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Fog Networks in Healthcare Application

Suryadip Chakraborty, Satyajit Bhowmick, Paul Talaga and Dharma P. Agrawal
Department of Electrical Engineering and Computing Systems, College of Engineering and Applied Sciences
University of Cincinnati, Cincinnati, OH – 45219, United States of America
{suryadip.chakraborty, bhowmick.sj, fuzzpault, dharmaagrawal}@gmail.com

Abstract— **Fog computing is a recently proposed computing paradigm that extends Cloud computing and services to the edge of the network. The new features offered by fog computing (e.g., distributed analytics and edge intelligence), if successfully applied for time-sensitive healthcare applications, has great potential to accelerate the discovery of early notification of emergency situations to support smart decision making. While promising, how to design and develop real-world fog computing-based data monitoring system is still an open question. As a first step to answer this question, in this research, we employ a fog-based cloud paradigm for time-sensitive medical applications and also propose to show the practical applicability and significance of such a novel system. The ubiquitous deployment of mobile and sensor devices is creating a new environment, namely the Internet of Things (IoT) that enables a wide range of future Internet applications. In this work, we present dynamic Fog, a high level programming model for time-sensitive applications that are geospatially distributed, large–scale, and latency–sensitive. We also analyze our fog model with healthcare data, more specifically with Heartrate data that is one of the most time-sensitive medical data which deals with life and death situations. Our experiments show that our proposed system achieves minimum delay while it also achieves the data accuracy and data consistency which are very important in many applications like medical data.**

Keywords—Fog networks; Healthcare data; IoT; Delay;

I. INTRODUCTION

1.1. Fog Concept

Related researches in the domain of Fog computing have outlined the vision and defined the key characteristics of Fog Computing. Fog is the appropriate platform for a number of critical IoT services and applications like Smart Grid, Smart Cities, and Connected Vehicles and in general, Wireless sensors and actuator networks. In the comprehensive definition of the Fog, there remain a broad overview of the Fog and highlight some of the main challenges faced by the emerging fog paradigm. Cloudlet was a earlier platform that was built even before the proposal of fog model, however inherently coincides the concept of fog computing. The definition of the Fog computing introduces some application scenarios and highlights the opportunities and challenges that might come up while designing fog computing system. The concept of mobile fog concept is a high level programming model consisting of set of functions and event handlers for future internet applications. Fog model provides benefits in advertising, computing, entertainment and other applications, well positioned for data analytics and distributed data collection points. End services like, set-up-boxes and access points can be easily hosted using fogging. It improves QoS and reduces latency. The main task of fogging is positioning information near to the user at the network edge.

1.2. Fog Computing for Time and Delay sensitive Applications

Currently there are a few existing works on time and delay sensitive fog based application. Hong et al. [1] provides a simplified programming abstraction for latency-sensitive applications. They also analyze two use cases such as Vehicle tracking using cameras and traffic monitoring using Mobility-driven distributed complex event processing (MCEP) system [3]. However, the proposal does not enlighten us on how to develop a runtime system that implements the mobile fog programming model on real fog-enabled devices.

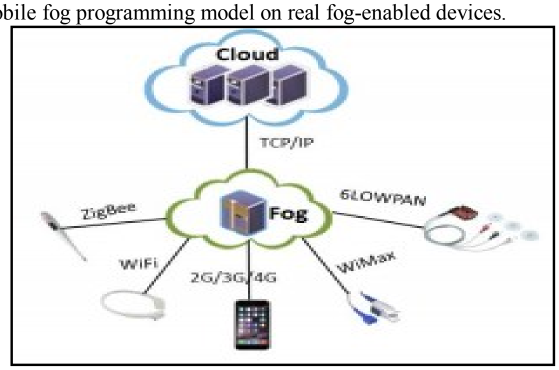

Figure 1: Typical Fog Computing Setup [2]

