ENERGY EFFICIENT FOG-ASSISTED IOT SYSTEM FOR MONITORING DIABETIC PATIENTS WITH CARDIOVASCULAR DISEASE

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Abstract: The prime motive of the emerging technology named as Internet of things (IoT) is to bring everything including wearable sensors, medical care sensors, cameras and home machines, advanced mobile phones, and so on the web or internet. These various things create enormous information which subsequently leads to the need of prerequisites of productive stockpiling and preparing. Fog computing is an arising innovation to defeat this issue. Nonetheless, there are a few applications (medical care) which need to deal with information continuously to improve its presentation and require low idleness and postponement. Fog computing is one of the efficient solution for providing better facilities in the domain of medical care. In this research, a fog-based framework is presented for distant wellbeing monitoring. This proposed framework majorly focuses on monitoring blood glucose level of the patients suffering with diabetes and having cardiovascular disease. It also ensures to limit the energy utilization. Exploratory outcomes uncover that the presentation of the proposed structure is productive regarding network postponement and energy utilization.

Keywords: IoT, Fog-computing, diabetes monitoring, remote monitoring, healthcare, ECG, Glucose, Hyperglycemia, medical care, technology.

1. Introduction

The most significant energy source used by our brain is glucose. Blood glucose assumes a significant part in keeping up body's exercises. In any case, when blood glucose level is strange, it causes some serious outcomes. Hypoglycemia which is a disease caused due to low blood glucose level can incite cardiovascular arrhythmia. This can also lead to abrupt cardiovascular deaths. Diabetes is a disease which can be seen as a high-blood glucose level for a significant stretch of time, is a perilous sickness as it can straightforwardly or in a roundabout way causes heart assault, stroke, cardiovascular breakdown, and other awful infections. [1] An answer for diminishing these serious outcomes brought about by diabetes and hypoglycemia is to consistently screen blood glucose level for continuous reactions. Along with monitoring blood glucose level and adjusting the insulin levels, it is also important to keep a check on the data such as Electrocardiography (ECG) since they have close connections. When the blood glucose level goes under 60 mg/dl, then the disease called as hypoglycemia portrays a strange phenomenon. [1, 2]

It causes heart repolarization and may prompt cardiovascular arrhythmia which is one of the essential drivers of abrupt cardiovascular deaths. As indicated by Centers for Disease Control and Counteraction, many people are influenced by arrhythmia particularly; individuals with the age of at least 60 are at high danger of arrhythmia. [3] As of late, researches have proposed the expectation of hypoglycemia by dissecting QT-period and T-Wave. [1, 3] Hyperglycemia portrays an anomalous high-blood glucose level.

Hyperglycemia can be anticipated by estimating time taken by the ventricles of heart to contract and relax. QT interval is inversely proportional to the heart rate. Individuals from any sex and any age can have diabetes. Diabetes not just happens in created nations yet additionally in agricultural nations. As per National Vital Statistics Reports (NVSR), diabetes has a position of 7 among the 15 driving reasons for deaths in 2014. [4] Also, diabetes can straightforwardly or in a roundabout way cause stroke, cardiovascular breakdown, kidney disappointment, visual impairment and other horrible illnesses which are essential drivers of deaths. Sadly, diabetes can't be restored with the current information. One of the strategies for overcoming the problems brought about by diabetes is to ceaselessly screen the blood glucose level and monitoring and adjusting the insulin level simultaneously. [4, 5]

Diabetes, cardiovascular infections, fall and elderly individuals regularly have a few connections. It has been discovered that diabetes is a danger element for falls. For instance, individuals that are more than 65 years of age resemble to have diabetes, cardiovascular illnesses and fall all the more regularly. As per measurements, more than 25% of individuals who are more than 65 years of age have diabetes and more than 30% of these individuals fall each year with dangerous outcomes. [6] In expansion, over 68% of these individuals having diabetes passed away because of cardiovascular sickness. Consequently, it is needed to have a framework which can both screen diabetes, ECG and advise variations from the norm (e.g., a fall, low or high glucose level, and irregular pulse) continuously without meddling the patient's every day exercises. [5, 6]

