Fog-Based Smart Healthcare as a Big Data and Cloud Service for Heart Patients Using IoT

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4 authors:

Sukhpal Singh Gill
Queen Mary, University of London

Rajesh Chand Arya

Gurpreet Wander
Dayanand Medical College & Hospital

Rajkumar Buyya
University of Melbourne

Fog-Based Smart Healthcare as a Big Data and Cloud Service for Heart Patients Using IoT

Sukhpal Singh Gill[1(✉)], Rajesh Chand Arya[2], Gurpreet Singh Wander[2], and Rajkumar Buyya[1]

[1] Cloud Computing and Distributed Systems (CLOUDS) Laboratory, School of Computing and Information Systems, The University of Melbourne, Melbourne, Australia
{sukhpal.gill,rbuyya}@unimelb.edu.au

[2] Department of Cardiology, Hero Heart Institute, Dayanand Medical College and Hospital, Ludhiana, Punjab, India
drrajesharya@yahoo.com, drgswander@yahoo.com

Abstract. The leading-edge of Internet of Things (IoT) gradually make item available on the Internet but data processing is not scaling effectively to fulfil the requirements of centralized cloud environment. One of the main reason of this problem is that deadline oriented cloud applications such as health monitoring, flight control system and command control system, which needs minimum latency and response time originated by transmission of large amount of data (Big Data) to centralized database and then database to an IoT application or end device which leads to performance degradation. Fog computing is an innovative solution to reduce the delay (or latency), resource contention and network congestion, in which cloud is extended to the edge of the network. We proposed a fog-assisted information model in this paper, which delivers healthcare as a cloud service using IoT devices. Further, proposed model efficiently manages the data of heart patients, which is coming through their user requests. iFogSim toolkit is used to analyse the performance of proposed model in Fog-enabled cloud environment.

Keywords: Cloud computing · Fog computing · Internet of Things Healthcare · Big Data

1 Introduction

Cloud computing paradigm utilizes Internet to provide on-demand services to cloud users and emerged as a backbone of modern economy [1]. Recent technological developments such as edge computing, fog computing, Internet of Things (IoT), Big Data and smart city are creating new research areas for cloud computing [2]. In current scenario, cloud has emerged as a fifth utility of computing and capturing the significant attention of industries and academia. Now, cloud computing supports emerging application paradigms such as IoT, Fog computing, Edge cloud and Big Data through service and infrastructure [3]. Fog computing uses network switches and routers, gateways and mobile base stations to provide cloud service with minimum possible

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network latency and response time. IoT based healthcare system connects preconfigured devices for processing of data of different heart patients to make smarter decision in a deadline-oriented fashion. Literature reported [1, 3] that there are two types of healthcare data is collected from heart patients using different devices (IoT sensors and satellites): Little data (processed at fog server) and Big Data (processed at centralized cloud repository). The healthcare data is coming from IoT sensors has huge volume and velocity (150 MB/min or more). There is a need to utilize both types of data to predict the current status of heart patient, which contributes towards the fully development of smart cities. Data is stored and processed on cloud servers after collection and aggregation of data from smart devices of IoT networks.

To provide high scalable computing platform, cloud performs the Big Data processing at infrastructure level. These platforms can be configured using pay-as-you-go basis mode to fulfil the dynamic requirements of IoT applications, which decreases the cost and process huge volume of big data effectively using cloud repository [7]. Current, cloud computing paradigm is unable to fulfil the dynamic requirements of IoT applications such as minimum response time and low latency. Therefore, a new paradigm namely, fog computing is introduced by Cisco [4], which fulfil the requirements of IoT applications and process data within their specified deadline. Fog computing environment offers a function of storage, compute and networking service between centralized cloud databases and IoT devices [5]. Moreover, this new paradigm provides a platform to create Internet of Everything (IoE) applications which needs minimum latency and response time. Application components such as smart gateways, routers and fog devices are working between sensors and cloud on both cloud and edge devices [6]. To provide efficient compute service between heart patient users and centralized cloud database, Fog computing-based model is required to deliver healthcare as a fog-assisted cloud service.

