A NOVEL ARCHITECTURE FOR MONITORING THE HEALTH OF A DIABETIC PATIENT USING HIOT (HEALTHCARE INTERNET OF THINGS)

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ABSTRACT
Numerous studies on healthcare services and technological developments have been conducted throughout the preceding ten years. The Internet of Things (IoT) has exemplified the purpose of delivering first rate medical care in a far-off location. Safety of patients have increased, healthcare costs have dropped, access to healthcare facilities and services have increased, and operational effectiveness in the medical industry has increased. Latest research study offers a current overview of various healthcare tools available on IoT-based technology. Utilisation of the various IoT enabling technologies addressing various healthcare tools for diabetic patients has been addressed in this paper. With the aim of gaining knowledge and understanding of the various IoT based applications the current paper offers a current source of knowledge and information on several domains and use of HIoT for diabetic patients. It also shows a novel architecture for monitoring the health of a diabetic patient.
Keywords: Internet of Things **(**IoT), Healthcare, Diabetes, HIoT

Introduction

The Healthcare industry is very interested in the IoT application domain of healthcare. To enhance operational effectiveness, worker happiness, and safety of patients in the medical sector IoT and Cloud are playing a major role. The healthcare industry is looking at how cutting-edge big data wearables, ambient assisted living, and various cloud-based tools are used (Dang 2019). They also study various laws and regulations related to IoT and e-health around the globe to ascertain long-term expansion of cloud and Internet of Things in this sector (Khadim 2020).

By Pradhan (2019) it was said that Blood glucose is crucial for keeping the body functioning. For instance, the brain solely relies on glucose for energy. However, abnormal blood glucose levels have several very negative effects. For instance, the hypoglycaemia phenomenon, which is characterised by low blood sugar levels, can result in cardiac arrhythmia and sudden cardiac fatalities by triggering heart repolarization. Diabetes, which is characterised by persistently high blood glucose levels, is a serious illness that can induce heart attacks, strokes, heart failure, and other virulent conditions.

Literature Review

In this section, we present a summary of some published previous work related to some diabetes- related IoT solutions. Glucose levels of blood in the body are very high in the condition known as diabetes. It is one of the ailments that affect individuals the most. The three primary types of diabetes that are usually present are type I, type II, and gestational.

Pradhan (2021) assesses that commonly referred tests can determine blood glucose levels i.e. the random plasma, the fasting plasma and the oral glucose tolerance test. Method of diagnosis used most commonly to identify diabetes is fingerpicking. Recent developments in IoT technologies have enabled the development of a variety of non-interfering, useful and secure wearable blood glucose monitoring gadgets.

Oryema (2017) notes that there is still potential for study given that IoT offers unique capabilities that allow a small, restricted device to gather and transmit communications over complex networks. In the healthcare industry specifically, a few Personal Health Gadgets (PHGs) have been created for sharing and gathering data online. Some of the healthcare standards that have been established to address the interoperability problem in the IoT include oneM2M (One Machine to Machine) and Personal Health Device standards (ISO/IEEE 11073 PHD).

Rahmani (2019) evaluates continuous monitoring of glucose levels of blood for in reality time reactions. For example, the insulin pump's ability to change insulin levels, is one way to lessen the devastating effects of diabetes and hypoglycemia. However, it is a mistake to only monitor without considering additional signs or data, such as electrocardiography, such as blood glucose (ECG) and activity status, given their close connections. Falling is a common occurrence when hypoglycemia occurs, especially in persons over 65. The effects of a fall are more dangerous if it is not discovered.

The system allows remote real-time monitoring of circumstantial data, such as air quality, humidity and room temperature. Also e-health signals, such as body temperature, glucose levels and electrocardiograms. By utilising Fog computing at the network's periphery, the system provides a number of sophisticated features, such as extraction of various features from the ECG and security. The findings reveal the accuracy of the system and the efficacy of the wearable sensor node. The node can securely operate on a single charge for up to 157 hours when using a 1000 mAh Lithium battery, despite having a variety of sensors.

Bhat (2017) found a basic component of managing diabetes is blood glucose monitoring and assistance with homeostatic blood glucose regulation is the major means by which a diabetic can avoid dangerous diabetic confusions. Over the past four decades, ongoing advancements have been made in the area of glucose monitoring, resulting in the emergence of extremely sophisticated blood glucose metres and numerous technologies for continuous glucose monitoring.