One of the most appropriate possibilities for tending to the objective is Internet of Things (IoT). IoT can be communicated as A stage where physical and virtual articles are interconnected. IoT comprising of many trend setting innovations, for example, detecting, sensor organization, Internet and Cloud figuring is equipped for giving far off wellbeing checking continuously while the personal satisfaction can be kept up. By means of IoT frameworks, gathered information is put away in Cloud workers. Moreover, IoT frameworks can perform ongoing reactions or activities. For instance, an insulin pump of IoT frameworks can naturally or be distantly controlled for infusing insulin into the patient's blood when the blood glucose is low. [7]

In spite of the fact that glucose checking IoT frameworks have focal points, for example, distant continuous observing and worldwide information stockpiling, they also have constraints. For instance, the vast majority of them are not gotten in light of the fact that the information sent over the organization isn't secured. The sent information can be tuned in and adjusted by unapproved parties. Besides, the greater part of the current wellbeing observing IoT frameworks don't uphold disseminated nearby capacity. Basic information might be lost when the association between the frameworks and Cloud workers are intruded. In medical care spaces, losing basic information can prompt wrong diagnosis of diseases. [6, 7]

A legitimate way to deal with difficulties in IoT frameworks is to apply an additional layer named as Fog among passages. Fog layer is run on the highest point of brilliant doors to offer progressed types of assistance for improving the nature of administrations. For instance, Fog assists with saving organization data transfer capacity among doors and Cloud workers by handling and compacting information. Besides, Fog assists with decreasing the weights of Cloud workers by pre-preparing information at brilliant passages. [8] Fog makes a merged organization of interconnected and intercommunicated entryways that serves to conquer administration interference. With the advantages of cutting edge administrations, Fog solves numerous difficulties of IoT frameworks as well as upgrades the quality of administrations significantly. [9]

An IoT framework dependent on Fog computing for ongoing and far off medical care observing is presented in this chapter. The framework monitors the blood glucose, ECG, patient's development and internal heat level and also logical information, for example, room temperature, stickiness, and air quality. The framework assists a fall, high pulse or high blood glucose. The gathered information is secured with cryptographic calculations. Especially, information is scrambled at sensor hubs prior to being communicated and decoded at brilliant entryways. To wrap things up, the energy-proficient sensor hub for observing fundamental signs is introduced. [8, 9]

2. Literature review

A proposal of real time and remote health monitoring IoT based system has been made. An IoT system with a smart gateway for e-health monitoring has been presented by Rahmani. The gateway supports interoperability. Also, many advanced services such as data compression, data storage, and security has been provided by gateway. A proposal of an ECG monitoring IoT based system using 6LoWPAN that consist of smart gateways and sensor nodes which are energy efficient. IoT systems have been presented by the authors for detecting the falls. [10]

For determining the 3-D acceleration and 3-D angular velocity, wearable sensor nodes are utilized by the frameworks. Push notification services are offered to the caregivers for letting them know about the status of a fall. A glucose observing IoT-based framework which shows a few degrees of energy effectiveness by implementing 6LoWPAN and RFID is presented by the authors. The framework can recognize non-fasting and fasting cases for a precise determination. Additionally, an IoT framework is proposed for detecting & sensing non-intrusive glucose levels. The framework utilizes a PC as a door for getting information from 6LoWPAN nodes and sending the information to Cloud workers. Some of the works do not support interoperability which limits the flexibility and ubiquity of the health monitoring system. [11]

IoT frameworks for monitoring the health have been proposed by the researchers with the help of Fog Computing technology. The Fog-based frameworks have points of interest, for example, data transfer capacity saving, energy proficiency, and an undeniable degree of security. Authors apply a savvy entryway and Fog computing into an ECG observing IoT framework. The framework offers numerous types of assistance, for example, pop-up message or push-notification service and distributed local storage. Authors also proposed an IoT framework with Fog Computing for ceaseless glucose observing framework. The framework utilizes a versatile based door for preparing and breaking down information.

Fog approach for ECG monitoring frameworks is proposed by the authors. The frameworks can separate ECG highlights at Fog and accomplish a few degrees of energy effectiveness at sensor nodes. Wellbeing observing IoT frameworks with Fog processing are proposed. These frameworks give many progressed Fog administrations like information examination, information combination, distributed local storage, and compression of data.

