An Architecture for Smart Health Monitoring System Based on Fog Computing

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***Abstract*—** In many countries, especially in under developed and developing countries proper health care service is a major concern. The health centers are far and even the medical personnel are deficient when compared to the requirement of the people. For this reason, health services for people who are unhealthy and need health monitoring on regular basis is like impossible. This makes the health monitoring of healthy people left far more behind. In order for citizens not to be deprived of the primary care it is always desirable to implement some system to solve this issue. The application of Internet of Things (IoT) is wide and has been implemented in various areas like security, intelligent transport system, smart cities, smart factories and health. This paper focuses on the application of IoT in health care system and proposes a novel architecture of making use of an IoT concept under fog computing. The proposed architecture can be used to acknowledge the underlying problem of deficient clinic-centric health system and change it to smart patient- centric health system.

***Index Terms*—**Internet of things, smart health monitoring, LoRaWAN, wireless sensors, body area network, fog computing, gateway

I. Introduction

One of the most marvelous achievements in the field of technology in the human history is the wireless technology. It has changed the way we are living today from our past old days. This achievement has eased our day to day life by making communication, learning, and travelling a lot easier. Not only are we being benefited through our day to day life but also by its discovery in the field of healthcare, transport and industries. In the sector of healthcare, telemedicine and pervasive computing is another major application of the wireless advancement. In old days visiting clinic was only the option for getting the medical treatment but due to the advancement in the wireless sensor technology and its integration with the wearable device the scenario has changed. Such changes in the scenario has resulted the medical facility to patient-centric rather than the clinic-centric and this is referred to as "Telemedicine" by the authors in [1]. With some level of smartness, connectivity and the user interface, the embedded information or tiny mobile devices and communication technologies (ICT) are further spread. This results in the interaction between the humans and smart devices to be much efficient and authors [2]-[4] termed this as pervasive computing. The advantage of pervasive computing can be utilized in almost any sectors which can be industry, battlefield, education, disaster, etc. and even in the hospitals or health care. The application of pervasive computing on the field of health care also and is termed as "pervasive health care". In simple words, pervasive health care can be described as a way of providing healthcare facility to anyone at anyplace and at any time where there are not any boundaries of location, time or other hindrances [5]. These days, majority of people are familiar with the handheld and wearable devices. Wearable devices such as smartphones and others have become very popular among the people. These devices are well equipped with different kinds of sensors which can monitor sleep, heart rate, stress, oxygen level, body temperature, etc. In short, body vitals can be easily recorded and monitored with these handheld and wearable devices. Apart from such multipurpose devices, health service specific devices or Wearable Wireless Body/Personal Area Network (WBAN/WPAN) based on bio-sensors are also other solutions used to monitor the body vitals. This is also the reason IoT has gained much of the attention in the health care domain too. Day by day the cost of the electronic chips, sensors are decreasing resulting in the decrease of the cost of electronic devices more and more. The day is not far from the time when the cost of such devices will be so cheap that it could be affordable to every people in the country. As discussed earlier handhelds, wearables, or sensor networks make the accessibility of information by anybody at any time. So, there is no need of a person to be at the monitoring site always. People these days are much more aware of their health than in the past days, most of them are aware of their medical condition and physical health. However, in many cases even if people are aware of their certain medical condition from their past checkups they are unwilling to go to the physician. The cause of this can be either due to the cost, travel distance or their busy schedules. We can take high blood pressure, irregular heart rate, diabetes, insomnia, sleep apnea, etc., as some health problems which patient often neglect and refrain from regular medical checkup although they are advised to do so. Hence, it would be a good idea to have the availability of smarter health service which can remotely monitor their health status, give feedback, provide telemedicine service. Such

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smarter health service will prevent the patient from reaching the critical stage or even if it detects such stage, it can alert the patient to take immediate action on it. This will also save their precious time, lower their medical cost and even will help the government closely monitor their citizens' health. So, it can be clearly seen making use of pervasive healthcare and the telemedicine can significantly help the people.