The research focuses on developing a Non obtrusive framework to help a diabetic patient. The adopted method uses IR spectroscopy to assess a person's blood glucose level. A part-based intelligent mobile care system with a Wi-Fi module provides ready assistance in an ongoing care situation (Android Application). Our framework is divided into sections for patients, physicians, family, and providers of medical services. Each of the framework's components refers to a person who, for instance, uses a cell phone to communicate with a server installed at a medical facility, enabling him or her to move about freely. The framework is created for patients who should be continuously or periodically observed to use at home. Any basic condition is given the necessary eating schedule configuration and the vicinity of neighbouring medical facilities. This ensures quick support from the patients, and the writers can easily save many lives.

Gia (2017) described a real-time, remote Internet of Things (IoT) approach in Invasive Continuous Glucose Monitoring (CGM)**.** The IoT-based architecture that has been created is a complete system where medical professionals and caretakers can simply keep track of their patients from any location at any time using a web browser or a smartphone app. The system's sensor nodes may collect a variety of data (such as temperature of body, glucose, and ambient data) and conduct a wireless transfer to the gateway with little energy consumption. In order to increase the sensor device's functioning time, the sensor node is combined with the power control and energy harvesting units. The smartphone of a patient acts as a hub for data collection from sensor networks with the help of the tailored nRF receiver. Additionally, the gateway's application offers consumers cutting-edge capabilities including a notification service. The outcome showed that glucose can be continually monitored remotely and that the system can be altered to be energy-efficient in real-time.

Sargunam (2019) performed an investigative study for the basic methods of intelligent insulin regulation and blood glucose detection. The procedure that needs users to pierce their finger to obtain blood is the most popular and commonly used. The two sensing modes, optical and transdermal are the best prospects among all for non-invasive glucose monitoring. By transmitting IR radiation, a person's blood glucose content can be calculated. The strength of the radiation's particular wavelength affects the amount of glucose in the blood. The strength of the radiation's particular wavelength affects the blood's level of glucose. The detected blood's level of glucose is transmitted wirelessly to a smartphone, which uses IOT-based mobile medical applications to control safety-critical apparatus like an infusion pump for insulin.

The blood glucose level of diabetic patients is checked using glucose monitoring equipment. Through a wireless connection, a smart phone receives the measured levels of blood glucose and uses it to regulate devices that are vital to safety, like an infusion pump. The quality of life and health of diabetic individuals will improve thanks to non-invasive glucose monitoring devices.

Istepanian (2011) states, diabetes as a severe chronic condition with significant economic and societal repercussions, as widely known. The potential of m-IoT for non-invasive monitoring of levels of blood's glucose with cutting-edge opto-physiological evaluation approaches and treatment of diabetes has not yet been studied in any detail. The possible advantages of employing m-IoT for non-invasive glucose level detection and the prospective m-IoT based architecture for diabetes management are discussed in this work by the authors.

From the perspective of mobile healthcare, this technology will open new communication channels using cutting-edge IP-based networking designs between mobile patients and care services. A non-invasive, real-time blood glucose tracking has been suggested using an m-IoT-based glucometer. The wearable sensors and medical staff in this instance were linked via IPv6 networking.

Paredes (2019) in his study found that Diabetes mellitus patients who want to control their glycaemia must keep an eye on their blood glucose levels. As a result, they are required to conduct a monthly or bimonthly laboratory examination. These conventional procedures are challenging for patients because they must prick their finger to measure which causes discomfort and distress. A camera having Raspberry Pi and a laser stream are used in the device, which is built within a glove and powered by a battery bank. The Raspberry Pi does data collection for non-invasive monitoring by taking a sequence of photos of the user's forefinger and creating their histograms. Developed on a Flask micro service, artificial neural networks (ANN) were used in this study to evaluate the results against laboratory blood tests, which were all performed in vivo. A monitoring tool, like a smartphone, can gather estimated glucose readings.

A framework for Non-invasive monitoring of blood’s glucose using Internet of Things (IoT) i.e., a glove was created for monitoring blood sugar levels with a camera having Raspberry Pi and a visible laser stream. The diabetic status of patients had been discovered using a collection of pictures that were captured from the fingertip.

Valenzuela (2020) stated a metabolic condition called diabetes mellitus (DM) is characterised by blood glucose levels that are higher than normal. In recent years, the disease's effect on the populace has grown. It is currently one of the main killers and a global public health issue. Several ideas have recently been explored for more effective and consistent glucose monitoring. However, these ideas are unable to foresee a critical circumstance and do not discard incorrect readings. Our contributions concentrate on utilising an IoT infrastructure with a prognosis algorithm to better notify physicians and patients' loved ones.