In the system, a new set of fall detection algorithms is investigated and developed for improving the results of fall detection. Craciunescu et al applied Fog computing for reliable e-health applications. The system has both e-health and contextual sensor nodes which are built from general purpose devices. These sensor nodes transmit the collected data to a computer for processing. The Fog-based approaches which have been referenced or mentioned provide many advanced services to enhance the health monitoring frameworks, none of them considers parts of sensor node's energy productivity, security, and the relationship of e-health data (i.e., diabetes, ECG, body motion and body temperature).

At the point when a sensor node isn't energy effective, it can cause administration interference which is one reason for lessening the precision of sickness investigation. [12] Patient's information can be stolen or the system can be instructed for doing unacceptable actions when the system is not secured. The analysis and diagnosis of disease might be not accurate when independent e-health information is utilized without thinking about logical information or action status. The framework not just screens e-health (i.e., blood glucose, ECG, and internal heat level), every day action, and context oriented information (i.e., room temperature, stickiness, air quality) yet in addition offers progressed types of assistance for improving the precision of disease investigation and educating anomalies (i.e., hypoglycemia, hyperglycemia, and heart infection) continuously. [11, 12]

3. Architectural design of the proposed framework

The design of the proposed framework has 3 layers as follows:

Sensor layer: Sensor layer incorporates various kinds of sensor nodes, for example, context oriented nodes, e-wellbeing hubs, and actuator nodes. Context oriented nodes can be fixed at a solitary space for social occasion relevant information from general conditions for example, a room temperature, moistness, time, area and air quality. The relevant information assumes a significant part in accomplishing exact investigation.

E-health nodes can be ordered into various sorts relying upon the given wellbeing observing application. There are 3 sorts of e-health sensor nodes as follows:

- low information rate sensor nodes
- high information rate sensor nodes
- mixed or hybrid sensor nodes(outfitted with both low and high information rate sensors)

Low information rate sensor nodes can be utilized for obtaining blood glucose, body temperature, and dampness. High information rate sensor nodes can be utilized for gathering ECG and body movement. Mixed sensor nodes can be utilized for gathering all referenced information. [13]

Actuator nodes are utilized for controlling activities identified with wellbeing or the general climate. Actuator nodes frequently get guidelines from a smart door. For instance, an environment controlling actuator can change a room's temperature and mugginess. The gathered information from sensors is shipped off to smart doors by means of one of a few remote conventions. A decision of a particular remote convention relies upon the application's necessities. For instance, Wi-Fi is utilized for high information rate checking applications. A nRF convention, which is ultra low force 2.4 GHz ISM band remote convention, is used in the proposed framework because of its adaptability of information rate backing and energy proficiency. The nRF convention upholds information paces of 250 kbps, 1 Mbps, and 2 Mbps. The gathered information can be kept flawless or pre-handled prior to being communicated. [14]

Fog computing layer: The next layer is fog computing layers which consists of fog-assisted various smart entryways. These entryways can be fixed or mobile relying upon the given application. As of now, it is discovered that fixed entryways are more preferable because of their flexibility. Furthermore, they offer progressed administrations running weighty computational calculations while portable entryways are not proficient because of restricted battery limit. Synchronized and intact databases are the two prime components of dispersed local storage wherein context oriented data and e-health data is stored in the synchronized database and information which is required for calculations and important information such as the username and password of system if stored in the intact databases. Compressing the Information helps in saving the bandwidth of network despite the fact that compacting and decompressing cost a few assets and idleness; they don't influence the exhibition of different administrations and just increment the complete dormancy marginally. [15]

Neighborhood clients and outer clients are categorized using the categorization services. The categorization service particularly screens the Wi-Fi devices at the point when a client attempts to interface with keen entryways; the framework checks the data set. In the event that the client is a nearby client, the shrewd entryways send constant information straightforwardly to the client's terminal without experiencing Cloud workers.

