need of hour that provides the medical facilities to the people at their homes.

The excessive growth of communicating electronic devices, smart phones, tablets, laptops etc., has made these devices a part of daily life. So, this generation is time of connected devices which is known as Internet of Things(IoT). IoT connects various devices, sensors, vehicles and different other “things” that are able to communicate.[1] With the help of IoT, we can connect anything, get its access from anywhere and anytime to get information about any object. IoT extends the capability of internet by enabling remote control access, data sharing, full connectivity etc. These properties of IoT can be well exploited in smart healthcare systems. The

smart healthcare system can provide better medical facilities to people anywhere and at any time that to in user friendly manner. Such a system is called IoMT(Internet of Medical Things) that interconnects various devices for measuring the physiological parameters, or "vital signs," of a patient such as temperature, blood pressure, heart rate, heart activity, etc. Main facilities provided by IoMT include remote monitoring of patients, tracking their location, tracking medication taken with the help of various wearables that transmit health information to concerned doctors/professionals through internet.[2]

Many researchers have proposed different healthcare architectures. Depending on the technology used, these architectures may be broadly classified into two categories:

- 1) IoT based healthcare system using cloud.
- 2) IoT based healthcare system using FOG.

IoT based healthcare systems which use benefits of cloud computing. Cloud computing is defined as a large scale distributed computing system which support excess to a large analyzed, abstracted, scalable, computing, storage, platform services on demand.[14] Distributed computational framework utilizes the computing capabilities of the smart devices like biosensors, smart phones and smart watches to collect the data from these devices.

Fog based IoT healthcare systems overcome the limitations of cloud computing by providing the facility of processing, storage and communication capabilities to the smart devices near the patient. This helps in reducing communication delay and response time [19].

The detailed study of both the architectures is presented later in the paper. Considering the features and limitations (specially of medical data security) of both the architectures present in literature, the dependency of healthcare system on computing platform must be resolved. So a more secure high level platform independent architecture is proposed in the paper.

The organization of paper is as follows: section II discusses the work done related to IoT based healthcare system using cloud computing, section III presents the fog architecture of IoT based healthcare system. Section IV presents the proposed framework followed with discussion in section V.

Section-II: IoT and Cloud based healthcare systems

IoT is going to bring a revolutionary change in traditional healthcare systems in the terms of accessibility, cost, quality, security, privacy, reliability etc. Bringing IoT with cloud can provide a better solution to achieve the purpose of smart healthcare. Cloud provides large amount of space and different services like data gathering, storage, access, analysis of medical data, visualization of data as well as results etc. Cloud helps in accurate diagnosis and monitoring of patient's condition based on the large medical data containing different physiological parameters.[6]

Researchers are doing a lot of work in designing cloud based IoT enabled healthcare systems. Authors in [20] present an IoT based intelligent home based healthcare system, iHome Health-IoT to realize integrated Health Information System(HIS). Sensors collect the data, smart devices preprocess it and send it to cloud for further processing and storage. Medical resource management is done by accessing the services of cloud computing. Authors in[8] propose a cloud based healthcare system where a network of various actors of health care(like doctors, patients, pharmacists, labs etc.) is created to share the data and services like EHR, clinical decision systems, pharmacy systems etc. on a single cloud platform. Cloud platform can act as Platform as a service and Infrastructure as a service. This data is saved in patient's medical profile that may be diagnosed by various doctors at any place. Another paper[10] IoT based healthcare system using watermarking technology. The watermark secured data is transmitted to cloud. The cloud act as authentication manager, data manager, feature extraction server (through LBP algorithm), classification server(by using ELM machine learning algorithm), and storage. The authors in [11] presented a distributed framework for monitoring the health of patients. The framework integrates sensing and computational capabilities of network at different levels and distribute the computation load among different available devices. Yet in another paper [13] the authors propose CloudDTH framework of cloud healthcare system. The DTH(digital twin Healthcare) is interaction between real medical world and virtual space. The results of DTH are communicated and supported by cloud where virtual as well as real data is stored. CloudDTH system is supported by cloud computing, health IoT, digital twin and big data.