In the IoT architecture, a double moving average-based algorithm was used to measure glucose levels. The suggestion is a novel method for anticipating the highs and lows of glucose levels. The tendency can only be produced by past readings hence avoiding erroneous notifications. According to the authors' knowledge, there have not been many studies that use strategies like the ones they suggest for older persons, which is why their recommendation is relevant.

The work includes a complete IoT infrastructure in addition to a real-time prognosis method, in contrast to current approaches that can be found in the literature. In order to complete the prognosis without sending out notifications and so avoid network overload, the authors describe a novel approach. The server is given the responsibility of sending messages. Compared to the energy used by an application on a smartphone, the sensor stage uses little energy. The technology uses a unique ID provided to every individual patient within an embedded system for privacy purposes. By including a mobile device with an Internet connection, carers can have a remote awareness of each incident that happens and give caregivers a tool to aid them.

Sunny (2018) shows Diabetes mellitus (DM), sometimes known as sugar, is a serious and intractable problem for the medical community. Serious conditions can be monitored continuously from a distance, such as early mortality or the cause of death. The typical and conventional approach, such finger pricking, has drawbacks including pain and tissue damage that might lead to infection. Such infections are treatable with non-invasive methods.

Here optical and IoT technology is used to non-invasively monitor glucose levels. The suggested sensor circuit consists of NIR photodetectors to detect the light that body components reflect and IR LEDs with a wavelength of 650–2500 nm for optical blood glucose monitoring. The project is carried out utilising the Arduino IDE to determine the system's performance matrix and numerous analytical tests. To create an IoT-based optical non-invasive glucometer for diabetic patients to measure their blood sugar levels painlessly.

It is significant to observe that optical sensors, such as near-infrared photodiodes and infrared LEDs, have been employed to measure blood sugar levels. Here, a human body's light signal reflection is taken into consideration to determine the body's blood glucose levels.

Objectives of the study
1. To learn more about the working and underlying architectures for the latest IoT based healthcare applications for diabetes management through extensive literature study,
2. To propose a framework of diabetic patient monitoring in view of the Internet of Things.

HIoT Services and Application

Ambient Assisted Living. Age-related assistance is provided by the specialist field of artificial intelligence known as ambient assisted living (AAL), which integrates with the Internet of Things. AAL's key objective is to help in enabling elderly people to live independently at home in a comfortable and secure atmosphere. With the help of AAL, it is possible to track these patients in real-time and ensure that they will be given assistance like that of a human service provider in the need of a medical situation. This is made feasible using cutting-edge AI technologies, big data analysis, machine learning, and their integration into the healthcare sector. Figure 1 depicts the fundamental layout of a smart healthcare framework for AAL. Later, a more advance protocol was used to create cutting-edge IoT-based AAL systems that was developed using the framework as a foundation (smart objects, devices, and kits). A secure, open, and flexible framework for AAL where an IoT-based hub was used has been proposed using the combination of cloud computing and IoT. The gateway assisted in resolving several problems with the IoT system's compatibility, data storage, and security.

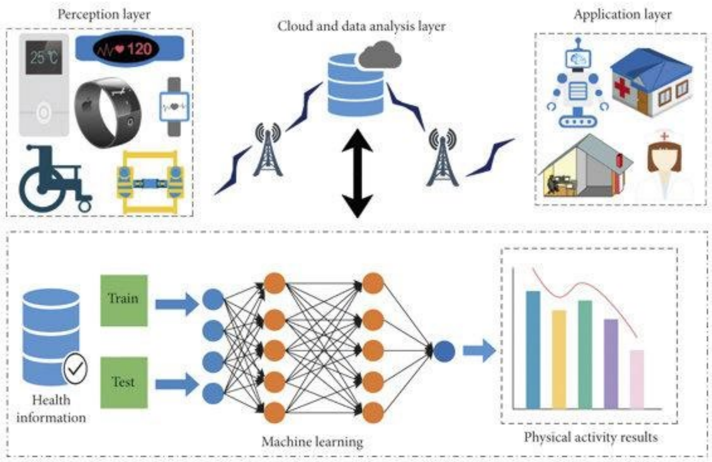

Figure 1. Healthcare framework for AAL (source:https://www.researchgate.net/figure/A-smart-healthcare-framework-for-AAL-reproduced-from-27-license-no-496010299387)

Mobile IoT. Tracking patient health data and other physiological conditions using mobile computing, sensors, communication devices, and cloud computing is known as the "mobile Internet of Things," or "m-IoT." (Figure 2). In another words, it serves as a transmission link between local area networks and mobile networks. (like 4G and 5G) in order to deliver effective Internet-based healthcare services. Healthcare executive can access more easily HIoT services and can diagnose patients. Thanks to the use of mobile that a quicker administered therapy can be advised.