In this research paper, a fog-enabled information model is developed to provide healthcare as a cloud service and efficiently manages the data of heart patients, which is coming from different IoT devices. This is recognized through the following aims: (a) design a fog computing-based resource management model, (b) gather the information from heart patients using different fog nodes (IoT devices), (c) analyze the patient information to diagnose the status of their health and (d) use iFogSim toolkit [13] to evaluate its performance. The rest of the paper is organized as follows. Section 2 presents related work of existing healthcare systems. Proposed model is presented in Sect. 3. Section 4 describes the experimental setup and presents the results of evaluation. Section 5 presents conclusions and future scope.

2 Related Work

The emerging paradigm of fog computing processes healthcare data effectively in the IoT environment. The data of heart patients is handled at fog nodes or edge devices in fog computing with high processing power and it decreases the delay, response time and latency because fog devices are closer to the IoT devices (fog nodes) than cloud repository. Gia et al. [8] proposed a low-cost health monitoring model which collects the health status of heart patients. Further, sensor nodes can be used for real-time monitoring and analysis of Electro Cardio Graphy (ECG) for effective healthcare management but response time is higher. He et al. [9] proposed an IoT based architecture called FogCepCare, which integrates sensor layer with cloud layer to measure the status of patients. Ali and Ghazal [10] proposed IoT e-health service which measure the status of patient using voice control by collecting data through smart watch. Akrivopoulos et al. [11] proposed a healthcare system to diagnose cardiac abnormalities [15] using ECG but accuracy of detecting abnormal events is less because they are fetching data directly without using data analytics. There is a need to solve the following challenges [6–11] to recognize the full capability of IoT based fog-assisted cloud computing for healthcare systems: (a) IoT based Healthcare applications process a huge amount of heart patients data in an efficient manner to reduce power usage and response time and (b) a well-organized resource scheduling technique is needed for fog-assisted cloud enjoinment to execute user workloads with maximum resource utilization and minimum response time to fulfil the deadline of workloads.

3 IoT Based Fog-Enabled Cloud Computing Model for Healthcare

In this section, we proposed an IoT based fog-enabled cloud computing model for healthcare, which can manage the data of heart patients effectively and diagnose the health status to identify the heart disease. Figure 1 presents the architecture of fog-assisted model, which comprises of following components:

- *Body Area Sensor Network:* This component consists three different types of sensors: medical sensors, activity sensor and environment sensor. Medical sensors such as body oxygen sensor, temperature sensor, ECG sensor, Electro Encephalo Gram (EEG) sensor, Electro Myo Graphy (EMG) sensor, respiration rate sensor and glucose level sensor. This module senses the data from heart patient and transfer to attached IoT devices.
- *IoT Devices*: There are three different type of IoT devices (mobile phones, laptop and tablets), which are acting as a fog device to collect sensed data from different sensors and forward this data to Fog server for further processing.
- *Fog Server*: This component receives the data from fog devices. *Listener* module receives the request from fog device just before transferring the data. *Security* module provides secure communication, which protects the collected data from unauthorised access to improve the accuracy of health status of heart patients. *Message handler* manages the received data along with patient details. *Service broker* is the main component of fog server, which provides the patient data in terms of workloads for further processing at cloud server [12].
- *Resource Manager*: This component consists of two main modules: workload manager and resource scheduler [12]. *Workload manager* handles the patient data in terms of bulk of workloads and maintains a workload queue for processing of data based on urgency. *Resource scheduler* schedules the provisioned cloud resources for processing of cloud workloads.

