A Smart Healthcare Monitoring System Based on Fog Computing Architecture

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Abstract— **Access to adequate medical care can be difficult in many countries, particularly in economically developing countries. There aren't enough medical professionals, such as doctors or nurses, and the nearest hospitals are too far away. Because there is such a severe shortage of resources, it is extremely challenging to provide preventative therapy to persons who are ill. As a direct consequence of this, even persons in good health are falling more behind in their surveillance of their fitness. It is crucial to have a plan in place to address this problem in order to guarantee that persons will not experience a disruption in their capacity to get necessary medical care in the event that this problem arises. Applications of the Internet of Things include ensuring public safety and improving operational efficiencies in transportation, municipal management, manufacturing, and physical activity (IoT). This study investigates its application in medical equipment and suggests an innovative approach to combining the ideas of fog computing and the Internet of Things. A poor health care system that focuses on clinics can be converted into a high-quality system that puts patients at the center with the help of the framework that has been proposed.**

Keywords— IoT, fog computing, gateway, Smart Health Monitoring, LoRaWAN, Wireless Sensors, Body Area Network

I. INTRODUCTION

The invention of wireless generation is unquestionably one of the most impressive technological accomplishments in recent history. As a direct consequence of this, contemporary life is incredibly dissimilar to that of the past. Because of this discovery, it is now much less difficult to participate in activities that are part of daily life, such as chatting to one another, learning new things, and going to new locations. The current level of our standard of living is in large part due to developments that have taken place in industries such as healthcare, transportation, and commerce. In the world of medicine, two of the most exciting potential uses for wireless technology are telemedicine and ubiquitous computing. Going to a clinic was traditionally the advised way to get medical care, but more recently there are other options available. However, things are different now that wireless sensor technology is developing and becoming more compatible with wearable devices. This has caused a change in the status quo. These changes, which the authors of [1] have dubbed "Telemedicine," have caused the hospital's focus to move from the clinic to the individual patient. Disseminated information and communication technologies (ICT) have a particular amount of intelligence, connection, and user interface. These characteristics are based on the information that is incorporated in the ICT.

The adoption of smart devices by humans has consequently resulted in a greatly reduced influence on the environment. The authors [2]-[4] refer to this concept as "ubiquitous computing." [2]-[4] Pervasive computing has a wide range of possible applications, some of which include the commercial sector, the armed forces, schools, emergency services, and even healthcare institutions such as hospitals. Computing is becoming so prevalent that it is even being used in the medical field. This is what we mean when we talk about "universal health coverage." A system that makes it feasible to deliver medical attention to anyone, at any time, in any location is referred to as "pervasive health care" [5]. The average person in this day and age has a good level of expertise when it comes to handheld and wearable electronic gadgets. The general public's interest in mobile devices such as smartphones and other wearable gadgets has recently seen an uptick. The sensors that are built into these wearables have the capability of monitoring a variety of different metrics, some of which include temperature, stress, oxygen levels, heart rate, and sleep. The ease of recording and monitoring vital signs made possible by the portability and wearability of these devices is, in a nutshell, a direct result of this convenience. For the purpose of monitoring vital signs and overall fitness levels, there are also wearable wireless body/personal area network (WBAN/WPAN) devices available with built-in biosensors. Because of this particular motivation, the health and fitness industry is quite ready to implement IoT.

Every day, the price of CPUs and sensors and other digital components like them falls further. In the not-too-distant future, the price of these electronic devices will plummet to the point where they are affordable for every person in the United States to own one. As was discussed earlier, the proliferation of wearable technologies like smartphones, smart watches, and other similar devices has made it possible to instantaneously access a tremendous amount of data. As a direct consequence of this, the employment of any people is not necessary. In comparison to inhabitants of previous generations, people living in today's society are in general very knowledgeable about their medical history as well as any physical diseases they may be currently suffering from. Even when they have strong grounds for suspecting they have a medical ailment, the vast majority of people still put off going to the doctor. This is probably the case for a variety of reasons, including the cost, the length of the trip, or their busy schedules.