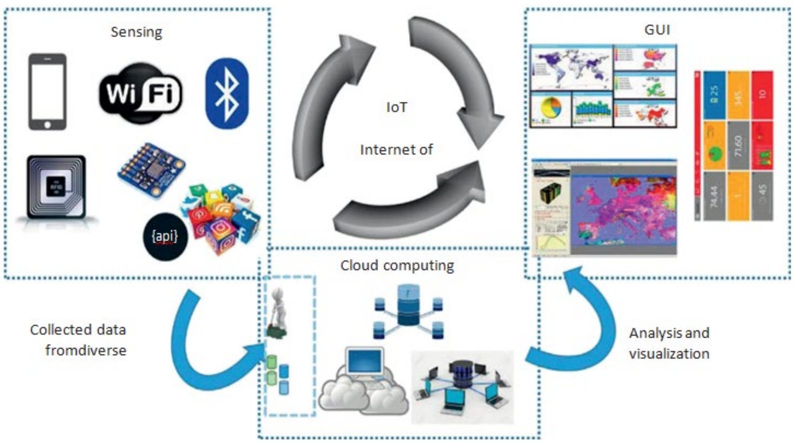

Figure 2. A m-IoT environment (Source: https://www.researchgate.net/figure/A-generalized-m-IoT-environment-reproduced-from-38-under-Creative-Common-License)

Wearable Devices. More affordable technological ways for patients has been offered by the wearable technology and healthcare providers to address a large range of health problems. These instruments are non-invasive and can be created by combining different sensors with human wearables like watches, wristbands, necklaces, shirts, shoes, handbags, hats, and so forth. Information about the environment and the patient's wellbeing is gathered using the attached sensor. After that, this material is uploaded to the server or databases. Through health apps, some wearables are also linked to smartphones. These wearable gadgets' computational capacity is increased by their connectivity to a mobile application. The programme can also be used to easily process and visualise the information gathered.

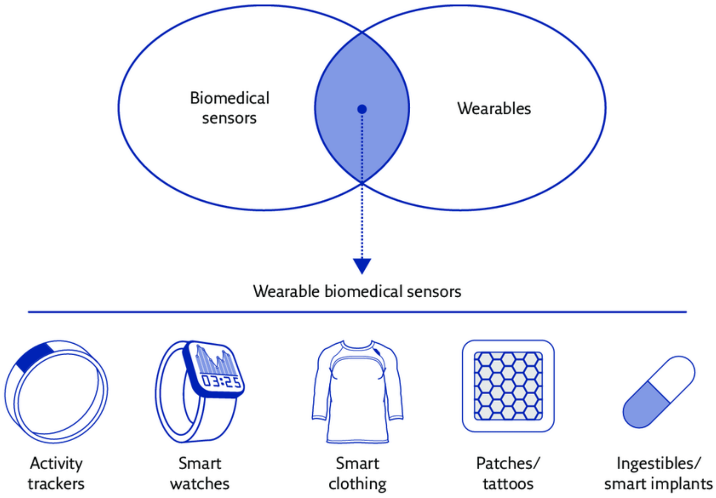

Figure 3. Wearable Sensors (Source: https://www.researchgate.net/figure/Wearable-biomedical-sensors)

Applications. The creation of various IoT-based applications uses the HIoT services and concepts. Investigators in these fields have offered a variety of ideas for the benefit of humanity. Due to the quick growth the IoT has reduced the cost and increased the usability of medical tools, portable devices, and wearable sensors.. These systems can be employed to collect data on patients, recognise diseases, monitor the health of the patients, and send out notifications in the event of a medical emergency (Figure 4). Some of the newest devices that are currently on the market have been discussed in the part that follows. Additionally, a few HIoT based apps have been discussed, including both single-condition and multiple-condition applications.