In smart health monitoring system, various sensors are used for monitoring the vitals of human body. However, the sensor and smart devices which are employed for health monitoring normally have limited storage and low computation capabilities due to which they are not able to handle huge amount of generated data. On top of that, there is always a huge challenge in IoT when it comes to dealing with data exchange, availability of resources, security, privacy and interoperability [6]-[8]. The cloud computing is one of such approaches that was used as a solution of the aforementioned problems posed by IoT. It can acknowledge the problem for scalability and the tremendous rise of the IoT devices. However, as the continuous data transmission and retrieval process increases it gives a huge stress in the cloud and the network. In addition, if there is no sufficient bandwidth allocation, low latency or network failure, cloud can lead to intolerable delays causing the smart health service to a complete failure. Moreover, the distance of cloud from the edge network, network load or continuous communication with the cloud, etc. leads to the massive energy consumption. Therefore, some alternatives to cloud computing is required for provisioning proper smart health care and fog computing can be the one which is briefly discussed in Section 3.

To acknowledge the underlying problems in the smart health system, in this paper we propose an efficient IoT based patient centric smart heath monitoring system making use of fog computing. With the help of fog computing and LoRaWAN the architecture can even perform when there is no availability of internet on the client side or the patients side

II. Internet of Things

IoT is one of the ongoing buzzword in the Information Technology (IT). It is composed of many objects forming it into a huge information system. IoT is coined from the two different words, first one is the "Internet" and other is the "Things". Internet is a global network or network of networks that comprises of networks of millions of organizations which can be private, public, government, academic or business networks [9]. "Things" on the other hand can be of any object that we know in this world. Not only does it comprise of electronic gadgets and equipment but also the non-electronic things like furniture, cloth, material parts, landmarks, monuments and also the group of culture, sophistication and commerce [10]. With standardized communication protocol these objects are sensed, identified and processed to unify everything around us not only to control them but also keeping us informed about the status and states of the things. It's the IoT and its ability to code and track objects due to which the companies are being able to be more efficient, reduce the error, speed up process, maximize productivity with limited resources [11]. Having the ability to make the treatment process patient centric, non-hospital based and providing patients the power to self-manage their disease, get health assistance remotely, get the medical assistance in case of emergency have made IoT best candidate for smart health care system [12]-[14]. Therefore, having such a huge potential in the current world the importance of IoT has been realized not only in the business but also in the field of health care and social service. Its application is thought to be more practiced in future to leap much further in the field of IT convergence.

III. Fog Computing

"Fog network" was coined by Cisco in 2012 [15]. Fog can be regarded as the "descended cloud" much near from the reach of the network edge. It is also one of the key promising technology for future 5G wireless communication system [16]. Fog Node enables the end user devices to collaborate for task of storing, management and network communication. Carrying out these tasks near or at the end users will decrease the latency since it's clear that getting data from cloud takes much longer than fetching it from the network edge itself.

Similar to cloud, fog server can also store various contents such as videos, audios, local information such as maps, availability of restaurants and shops in particular area etc., and in our case, can be a health data. A typical fog computing architecture is shown in Figure 1. Having such capabilities Fog computing is much suitable in the field of IoT. Since the increase of communication able objects and smart devices lots of sending and requesting tasks are on the edge of network. Such request can be served without the need of the information from the cloud. Having such availability an efficient architecture can be designed which can have higher service rate, higher QoS and less burden to the cloud. Hence, the application of Fog computing can be highly realized in the field of IT convergence.

IV. LoRa™ Overview

LoRa wide area network or in other form the LoRa wireless protocol is governed under LoRa Alliance [17]. LoRA™ which is based on IEEE 802.15.4g protocol is basically a long range wireless radio. It is specially designed to be maximally used with IoT. Not only it facilitates wide area network connectivity but also requires much lower power to operate than its counterparts. However, as it has low throughput its application is more realized when designing a low powered network with low throughput requirement. The

modulation of the LoRa™ is based on spread-spectrum and utilizes the unlicensed industrial, medical (ISM) frequency band. For encoding the information, it uses the wideband linear frequency modulated signals and for the transmission of signal uses the total channel bandwidth.