After reviewing the literature, it is concluded that the architecture of IoT based cloud assisted healthcare is as shown in fig1. The architecture comprises of mainly three layers: the architecture comprise of mainly three layers: Sensor Network Layer, Gateway and Cloud data center.

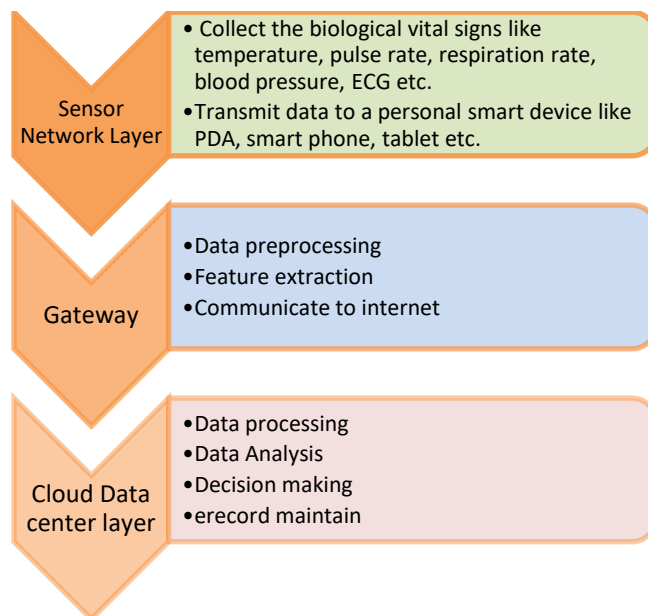


Fig1. Three layer architecture of IoT based cloud assisted healthcare

Sensor Network layer: This layer comprises of various biomedical sensors that are either carried or worn by patient. These sensors combinely make personal Wireless Body Area Network(WBAN). The sensors collect the biological parameters like temperature, pulse rate, respiration rate, blood pressure, ECG, blood glucose etc. The sensors transmit their data to a personal smart device like PDA, smart phone, tablet etc. using low power transmission method like Bluetooth.

Gateway: the smart devices act as gateway. These receive data from sensors, process the data to extract meaningful information and analyze the data. Various machine learning algorithms may be used at this level to preprocess the data, extract features from it and develop a predictive model that can be trained to extract features from a training data set and realtime data lateron. The extracted features may be then communicated to doctors through internet.

Cloud Data center layer: the facilities provided by cloud enables to process the data obtained from gateway layer, store the information for analysis and decision making. Also erecord may be maintained at this layer.

Benefits of Cloud computing in healthcare system

High Speed: faster deployment allows to get the resources required for the system within fewer minutes.

Back-up and restore data : it is easy to get the back-up and recovery of that.

Automatic Software Integration: In the cloud, software integration occurs automatically. Therefore, need not to customize and integrate applications.

Reliability: can always get instantly updated about the changes.

Mobility: Anyone can easily access all the could services just by having Internet connectivity.

Unlimited storage capacity : The cloud offers almost limitless storage capacity.

Collaboration: People who are located in different geographies can collaborate in a highly convenient and secure manner.

Quick Deployment: rapid deployment, so entire system can be fully functional in very few minutes.

Obstacles: following challenges are the noted while dealing with smart healthcare cloud

Security Threat in the Cloud: Sharing medical sensitive data to a third-party cloud computing service provider poses threat.

Downtime: Cloud provider may face power loss, low internet connectivity, service maintenance, etc.

Internet Connectivity

Lower Bandwidth: Many cloud storage service providers limit bandwidth usage of their users.

Performance Can Vary: Any greedy behaviour or DDOS attack on could affect the performance of system.

Section-III: FOG based IoT healthcare systems

CISCO had coined term ‘FOG’ that means a layer present in between sensor gateway layer and cloud layer. The purpose of Fog layer in healthcare systems is to analyse realtime sensitive medical data at edge layer instead of sending the complete data to cloud. So, it is basically providing lightweight cloud facility at edge node. Fog resolves various problems of cloud computing like edge location, latency issue, location awareness, reliability etc. as fog can be deployed at various locations as the services desired by the mobile user.