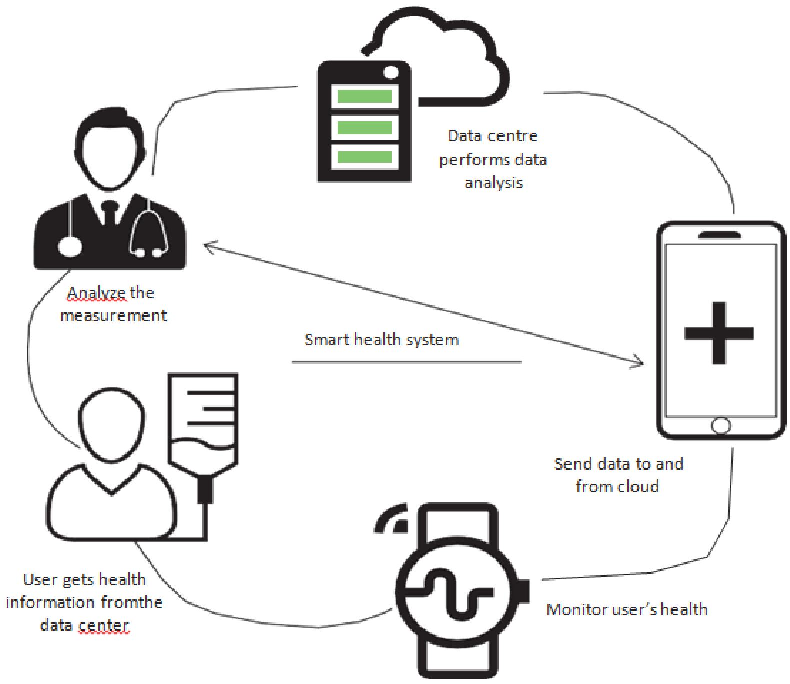

Figure 4. Application of HIoT (Source: https://www.researchgate.net/figure/Application-of-HIoT)

Proposed Framework: HIoT (Healthcare Internet of Things)

Recently, Internet-of-things (IoT)-based health monitoring applications have been created to raise the calibre of healthcare services. However, there are not many cutting-edge IoT-based continuous blood glucose monitoring systems, and the ones that are already in place have several drawbacks. This is because certain technologies can improve an IoT system's functionality.

The architecture describes the steps involved in sending patient statistics from various sensors and medical equipment to a particular network of healthcare. The design of different logically connected parts of a healthcare infrastructure or network in a health-care setting makes up the topology of a HIoT. Three essential elements that make up a basic HIoT system are publisher, broker, and user (Figure 5).

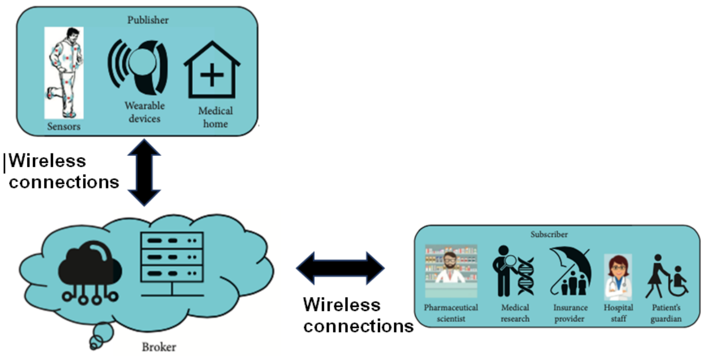

Figure 5: Framework of HIoT

The patient's vital signs are recorded by the publisher using an integrated system of sensing devices and other medical apparatus that can function both independently and in unison. These readings could include ECG, EEG, EMG, blood pressure, heart rate, temperature, oxygen saturation, and others. This information may be continuously transmitted from the source (publisher) to a broker through a network. The vendor (broker) is responsible for processing and cloud-based storage of the collected data. In order to access and examine the data, the subscriber conducts on-going patient information monitoring using a computer, smartphone, or tablet, etc. The publisher can assess data and offer comments here if there is any physiological anomaly or decline in the patient's health status.

Each distinct part of the IoT network and the cloud in the hospital network is dedicated to a specific motive, thanks to the integration of the HIoT into a hybrid grid. It is difficult to suggest a general HIoT structure because the topology depends on the need and use in healthcare. Many structural modifications have previously been applied for a HIoT system. While developing a new real time, IoT-based healthcare system for patient monitoring, it is essential to list down all relevant activities with the required application. How well the IoT system satisfies the needs of healthcare practitioners will determine its success. Its topology must adhere to the medical guidelines and processes in the diagnosis process because each condition necessarily is a complex set of healthcare operations.

Conclusion

For the past three decades, diabetic patients have employed glucose monitoring technologies to check their blood glucose levels. This paper gives details on the current IoT based healthcare services. These are just a few of the technical options for IoT in healthcare that are currently accessible, and it is certain that several new and enhanced devices will develop over the following years. The proposed framework of diabetic patient monitoring in view of the Internet of things is an alternative that can be utilized to assist patients with the diabetic disorder. By applying these ideas, IoT technology has made it easier for medical professionals to monitor and diagnose blood sugar, measure several blood sugar-related health factors, and offer diagnostic services in remote areas. As a result, the healthcare industry is no longer just concerned with institutions or hospitals but has started being more patient-centric.

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