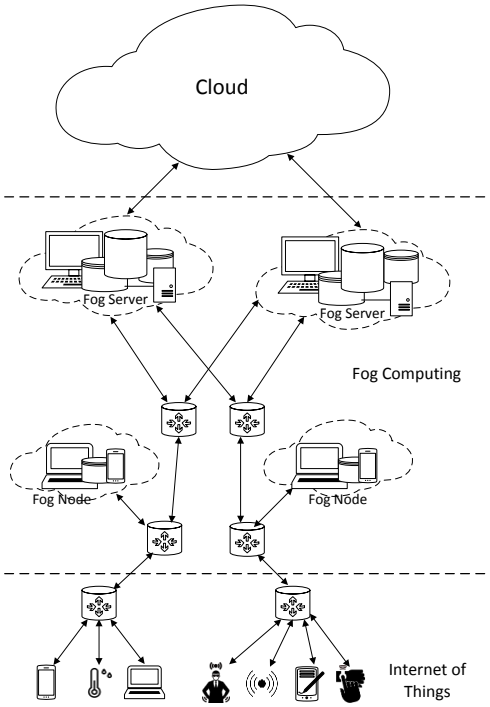

Fig. 1. Typical fog computing architecture

V. Literature Review

In this section, we present recent related works on IoT based health monitoring system. Recent and previous literatures have designed different prototypes for patient monitoring system. However, there have been several limitations for these studies. In [18] the authors provided an overview, network structural design, vital technologies, requirements, and over all architecture of IoT. They also overviewed the different layers in IoT including the different IoT related applications such as smart industry, remote nursing, smart government, and others. Their paper discussed the possible deployment of different wireless communication infrastructures including wireless fidelity (Wi-Fi), Bluetooth, and ZigBee although they didn't mention about Long Range (LoRa) wireless networks. In [19] the authors developed a real-time heart monitoring system. They considered wearable sensors interacting with low power Bluetooth to generate patient's diagnostic information, and used 3G cellular communication/ Wi-Fi to transmit the patient's information to the cloud. But this system is mainly applicable to users who are always connected to high data rate internet connections. But many people in developing and underdeveloped nations don't have such internet access. Therefore, a system should be devised which also incorporates offline mode of communication system. Authors in [20] discussed the application of IoT for elderly people health monitoring system proposing ZigBee as a wireless communication medium and wearable biosensor. Tuan Nguyen Gia *et al*. in [21] have proposed IoT enabled healthcare system architecture examining the use of fog computing solutions in IoT based healthcare facilities. They suggested a fog computing scenario comprising of smart gateways which are supposed to interoperable with Ethernet, Wi-Fi, Bluetooth, ZigBee and 6LoWPAN. Numerous pervasive healthcare systems and related challenges were discussed in [22] and [23]. In these papers, both short term and long term healthcare monitoring applications were surveyed. The authors also outlined the possible challenges such as lack of comprehensive coverage of wireless and mobile networks as well as the reliability of wireless infrastructure in health care. Most of the existing articles did not consider the importance of deployment of LoRa wireless modules on IoT based health monitoring. In this paper, we aim to propose the use of a commercially available LoRa wireless devices as a means of Wireless Sensor Network (WSN) infrastructure. To the best of our knowledge LoRa wireless sensor network based health monitoring system has not been reported in the literature.

In this paper, our main contribution includes: (a) the study of current state-of-the-art IoT based health monitoring applications and investigate the relevance of low power WSN for the domain. (b) Propose a novel architecture of smart patient- centric health system.

VI. Proposed Architecture

The proposed architecture for the fog based smart health monitoring system is presented in Fig. 2. In the proposed architecture, the edge users are equipped with different kinds of wearables, medical devices or medical sensors. Thus, these devices can perform various medical measurements. Such measurements can monitor the body vital signs like blood pressure, body temperature, heart rate, respiratory rate, sleep, stress level, etc. Devices can have different kinds of connectivity like Zigbee, Bluetooth, Wi-Fi, LoRa, 2G/3G, LTE, etc. These devices are connected to the LoRaWAN gateway so that the information generated by these end devices can be sent directly to the Fog nodes or primary Health Centers in our case. These primary Health Centers can be more than one which serves people based on their location. The use of LoRaWAN gateway makes it possible to transmit the data recorded by those devices to the primary Health Centers tens of kilometers away even if there is no internet facility. This can be a huge benefit in villages or remote places where there is no proper internet or internet facility. The data sent through these devices is interconnected with the smart devices, laptops or computers of the medical personnel and backed up on the Health Center's storage. For the people who are already diagnosed with some medical problems, their medical data are stored based on their illness so that it would be easy for the medical personnel to track on their patient.