Less literature is available availing the FOG computing in IoT based healthcare systems. Authors in [15] present a novel Fog architecture-based anomaly detection framework. The proposed architecture involves a fog layer in between physical layer and cloud that collects data from sensors using hyperellipsoidal clustering technique. Then the architecture is examined for distributed as well as centralized computing. In another paper [16] the authors propose a fog assisted IoT based smart home patient monitoring system. In the architecture, a fog layer is introduced below the cloud. This fog layer helps in reducing the latency in real time monitoring of patients. Another paper [17] presented a healthcare architecture based on fog computing and using LoRa technology for communicating data from edge node(i .e. users) to fog node. Fog nodes have computing devices like computers, laptops etc. that may store the data. The authors in[18] presented a federated filtering framework in which the data sensed by sensors is transmitted to fog layer sever. At the fog server,all the data of one particular sensor or node is aggregated to make a prediction data matrix. Then filter parameters are computed through prediction data matrix and thirdly decision is taken by fog server, whether to send data at cloud or not. The local processing model is done by fog server. The architecture of Fog based IoT healthcare system according to literature review is shown in fig.2.

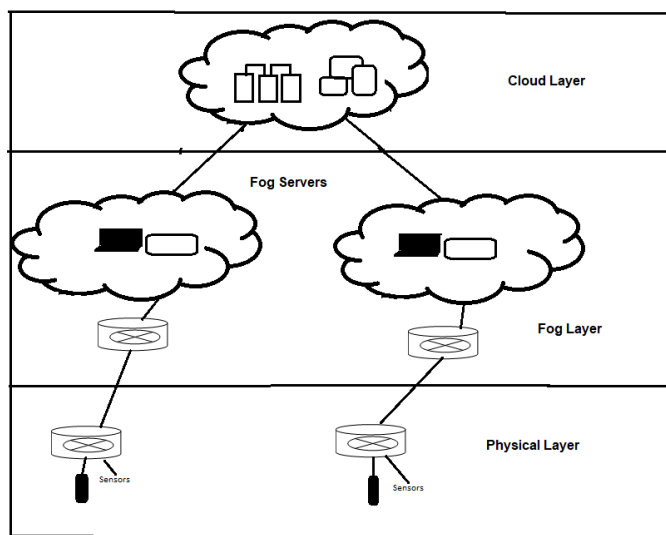


Fig2: The architecture of Fog based IoT healthcare system.

Fog based IoT applications consists cloud, fog and physical objects. The architecture comprises of mainly three layers as follows:

Physical Layer: This layer comprises of various devices like sensors, actuators etc. Patient's data is acquired in realtime through these devices wirelessly and collected by smart phones or tablets that act as fog nodes.

Fog Layer : Fog nodes collect and convert the data into proper format as required for analysis at cloud layer. The fog nodes process the data collected from sensors and takes decision whether the data should be sent to cloud or some assistance can be provided by the fog node itself to the patient. If needed, the processed data is transmitted to cloud.

Cloud Layer: The processed data obtained from the Fog layer is stored for analytics, decision making and other purposes. A database is created at this level to get information about the medical history and health of patients which helps to learn and detect trends to improve patient care and health. Engineers and scientists can acquire, store, and work with large amounts of medical data for designing and developing a model through machine learning algorithms that can predict the disease from the real time data obtained.

Benefits of Fog computing in IoT based healthcare systems:

Better security: Fog nodes can be protected.

Save network bandwidth, so lower operational costs

Reduces latency

Better privacy

Easy to develop fog applications

Mobility

Limitations:

More difficult encryption algorithms and security

Security issues like IP address spoofing, man in the middle attacks, wireless network security etc.

Fog computing is *challenging* and requires more efforts.

Data management is a challenge.

Trust and authentication are major concerns.

Scheduling is complex.