Cloud server layer: The cloud servers give numerous advantages, for example, stockpiling, adaptability, information security and information handling. Substantial computational undertakings, which can't be run at Fog, can be prepared easily in Cloud servers. Various advancements can be introduced at Cloud for facilitating a thorough site indicating ongoing information in both printed and graphical interfaces. Besides, Cloud workers uphold message pop-up sending the texts to an end-client continuously. In this proposed framework which is presented in this chapter, the abnormalities are informed to the system administrator through the push notification feature. [16]

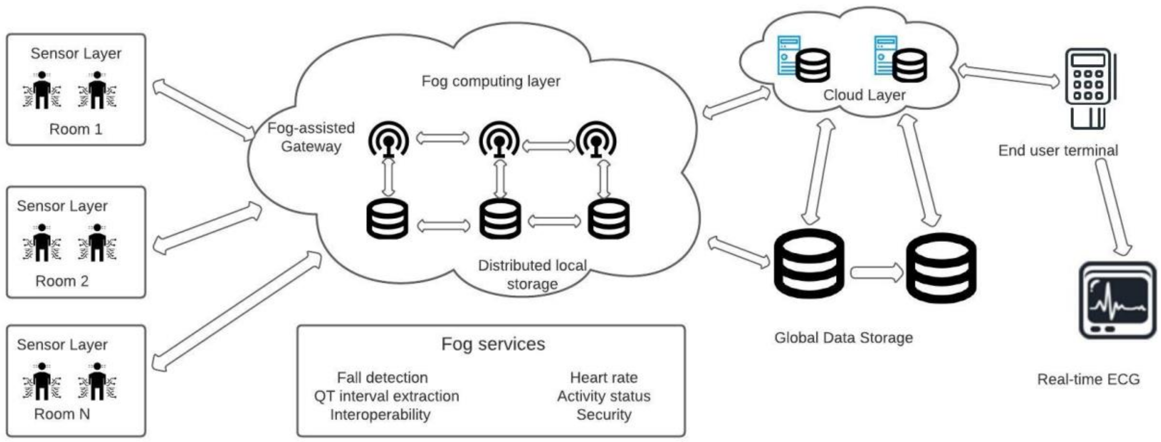

Figure 1: Architecture of the fog-assisted IoT framework for monitoring patients with diabetes and cardiovascular disease.

4. Fog services

Fog processing can offer many progressed administrations and consequently possibly upgrade the nature of medical care administrations. In this chapter, interoperability, security, information preparing are examined and clarified as follows:

4.1 Information processing: In fog-assisted health monitoring systems, data processing and data analysis play a major role in monitoring the health of the patients. Along with reducing the burden of cloud servers, they also play an important role in extracting the significant data which is required for making decision and push notification. The ECG waveform is used for extracting the data for the pulse rate and QT intervals. The data extracted from ECG waveform is combined with other e-health information, for example, blood glucose level, internal heat level, and movement of body is utilized for recognizing hypoglycemia.

4.1.1 Algorithm for extracting heart rate and QT interval:

Electrocardiography (ECG) is basically characterized as a periodic signal in which every ordinary waveform addresses the electrical occasions in single heart cycle. An ordinary ECG waveform, shown in Figure 2, regularly comprises of a few waves that are named as P, Q, R, S, T, and U. Out of these waves, wave P, R, T frequently have the positive peaks when the baseline of ECG is zero whereas Q, S have negative peaks.

We can calculate the heart rate from ECG waveform using the formula: HR = 60 / RR interval, where HR stands for Heart rate, RR interval stands for the time between QRS waves. The heart rate can be determined by taking the time between 2 QRS waves or complexes. We can easily calculate the RR interval because R waves have the highest amplitude among the other waves.