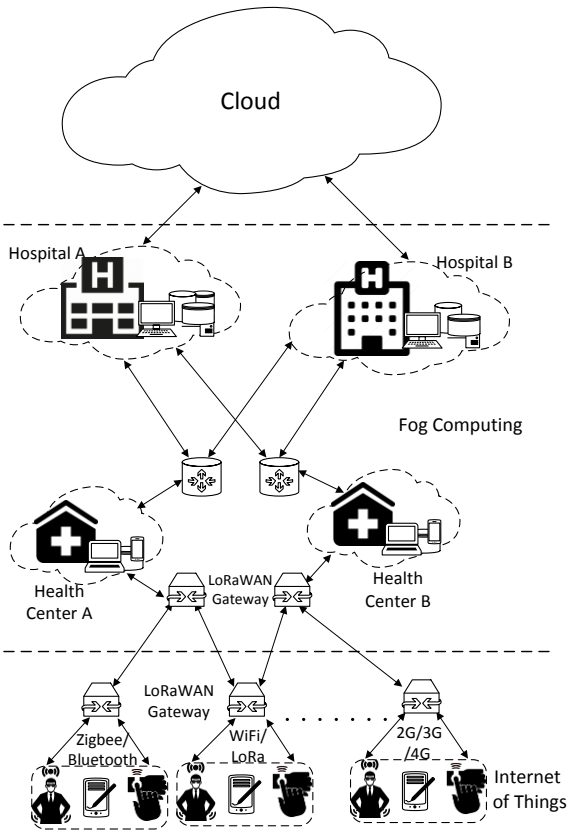

Fig. 1. Simple fog computing architecture

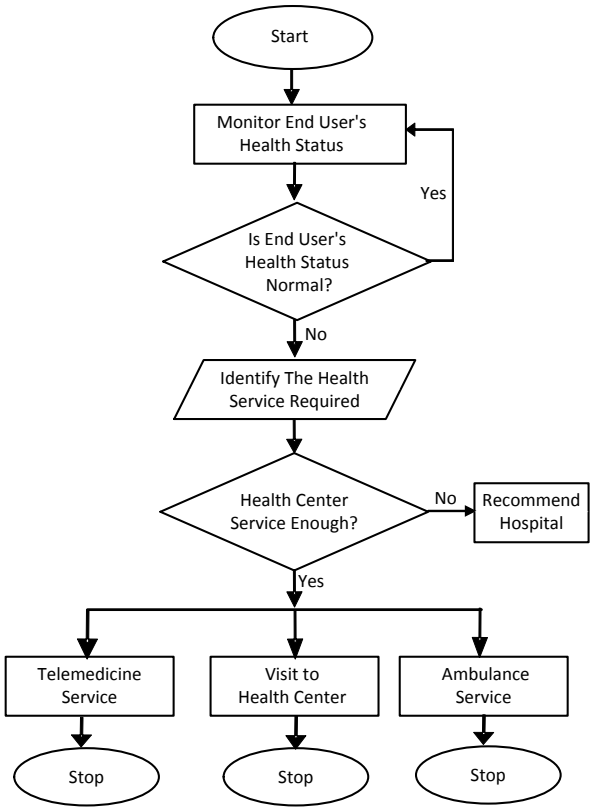

Fig. 3. Flowchart of health monitoring system

For example, blood pressure data is very important to be noted if the patient has blood pressure problem and breathing rate data is very important to be tracked if the patient has dyspnea. So, based on the patient's medical history the body vital information is stored in medical data records at the Health Centers. In this way, the doctors or responsible medical personnel will be tracking their patient's data all the time and notify the patient for their immediate visit to health centers if it is necessary; take other certain action like telemedicine service if applicable. Also in the time if the case is very serious or emergency, immediate health service like ambulance service can be provided by the Health Centers by contacting with the Hospitals. The process of this health monitoring system is depicted in the form of flowchart in Fig. 3.

VII. Conclusions

In this paper, we proposed a fog computing based health care monitoring system architecture for providing an efficient health care facility. Providing real time based seamless health service in the place where there is no proper internet connectivity or no internet connectivity is the major advantage of the proposed system. It will not only help patients who need to monitor their health condition periodically but also the normal people to track their body vitals regularly. Utilizing this architecture, not only will the people get ease on their basic health monitoring but will also help those countries where there is less doctor to patient ratio. Additionally, the proposed architecture also brings a new era of energy efficient health care monitoring system and minimizes the burden on the cloud.

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