Power consumption is high

Table 1: Comparison of Cloud Computing and Fog Computing

Computing Type	Benefits	Challenges
Cloud Computing	<i>High Speed</i>	<i>Security Threat</i>
	<i>Back-up and restore data</i>	<i>Downtime</i>
	<i>Automatic Software Integration</i>	<i>Internet Connectivity</i>
	<i>Reliability</i>	<i>Lower Bandwidth</i>
	<i>Mobility</i>	
	<i>Unlimited storage capacity</i>	
	<i>Collaboration</i>	
	<i>Quick Deployment</i>	
Fog Computing	<i>Better security</i>	
	<i>Save network bandwidth</i>	<i>Data management</i>
	<i>Reduces latency</i>	<i>Trust and authentication</i>
	<i>Better privacy</i>	<i>Scheduling is complex</i>
	<i>Mobility</i>	<i>Power consumption is high</i>

Section-IV : Proposed framework

After reviewing both the platform architectures and looking at the features and limitations of cloud as well as fog based healthcare system, there is a need to design a framework for healthcare system that can overcome the limitations of previous ones and provide better healthcare facilities to patients. IoT applications being diverse in nature in terms of reliability, scalability and security, these challenges are hard to meet with fixed three layer architectures as been presented in the literature review work. The three-layer architecture defines the main idea of the IoT but it is not sufficient for research on IoT because research often focuses on finer aspects of the Internet of Things. One probable solution to the problem is to adopt a distributive system that enables the use of deployed applications according to user's need. So we propose here five layered architecture in fig.3 in which workflow is automated.

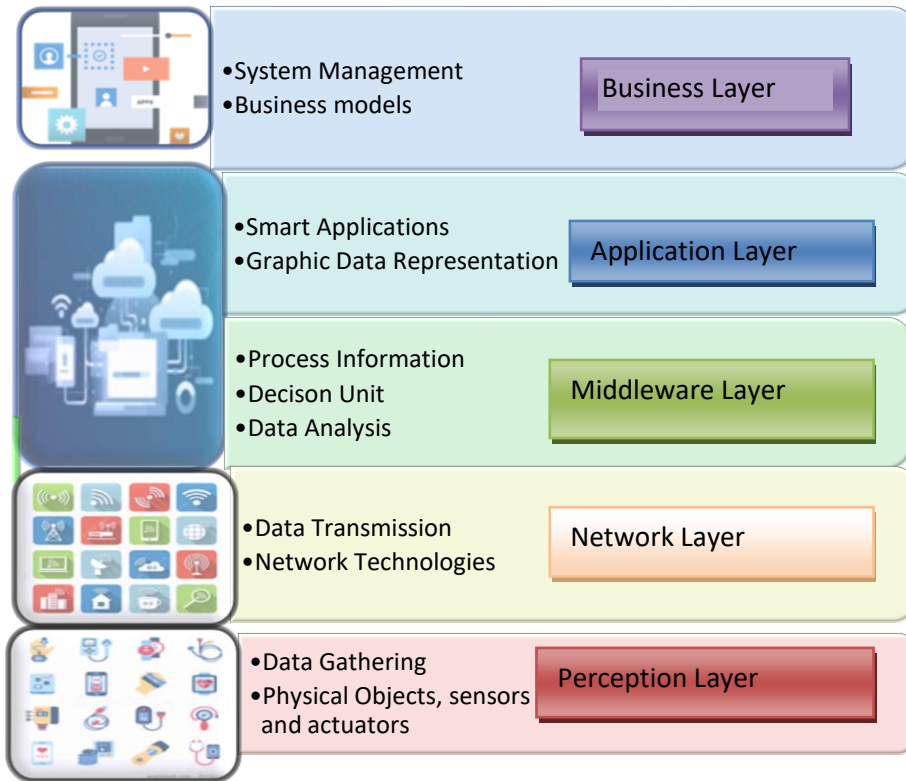


Fig3: Multilayered architecture of platform independent IoT based healthcare system.

The architecture comprises of mainly five layers:

Perception Layer: The perception layer is the physical layer, which has sensors, actuators and smart objects for sensing and gathering information about the environment. It senses some physiological parameters or identifies other smart objects in the environment. The main function of this layer is data gathering.

Network Layer: The network layer is responsible for connecting to other smart things, network devices, and servers through various communication protocols like Low Power Bluetooth, Wi-Fi, ZigBee, Internet etc. Its features are also used for transmitting and processing sensor data. The network layer transfers the sensor data from the perception layer to the processing layer and vice versa through networks such as wireless, 3G, LAN, Bluetooth, RFID, and NFC.