Even though they are urged to do so, many patients still do not visit a doctor for conditions such as excessive blood pressure, irregular heart rate, diabetes, sleeplessness, or sleep apnea, even though it is recommended that they do so. This emphasizes the potential utility of a more sophisticated fitness service that can remotely monitor their health, provide comments, and possibly even deliver telemedicine services. In either scenario, the patient will receive improved health care that will result in them being aware of their situation and encouraged to take prompt action. If people did this, not only would they be able to save time and money on medical care, but the government would also be able to keep a closer eye on everyone's health. Patients can reap significant benefits from telemedicine as well as traditional methods of receiving medical care, as has been demonstrated. Sensing sensors are built into most modern fitness trackers, and these gadgets record crucial facts. However, fitness monitoring devices and other smart gadgets are limited in their capabilities because of their incapacity to store or understand vast volumes of data. Data sharing, the availability of aid, the protection of private information, and interoperability are other topics of discussion [6]-[8].

Utilizing cloud computing is one approach that can be used to address the problems that are caused by the Internet of Things. It is cognizant of the scalability problem as well as the exponential growth of Internet of Things devices. On the other hand, as both the amount and the level of complexity of data flows rise, the cloud and the network are coming under increasing strain. If there is not enough bandwidth, there is a lot of latency, or the network breaks down, the cloud could cause delays that are too long, and it could lead the smart health service to fail completely. Consider how distant the cloud is, how active the community is, and how frequently the community can connect to the cloud. Because of this, a significant amount of energy, measured in kilowatt hours, is consumed[23-25]. Because of this, in order to provide efficient smart health care, it is necessary to make use of additional cloud computing options, such as fog computing, as was briefly covered in Section 3. The purpose of this paper is to present an Internet of Things and fog computing-based fitness tracking gadget that prioritizes the user experience and minimizes its impact on the surrounding environment. We will concentrate on fixing the most significant problems with intelligent workout equipment. The system is able to function properly even if the user, who may be a client or a patient, does not have access to the internet. This is made possible with the assistance of LoRaWAN[26][27][28] and fog computing[29].

II. INTERNET OF THINGS

The "Internet of Things," - "IoT,"[30][31][32] is now one of the most widely used in the field of information technology (IT) . It's a large data structure with a lot of different subsystems that are all tied together. "Internet" and "Things" are the two individual terms that make up the phrase "Internet of Things." The expression can be broken down into its component parts, which are these two words. [9] The Internet is a worldwide network that connects millions of independently owned and operated businesses. A more accurate description would be that it is a network within a network. It's possible that these organizations have some sort of connection to the United States government, the nonprofit sector, the academic community, or even Big Business. On the other hand, "things" can refer to virtually everything that we come into contact with on a regular basis. Included are things such as landmarks, monuments, cultural, wealthy, and commercial organizations, as well as electrical products and equipment [10]. Also included are things such as furniture, textiles, and material pieces. (Sources should be consulted) A consistent language is utilized throughout the tracking down, identification, and processing of these individuals. This connects everything in our environment, allowing us to keep an eye on and take command of our surrounds. This one rule brings everything together into a coherent whole[33]. Businesses may be able to improve their productivity, make fewer errors, speed up procedures, and produce more with the same number of resources if they implement the Internet of Things and take advantage of its ability to code and track specific items [11]. The Internet of Things is the best option for developing a forward-thinking healthcare system that puts the needs of patients first and is independent of hospitals. Additionally, it can give people the ability to self-manage their condition, obtain medical support remotely, and receive assistance in an emergency situation. [34][35] Because of the potential impact it could have on contemporary society, the Internet of Things (IoT) is important not only in the realm of business, but also in the fields of medicine and social work. It is projected that its general acceptance will increase in the not-too-distant future, which will make considerable progress in the area of IT convergence much easier to achieve.

III. FOG COMPUTING

When Cisco first introduced the word "fog community" in 2012 [15], it was the first time that a company had ever made use of the concept. [Cisco] created the phrase. (Sources should be consulted) One possible way to understand fog is as a "cloud that has come down," which is an exceptionally unlikely event in the region. In the not too distant future, when 5G wireless networks are being constructed, this technology will also be of great use to those networks. A fog node's capabilities range from the storage and management of data to the facilitation of social networking. As a direct result of this, end-user devices are given the ability to collaborate with one another in order to carry out these tasks. It is obvious that retrieving information from the cloud takes a lot more time than retrieving it from the network side, therefore doing these things close to or on the end users will reduce latency. This will be the case whether you do them on the end users themselves or near them. On a fog server, medical records are just one of the many different kinds of data that may be saved. A fog server is comparable to the cloud in that it can also store media files, music, maps, and listings for local businesses, among other forms of data. Figure 1 depicts a typical architecture for cloud computing in a fog environment. IoT is where fog computing really comes into its own because of these capabilities. Because of the growth of communication-enabled items and smart gadgets, many traditionally solitary actions, such as transmitting and requesting for, have moved into the realm of social interaction. It is not necessary for a request of this sort to involve data that is kept in the cloud. With such accessibility, a green building with a greater carrier rate, higher quality of service, and reduced cloud load is achievable. The widespread implementation of fog computing is encouraged as a result.