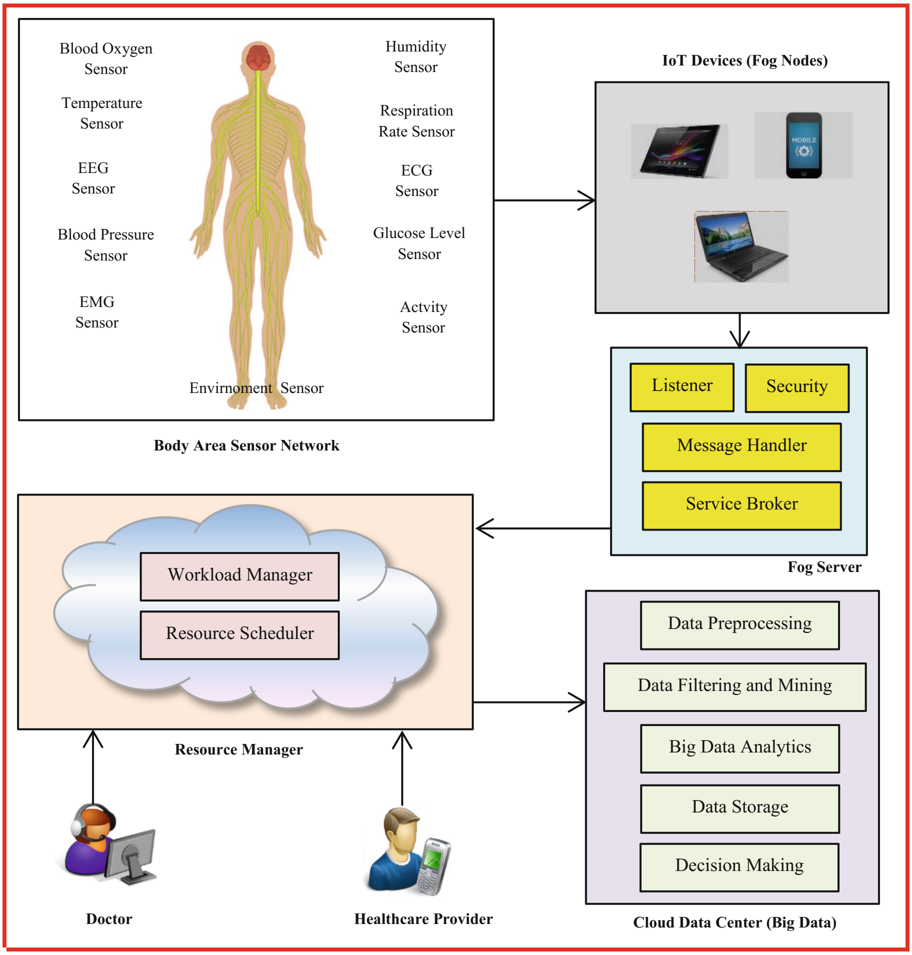

Fig. 1. IoT based fog-enabled cloud computing model for healthcare

- *Cloud Data Center*: Fig. 2 shows the processing of heart patient data. During execution of workloads, this component performs the data pre-processing, which converts the large amount of data (Big Data) into desired format. Further, filtering of data is performed to process data of only specific users using data analytics. Filtered data is compressed using Set Partitioning In Hierarchical Trees (SPIHT) algorithm [16] and encrypted using Singular Value Decomposition (SVD) technique [17] with the goal of discovering the status of health of heart patient. Based on the health status, it makes the decision automatically, which recommends medication and suitable check-up based on the continuous opinion of healthcare providers and doctors and stores their status into database for future purpose.

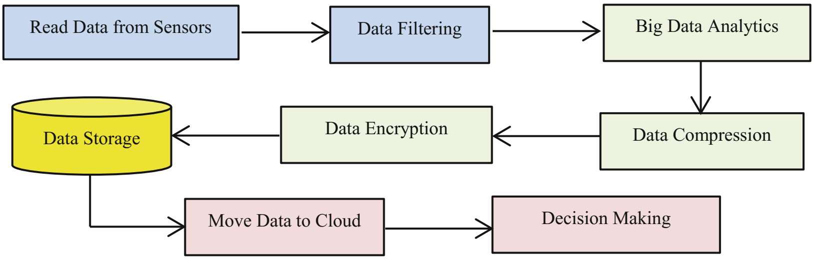

Fig. 2. Processing of healthcare data

4 Experimental Setup and Results

In this research work, basic event simulation functionalities of CloudSim [14] have been used for implementing functionalities of iFogSim architecture. CloudSim entities like datacenters and communication among datacenters through message sending operations. Therefore, events between Fog computing components in iFogSim [13] are handled by core CloudSim layer. Therefore, main CloudSim layer is accountable for managing the various functions among Fog computing components in iFogSim [13]. iFogSim implementation is established by simulated services and entities. The configuration (CPU GHz, RAM size and Power) of different fog devices is described in Table 1.

Table 1. Configuration details of different fog nodes

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

Furthermore, we used cloud simulation environment [13, 14] in which datacenter class is extended for realization of fog devices while VM is used to model patient data. In additional, Cloudlets were extended for realization patient data which is used to execute user requests. To execute the fog applications, only one host for each fog node is scheduled to provide resources. Fog-assisted cloud environment processes heart patient data on fog nodes, which is nearest to the IoT devices to save network bandwidth and decrease latency and response time.