There have been many efforts in designing smart gateway based fog computing platform for time-sensitive applications. Chen et al. [4] introduce a smart gateway based healthcare system using wireless sensor networks. The gateway acts as a bridge between public communication networks and the wireless sensor network. The gateway has a data decision system, lightweight database, and the ability to generate notifications in case of emergency. Yang et al. [5] present a smartphone based personal health monitoring gateway. In this proposed gateway, a Bluetooth interface is used to upload gathered data to remote servers. Yoon et al. [6] shows a sensor network system using sensing servers as gateways in their system. Authors in [7] propose a mobile gateway for pervasive healthcare system using Bluetooth and ZigBee. This gateway serves various purposes such as alarm generation in case of emergency and analysis of medical data. Zhong et al. [7] proposed a gateway based on a cell phone for connecting sensor nodes devices supporting Bluetooth or CDMA. In [5], authors propose an architecture that acquires data via personal health devices via ZigBee, USB or Bluetooth. None of the discussed works have considered taking full advantage of the fog computing paradigm and bringing intelligence to the gateways. So far, none of the literature discussed seemed to have explored a robust and significant use of the fog paradigm in real-world time sensitive applications. There is a lack of proper architectural specification as well as a lack of comprehensive time response comparison between fog and cloud. Also, none of the researches we discussed has focused on the data accuracy that is as important as time for some of the applications like health data. The node breakdown situation that can cause severe crisis for mission critical applications is also overlooked in the literatures. Therefore, an all-inclusive study of the efficacy of the fog paradigm for delay sensitive applications is extremely important. Therefore, in this research, we have brought together a couple of different areas of research in the context of time and delay sensitive Fog Computing applications in healthcare applications. We have also provided background information about these areas and also highlight recent work done on topics similar to ours in this research.

II. OUR CURRENT WORK AND THE FUTURE PROPOSAL

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Fog Computing enables a new breed of applications and services, and that there is a fruitful interplay between the Cloud and the Fog, particularly when it comes to data management and analytics. Fog Computing is a paradigm that extends Cloud computing and services to the edge of the network. In our application, we design the Fog as below:

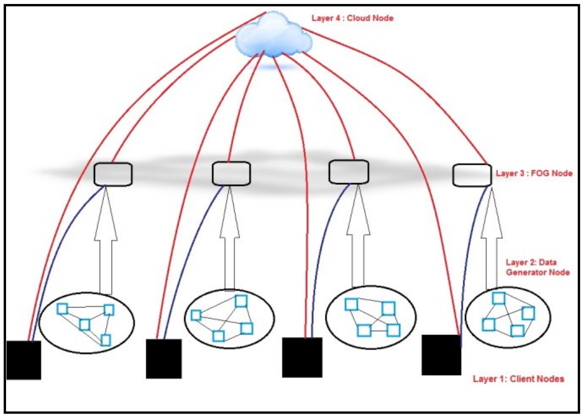

Figure 2: Proposed Fog bases cloud architecture for time and delay sensitive medical processing and analysis

III. SYSTEM ARCHITECTURE & RESULTS

There are only a very few fog computing models proposed in the literature. Therefore, we propose a unique fog architectural design for our application of analysis of critical healthcare. Here, in Figure 2, we propose this four layer architecture for efficient implementation of the application.

Layer 1 – This is the client node which might be a stand-by monitoring machine connected with the layer 3. This machine can be continuously monitored by human such as medical practitioners, nurses, physicians so as to regularly check the health status of injured and disease patients who are admitted in the hospitals. This layer is connected to layer 3 fog node as fog node immediately sends back the abnormality in patient's monitored data to layer 3 whenever emergency arises so that proper medical actions can be taken without any further delay. These machines in layer 1 also has a connection with the layer 4 cloud node as doctors at the clinic might want to see the historical and empirical health data of a patient over a certain period of time. Therefore, this connection with the cloud would trigger this request and retrieve the doctor's query and bring it back to the layer 1.