IV. LITERATURE SURVEY

The LoRa Alliance is in charge of managing the LoRa large region community, which is often commonly referred to as the LoRa wireless protocol [17]. The IEEE 802.15.4g standard serves as the foundation for this long-range wireless radio, which is known as LoRATM. It was developed to be interoperable with the Internet of Things in as many different ways as was technically possible. In addition to allowing for connection to wide area networks, it additionally makes use of a great deal far less electricity than its rivals do. However, because of its low throughput, it is a good technique for constructing a neighborhood that requires little in the way of power and has few requirements for throughput. This is because the neighborhood will have fewer requirements for both. Devices that use the LoRaTM protocol are extremely versatile due to the fact that it uses spread-spectrum modulation and operates in the unlicensed frequency region known as ISM (industrial and medical). The entirety of the channel bandwidth is utilized during the transmission process, and the encoding of records is done with wideband linear frequency-modulated signals.

In this section, we are going to talk about the fact that we were the first company to produce fitness monitoring solutions based on the internet of things.

Over the course of medical history, numerous iterations of patient monitoring systems have been established. However, these inquiries have been made more difficult by a number of favorable variables. The authors of [18] offered a high-level explanation of the structure of the Internet of Things, touching on its design, its fundamental technologies, its requirements, and its general architecture. This summary may be found here. The various levels of the Internet of Things were also explored, in addition to topics such as smart industry, telemedicine, smart governance, and other applications of a similar nature. Their examination of wireless communication infrastructures such as Wi-Fi, Bluetooth, and ZigBee did not include Long Range (LoRa) networks in any way, shape, or form. The authors of the paper [19] [37]developed a machine that can monitor the electrical activity of the heart in real time. They contemplated employing on-body sensors that were linked through low-power Bluetooth to generate patient diagnostic records. These information would then be transferred to the cloud using a 3G mobile connection or a Wi-Fi connection, respectively[38]. Having a consistently fast Internet connection, on the other hand, is a prerequisite for success with this tactic. On the other hand, a significant number of individuals in underdeveloped and poor nations do not have access to the internet. For this reason, it is essential to create a tool that enables communication even in the absence of the internet. ZigBee is proposed as both a wireless communication protocol and a wearable biosensor for Internet of Things-based geriatric health monitoring by the authors of [20]. Tuan Nguyen Gia and his colleagues developed an Internet of Things (IoT)-enabled healthcare machine [21] that investigated the use of fog computing in Internet of Things-enabled hospitals and its potential benefits. They came up with a plan for fog computing that involved the utilization of smart gateways that were capable of communicating with one another using Ethernet, Wi-Fi, Bluetooth, ZigBee, and 6LoWPAN[39-41].

Extensive research has been conducted in [22, 23] about large healthcare facilities and the problems that they cause. The utilization of both short-term and long-term healthcare tracking programmes is a topic that is covered in a few of these articles. The authors discussed a variety of capacity challenges, such as the deterioration of coverage provided by cell and large wireless networks as well as the instability of wireless infrastructure in hospital settings. Recent articles have mostly ignored the possibility of using LoRa wireless modules for Internet of Things-based fitness tracking. Within the scope of this investigation, we suggest building WSNs out of LoRa wireless devices that are currently on the market[42]. It appears that there is no longer any reference to a fitness tracking gadget that is based on a LoRa wireless sensor network[43]. At least, this is what we have determined. The fundamental innovative aspect of our contribution is (a) an analysis of the significance of the fitness monitoring domain for low-power WSN[44], as well as a survey of existing IoT-based fitness tracking programmes. (b) Suggest a completely new layout for an intelligent exercise equipment that is geared toward the needs of patients.