Figure 3 shows the calculated value of network usage time for different number of user requests launched by heart patients using both cloud and fog-based environment and it shows that the value of network usage time is lesser in fog-based as compared to cloud-based because fog environment reduces the user requests coming towards cloud. Fog reduces 22.61–26.78% average network usage time as compared to cloud.

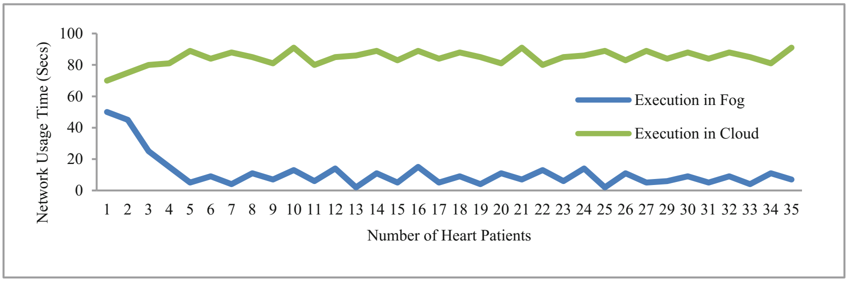

Fig. 3. Network usage time vs. number of heart patients

Figure 4 shows the comparison of latency for Fog and Cloud with different number of user requests launched by heart patients. Fog performs better than cloud in terms of latency. Fog reduces 19.56–29.45% average latency as compared to cloud.

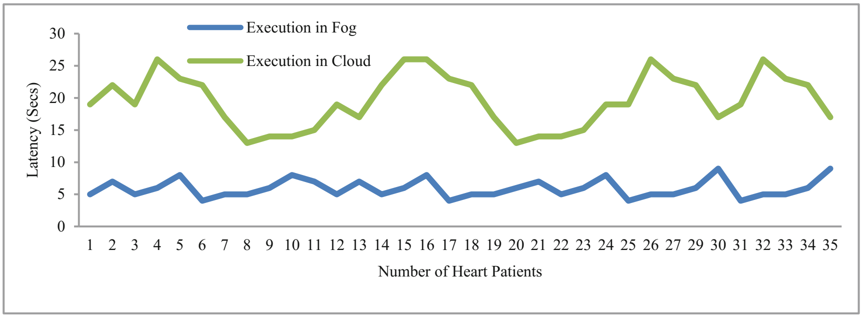

Fig. 4. Latency vs. number of heart patients

Figure 5 describes the consumption of energy for fog and cloud environment to process different number of user requests launched by heart patients and cloud consumes more energy than fog for same number of user requests. The value of energy

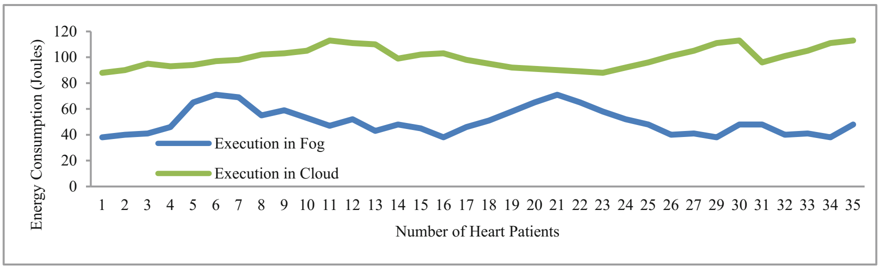

Fig. 5. Energy consumption vs. number of heart patients

consumption in fog is 33.45% less than cloud at 33 number of user requests while 8.25% less than cloud at 20 number of user requests. Fog reduces 23.56% average energy consumption as compared to cloud.

Table 2 presents the comparison of two different types of environments (Cloud and Fog Computing) based on three parameters such as network usage time, energy consumption and latency.

Table 2. Comparison of performance parameters for two different environments.

Environment	Processing layer	Avg. network usage time (s)	Avg. energy consumption (J)	Avg. latency (s)
Cloud computing	IoT to Cloud	84.58	101.30	24.33
Fog computing	IoT to Fog	11.14	34.46	3.25
	Fog to Cloud	12.22	16.64	5.05
	Total	23.36	51.10	8.30

5 Conclusions and Future Work

In this research work, we presented a fog-assisted information model, which provides healthcare as a cloud service and efficiently manages the data of heart patients, which is coming from different IoT devices. The performance of proposed model is evaluated using iFogSim toolkit. In future, this model will be verified in a real cloud environment for the practical realization.

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