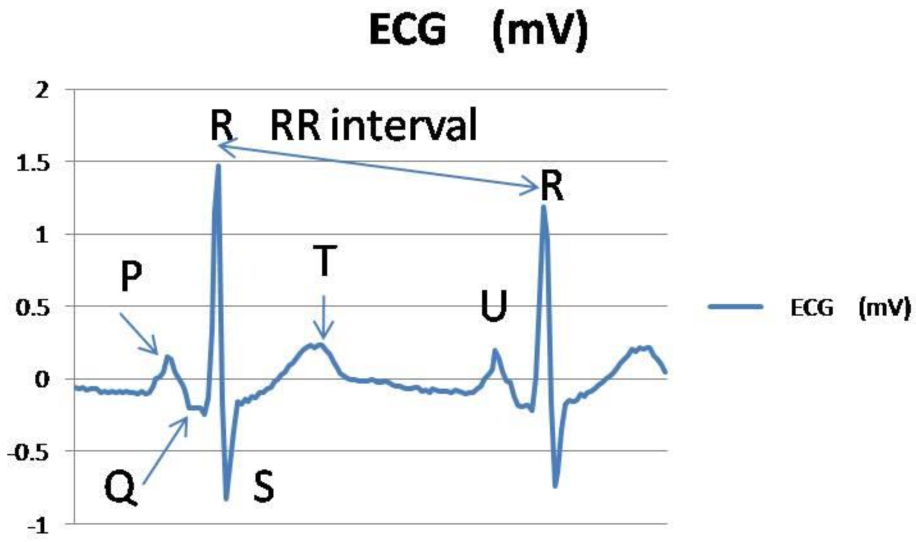

Figure 2: Generation of ECG signal in Excel using a database.

A linear time algorithm which requires the determination of local extreme can be used for computing the peak waves. QT interval can be determined by using the algorithm in which we first locate the lowest interval I_P in which P wave reaches its maximum value. Similarly, the other intervals i.e. I_R, I_S, I_T are also calculated where P, R, S, T are the different kind of waves. $I_{QT} = I_R + I_Q + I_S + I_T$ is the formula for calculating the length of QT interval. In the algorithm discussed below, function f(x) reaches its local maximum. Two inputs i.e. $x_i = f(t_i)$ are taken in this algorithm where t_i refers to the instant of time. Also, this algorithm does not require any memory which makes it suitable for tiny devices. [17]

Algorithm 1: To compute local maximum of a function.

Procedure: We take two inputs here (x_i, t_i), where x: value of ECG and t: specific time.
If ($x_{i-1} = 0$ and $x_i > 0$) then
$I_1 \leftarrow t_i$
$M \leftarrow x_i$
else if (I_1 not equal to 0 and $x_i > 0$) then
$M = \text{Max}(x_i, M)$
else if (I_1 not equal to 0 and $x_i = 0$) then
$I_2 \leftarrow t_i$
break
return M, [I_1, I_2]

4.1.2 Activity status categorization and fall detection algorithm:

An ECG cannot be analyzed without considering an activity status because the status of ECG changes on the current activity status. ECG of an individual is different during rest and motion. Hence, ECG and movement status should be observed and investigated at the same time. Movement status addressing day to day proactive tasks of an individual can comprise of three essential groups, for example, immobile/resting, strolling, and workouts. There can be numerous activities in each group such as sleeping, lying etc. Resting group comprises of standing and sitting. Whereas, training group consists of running, push up, weight lifting and other heavy activities. Activities belong to the same group have comparative impacts to the ECG waveform. Camera or wearable movement sensors are utilized to identify individual's action status. The calculation incorporates numerous means like the securing of 3-D increasing speed (acceleration) and 3-D precise speed (angular velocity), information separating and fall recognition. The calculation utilizes both 3-D speeding up and 3-D rakish speed since they help to improve the exactness of a fall calculation. [18]

Table 1: Formulas for calculating corrected QT interval

Algorithm	Formula
Bazett (QTcB)	QTc = QT / (√ RR)
Fridericia (QTcFri)	QTc = QT / (√3 RR)
Framingham (QTcFra)	QTc = QT + 0.154 x (1 - RR)
Hodges (QTcH)	QTc = QT + 0.00175 x ([60 / RR] - 60)
Rautaharju (QTcR)	QTc = QT - 0.185 * (RR-1)+k

Signals are affected by surrounding noise. Therefore, noise must be removed by using filters to achieve a high quality of signals:

$SV\ M_i = \sqrt{x_i^2 + y_i^{\,2} + z_i^{\,2}}$

$\Phi = \arctan\{\sqrt{y_i^{\,2} + z_i^{\,2}} / x_i\}\ 180 / pi$

SVM: Sum vector magnitude

i: number of sample

x, y, z : value of accelerometer

Φ: the angle between y-axis and vertical direction

The limits that we get after calculation are compared with the first set of thresholds and fall detection threshold. [19]