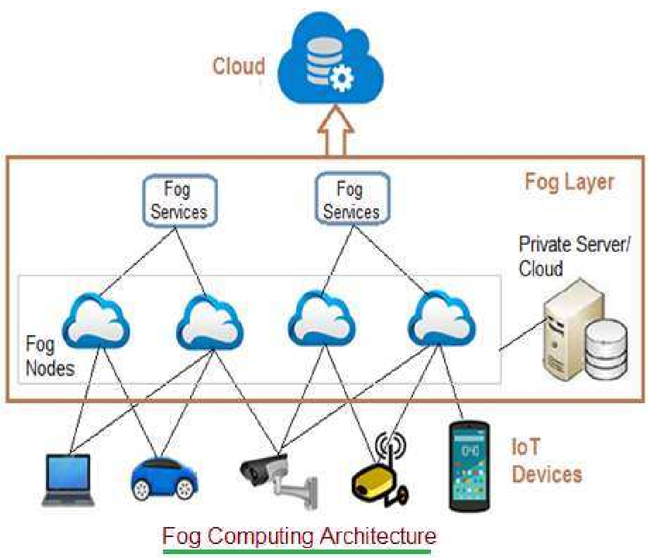

Figure 1. Typical fog computing architecture

V. PROPOSED ARCHITECTURE

Figure 2 depicts the advised structure for a fog-primarily based totally clever fitness tracking system.

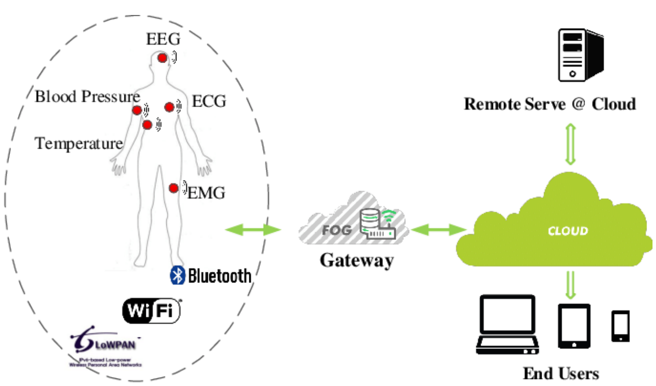

Figure 2. Fog – Computing Based Fitness Architecture

A wide variety of wearables, scientific equipment, and scientific sensors are included in the list of side consumers for the recommended structure. As a consequence of this, they are able to supply an exhaustive collection of quantitative indicators. Using these quantitative measures, vital signs including blood pressure, temperature, heart rate, breathing rate, the length of sleep, and stress level may all be evaluated. Connectivity is attainable by a wide range of technologies, such as Zigbee, Bluetooth, Wi-Fi, lore, and the many generations of mobile data networks (2G, 3G, and LTE). This piece of hardware is connected to the LoRaWAN gateway in order to ensure that data collected from the end devices may be promptly communicated to the Fog nodes, or in our case, the most reputable fitness centers. Depending on where a someone lives, they may have access to more than one well regarded fitness center in their area. Even if there is no Internet connection, the information that is gathered by these devices can be sent to primary health centers that are located tens of kilometers distant via a LoRaWAN gateway. This could be a lifeline in places where there is either patchy internet connectivity or none at all. The entirety of this information is then uploaded to the Health Information Exchange and sent to the mobile devices and personal computers used by the researchers. Patients who have medical conditions will have an organization of their medical records that is appropriate for the nature of their disease. Researchers in the medical field will have an easier time monitoring their patients as a direct result of this development.

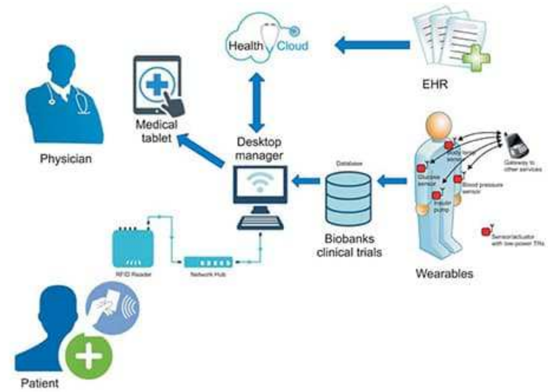

Figure 3. Fog – Computing Based Fitness Architecture - *Patient Monitoring|Solutions|Vervetronics,Pune | Verve Tronics*