Middleware Layer: The processing layer is also known as the middleware layer. It stores, analyses, and processes huge amounts of data that comes from the transport layer. It can manage and provide a diverse set of services to the lower layers. It employs many technologies such as databases, cloud computing, and big data processing modules.

Application Layer: The application layer is responsible for delivering application specific services to the user. It defines various applications in which the Internet of Things can be deployed, for example, smart homes, smart cities, and smart health.

Business Layer: The business layer manages the whole IoT system, including applications, business and profit models, and users' privacy. The business layer is out of the scope of this paper.

Section V: Discussion

The improvement of upgraded healthcare sensors is firmly identified with the structure and setup setting of a few detecting innovations for productive and compelling information securing. Especially, wearable sensors, for example, ECG, pulse sensors, accelerometers, and EGG, are a typical pattern in the plan of improved healthcare configurations. These sensors are usually situated on the hand, belt, wrist, as well as chest to give universal detecting. Cell phones, for example, cell phones, tablets, and smart-watches are at the same time utilized for information assortment utilizing worked in sensors, for example, GPS, camera, and amplifier, yet also as an extension to interface outside clinical gadgets. Additionally, the cell phones have likewise been utilized as handling units to change the gathered information into information. Besides, assistive robots are additionally utilized joined with surrounding sensors for movement acknowledgment and observing.

The network is amazingly important as it is dependable to give information communication and sharing amid the detecting gadgets and the remainder of the gear in the structure. Most of the healthcare configurations are situated in remote correspondences advances[13].

The entrance to observed information is given utilizing a few methodologies. From one viewpoint, most of the healthcare configurations give portable admittance to information gathered utilizing a web interface. Then again, some healthcare systems don't give remote information get to. Nonetheless, there is a reasonable inclination to create systems that can be universally gotten to anyplace, whenever. The consequences of the exploration of healthcare are assuring as it gives ongoing patient checking arrangements just as it often consolidates off-the-rack cell phones as detecting and preparing units. It likewise offers action and irregularity conduct acknowledgment, ongoing notices, and alarms to the clinical group and caregivers and an applicable usual meaning rate by the clients. Especially, the IAQ observing arrangements can give an applicable dataset of the tenant's natural quality and be corresponded with their health position and living condition to help clinical diagnostics[14]. Also, constant checking information can be utilized to produce alarms to encourage the inhabitants to act in a valuable chance to advance health and prosperity.

The framework is termed as platform independent because the services of healthcare are not bound to any one particular computing paradigm, or any specific type of devices. The perception layer that comprises of devices and sensors include wired or wireless sensors or devices that communicate by different protocols like RFID, Bluetooth, NFC etc. Also, these smart devices can act as edge nodes for a lightweight processing of data. The processed data may be communicated to fog nodes or directly to cloud for computation depending on requirement of application. Similarly the tasks of network layer are also not confined to any specific communication protocol. Any short range(LoRa, Low power Bluetooth) or long range

communication(Wi-Fi, ZigBee, Internet) protocol may be adapted by the layer to transmit the data depending whether it is to be transmitted to fog node or edge node or cloud.

The processing of middleware layer is also not confined to any one particular node either edge, fog or cloud. Any of the node (edge, fog or cloud) according to data and processing techniques can perform the tasks of storing, analysis etc. as per requirement of application.

Section VI: Conclusion

IoT recommends new techniques, designs, and answers for upgraded healthcare configurations and can be confronted with a chance to enhance clinical medicines for customized healthcare. Open-source stages and working configurations could enhance the accessibility, protection, and quality of healthcare configurations. Also, existing open-source arrangements may enhance the development and productivity of healthcare configurations by likewise empowering gadgets, purposes, and configurations to safely open APIs to outside systems. In this paper, we have discussed cloud computing and fog computing based IoT healthcare architectures. The working of main layers of both the architectures is studied alongwith the benefits and limitations of each computing platform. Then, a platform independent architecture is proposed in the paper. In this framework, it is proposed that using a fixed technology for performing some application is not much beneficial. There must be some flexibility among the various nodes present in the architecture (i.e. edge node, fog node and cloud) such that they can decide the operating platform and the architecture can perform the assigned task in a better way. This overcomes the problems associated with a fixed type of working platforms.

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