Layer 2 – This is the cluster of physiological sensor nodes connected with each other as well as connected with the intranet. These connected devices have formed an IoT cluster and send their data to upward towards the layer 2. This is the layer where multiple physiological sensors are connected and continuously sending the monitoring data to the layer 3 – the fog nodes. Layer 2 sensor nodes are only sensing the vital parameter data and sending them upward.

Layer 3 – This is the fog node in the proposed architecture. Sometimes, we call it as the local access point or the ephemeral storage. These nodes have a small storage which can hold the data for a few minutes, but not longer than that. These fog nodes are very important in our architecture as this is the point where the physiological data are continuously coming from layer 2 sensor nodes. In this layer, the computation is continuously performed to check the threshold of the incoming physiological data stream. If there are any immediate changes in the prescribed threshold, it would immediately send notifications and alert messages to the client nodes in layer 1 for immediate medical measures. If the data is in the prescribed medical ranges with normal and accepted values, it would store it for few minutes and then it would send it to the cloud node in layer 4. We are keeping the physiological data for few minutes in the fog nodes as sometimes, doctor might want to see the physiological data generated in the previous 5 – 10 minutes. So, in these cases, the data communication would be only among layer 1 and layer 3 and thus reduce the communication cost and leads to saving of energy in the system.

Layer 4 – The cloud nodes are located in this layer where we do the aggregation of all the incoming data and therefore it is sometimes called as the semi-permanent storage. Here, we store all the healthcare data coming from the entire networks and process any requests coming from the client nodes in layer 1. The main advantage of having the cloud is that these is very much helpful in getting the historical data of the patient's health and thus help the medical data analysis and interpretation.

So we can now outline the characteristics of the Fog that we propose in our system. We would use the following advantages in our entire study in this chapter:

a) Low latency and location awareness; b) Wide-spread geographical distribution; c) Mobility; d) Very large number of nodes, e) Predominant role of wireless access, f) Strong presence of streaming and real time applications, and g) Heterogeneity.

We considered a healthcare application that requires very low and predictable latency—the Cloud frees the user from many implementation details, including the precise knowledge of where the computation or storage takes place. This freedom of choice is welcome in many circumstances when delay and latency is at premium. Here during the experiments, we choose 10k, 100k and 1mb data file containing emergency heartrate data of critical patients and run them in our proposed system to validate.

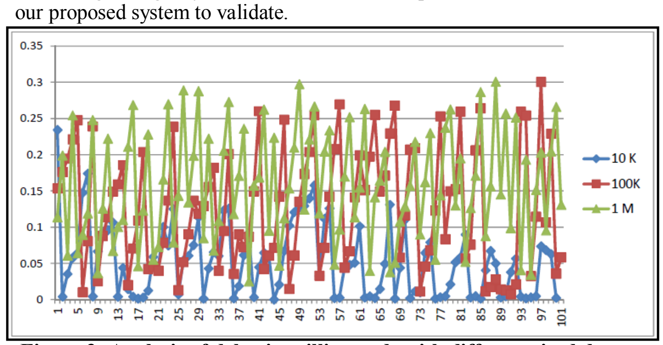

Figure 3: Analysis of delay in milliseconds with different sized data

The result was so much promising as the value of delay in the Y-axis for 10k, 100k and 1mb data was too less and thus confirm our determination of the proposal to use of Fog computing model in emergency healthcare application which is very much first of its kind in the literature.

IV. CONCLUSION AND FUTURE WORK

Fog computing performs better than cloud computing in meeting the demands of quick access to the data and smart decision making in emergency situations for time sensitive applications. The biggest advantage that Fog computing provides us is reduced delay, compared to the cloud, that is quite evident from our experimental results. Our proposed architecture is one of the very few prototypes to answer the open question – how to design and develop a real-world fog computing based medical data analysis system.

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