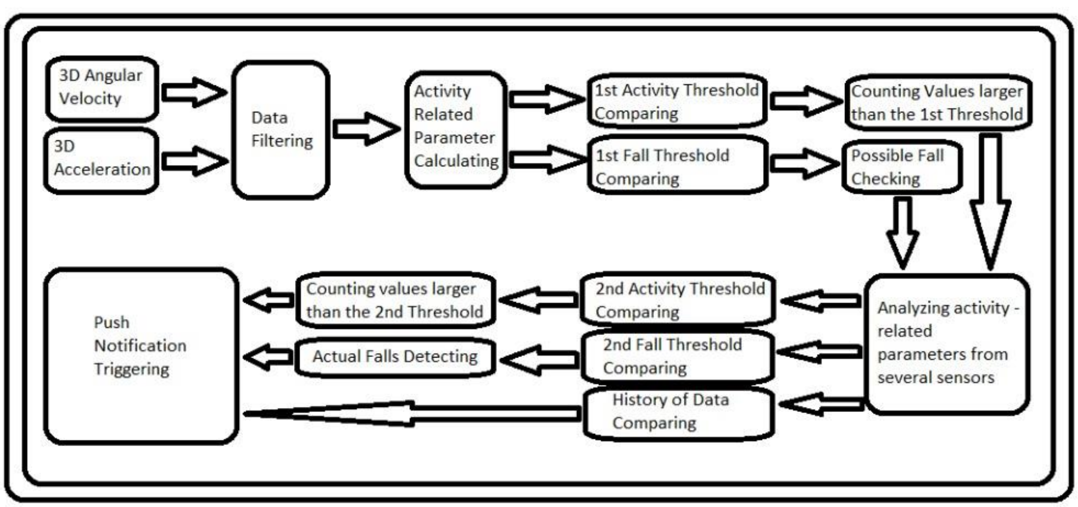

Figure 3: Algorithm of fall discovery and activity status

4.2 Interoperability:

A specific type of sensor nodes has been supported by traditional monitoring system that include Wi-Fi-based node which monitors EMG, 6LoWPAN-based node which monitors ECG, Bluetooth based node which monitors ECG, EMG or BLE-based node for detecting human fall. These frameworks are not appropriate for sensor nodes utilizing other conventions like Zigbee or nRF and LoraWan. Fog computing along with its potential offers interoperability to tackle these difficulties. The interoperability can be referred to as a potential of supporting various sensors from different makers as well as various conventions which includes both wire and wireless conventions. As per the application, other wire or wireless communication conventions can be combined into Fog-assisted brilliant entryways. For example, long-range distance related applications can be supported by LoraWan so it can be added into Fog-assisted smart gateways. The sensor nodes utilized in the Fog based framework can work in both the ways i.e. independently and cooperatively and can also speak with one another through Fog-assisted smart gateways.

4.3 Security:

In IoT based healthcare monitoring frameworks, the association between sensors and passages is probably the weakest point of the framework. The fundamental reason is that the sensors are wearable. Accordingly, they can't run complex security calculations. Despite the fact that unpredictable security calculations can be run effectively at sensor nodes, they are definitely not applied in light of the fact that inactivity prerequisites of the framework may be encroached and their battery is drained. In numerous IoT frameworks, crude information is frequently sent for saving battery life of sensor nodes. This methodology is hazardous since information can be tuned in by unapproved parties. In the most pessimistic scenario, they can educate orders to make damage to a patient. For instance, Klonoff utilizes his product to take the security qualification of the glucose observing framework. Therefore, he has a full access and control to an insulin pump. To evade such cases, lightweight security calculation should be run at sensor nodes.