If a person has hypertension, it would be extremely important, for instance, to monitor that person's blood pressure on a regular basis. When dealing with a patient who has dyspnea, it is essential to keep an eye on the patient's breathing rate. As a consequence of this, the medical history of the patient serves as the foundation for clinical facts, which are information regarding health centres. Therefore, doctors and other responsible medical professionals are able to constantly check the records of their patients and advise them to go to the emergency room if it becomes necessary to do so. In addition, should it become necessary, they may be able to take additional precautions, such as making use of services that are provided by telemedicine. If the patient's life is in danger or the situation is time-sensitive, the Health Centers are also able to provide prompt medical aid in the form of ambulance service by notifying the parent company of the ambulance service.

VI. RESULTS AND DISCUSSIONS

In this section, researchers will discuss about our previous experiments, as well as our analysis of the proposed system.

Table 1: Comparison of Average Latency and Network Usage.

Physical Topology	Average Latency		Network Usage (kbps)	
	Cloud Only	With Fog Layer	Cloud Layer	With Fog Layer
Config 1	208.18	7.36	124	11
Config 2	208.48	7.36	264	21
Config 3	208.59	7.36	562	52
Config 4	1412.65	7.36	1001	97
Config 5	2134.80	7.36	1013	178

Table 2 shows average latency and network latency comparisons (Kbps). As a result, five distinct configurations have been evaluated as physical topologies and discussed with the fog layer.

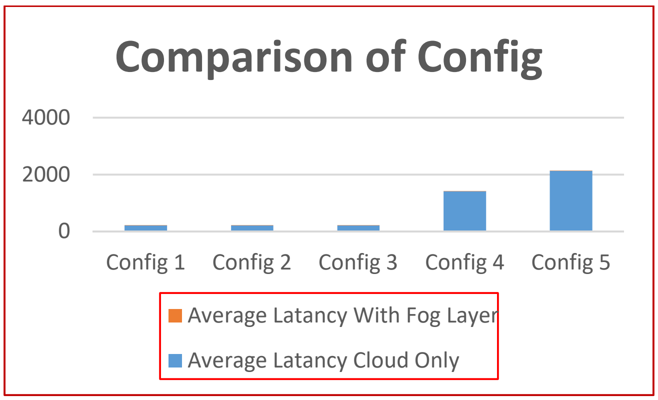

Figure 4. Graphical representation of Comparison of Config for physical topology and average latency

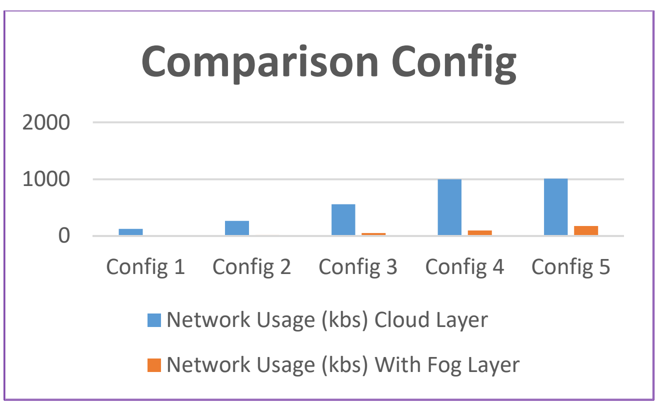

Figure 5. Graphical representation of Comparison of Config for physical topology and Network Usage

The graphical representations of physical topology, average latency, and network utilization is illustrated in figures 4 and 5. Furthermore, it shows the typical network utilization in Kbps.

VII. CONCLUSION

This research was conducted with the goal of developing a plan for a cloud-based healthcare monitoring tool that would assist in the creation of medical facilities that are more favorable to the environment. The capability of the suggested tool to provide uninterrupted medical care in real time, even in locations with a limited or nonexistent internet connection, is the most important feature of the proposed instrument. Not only is it helpful for patients who are required to monitor their health on a regular basis, but it is also helpful for people of any age who prefer to monitor their own health indicators. People will be able to take use of this format in the form of superior health monitoring, and it will be of assistance in parts of the world where there are insufficient numbers of medical personnel to meet the demand. The careful format also ushers in a new era of healthcare monitoring systems that use less power and emit fewer clouds. These advancements will be possible because of the format's attention to detail.

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