The calculation should give a few degrees of security while sensors' battery life can't be diminished essentially. AES calculations are applied in this chapter which comprises of four essential operations: SubBytes, ShiftRows, MixColumns, and AddRoundKey. Each sensor node has its private keys for scrambling the information while a passage has all private keys of all sensor nodes. In detail, every sensor node has three diverse private keys where every private key has an ID and is utilized during a timeframe. The sensor node sends messages to illuminate a relating door about the key ID before another key is applied. At a savvy passage, the encoded information got will be unscrambled by the right private key which has been recovered from a table of all private keys based on the given ID. [20]

5. Implementation of the framework and test bed scenario

A total IoT-based framework with Fog processing for consistent glucose, ECG, internal heat level and body movement observing is actualized. The framework incorporates the following:

a.) 4 savvy passages
b.) 6 relevant sensor nodes
c.) 4 e-wellbeing sensor nodes
d.) Cloud workers, and end-client terminals, for example, versatile applications.

Two entryways are set in two adjoining rooms while other two are set at passageways. These entryways are associated with the Internet. Every one of the rooms has 3 logical sensor nodes set at center, top and back corners of the room. The ECG data is collected by the e-health sensor nodes via electrodes. The tested rooms are office rooms comprising of PCs and furniture, for example, tables and seats. Definite data of the framework's segments are clarified as follows:

5.1 Sensor layer implementation

The system presented in this chapter has two types of sensor nodes:

- Context-oriented or logical
- e-health

Each sensor node consists of five primary components which include:

- sensors
- energy harvesting unit
- wireless communication chip
- power management unit
- microcontroller

ATmega328P-8-bit AVR which is an ultralow power microcontroller, is utilized in sensor nodes. This microcontroller deftly assists various frequencies and different rest modes for saving energy. In the framework presented in this chapter, a sensor node just performs straightforward computational work while weighty computational works are handled at Fog. Subsequently, the sensor node doesn't have to run at a high clock recurrence for saving energy utilization. 1 MHz clock frequency is applied to all sensor nodes in its execution. The microcontroller underpins distinctive correspondence interfaces also. Moreover, the microcontroller has 1 KBytes EEPROM and 2 KBytes inward SRAM. Therefore, it is fit for supporting numerous libraries for gathering information from various sensors. It is discovered that SPI is more energy-efficient and has a higher transmission capacity than different interfaces. Therefore, SPI is utilized in the majority of the cases. [21]

Context-oriented sensor nodes are outfitted with the following sensors:

- BME280
- SNS-MQ2
- SNSMQ7
- SNS-MQ135

These sensors are utilized for gathering temperature of the room, dampness, and air quality levels. DHT22 is a little size moistness and temperature sensor which yields the aligned advanced signs. With a high working reach, the sensor can work in unforgiving conditions. The sensor has a high goal and it is exact. Air sensors (SNS-MQ2, SNS-MQ7, and SNS-MQ135) are used for gathering LPG, hydrogen, propane, CO, methane, NH3, liquor, NO , smoke, benzene and CO2 from the air. These context-oriented sensor nodes are fixed in a room.

E- health sensors can be ordered into low information rate, high information rate, and hybrid nodes where half and half nodes comprises of both low and high information rate sensors. Low information rate sensor nodes are furnished with a glucose sensor and an internal heat level sensor. An implantable sensor under a patient's skin and a transmitter put on a top of the skin is incorporated by the glucose sensor. In the execution, the transmitter is associated with the microcontroller through SPI. The glucose sensor gathers the level of glucose at regular intervals as it doesn't change quickly. Likewise, the internal heat level sensor is associated with the microcontroller through SPI. The temperature information is gathered at regular intervals i.e. in every 120 seconds. [13, 21]

E-health sensors which have high information rate are outfitted with a movement sensor and an ECG simple front-end. An ultralow power movement sensor i.e. MPU-9250 is for gathering 3-D speeding up (acceleration), 3-D precise speed (angular velocity), and 3-D attraction. The information pace of the movement sensor is 50 samples/s. A low-power Schmitt trigger based circuit is the power managing unit having a few super-capacitors. The unit which manages power can distinguish the energy level of the battery, current, and force by means of INA226. INA226 is a current shunt and power screen created by TI. The remote correspondence chip is nRF24L01. This chip is an ultralow power RF handset which supports many-to-numerous interchanges. The nRF24L01 chip underpins up to 2 Mbps. Nonetheless, 250 kbps is utilized for conserving the utilization of energy. The chip can work with low-power, normal or greatest power. The framework presented in this chapter is designed to run at low-power mode and is associated with the microcontroller through SPI.

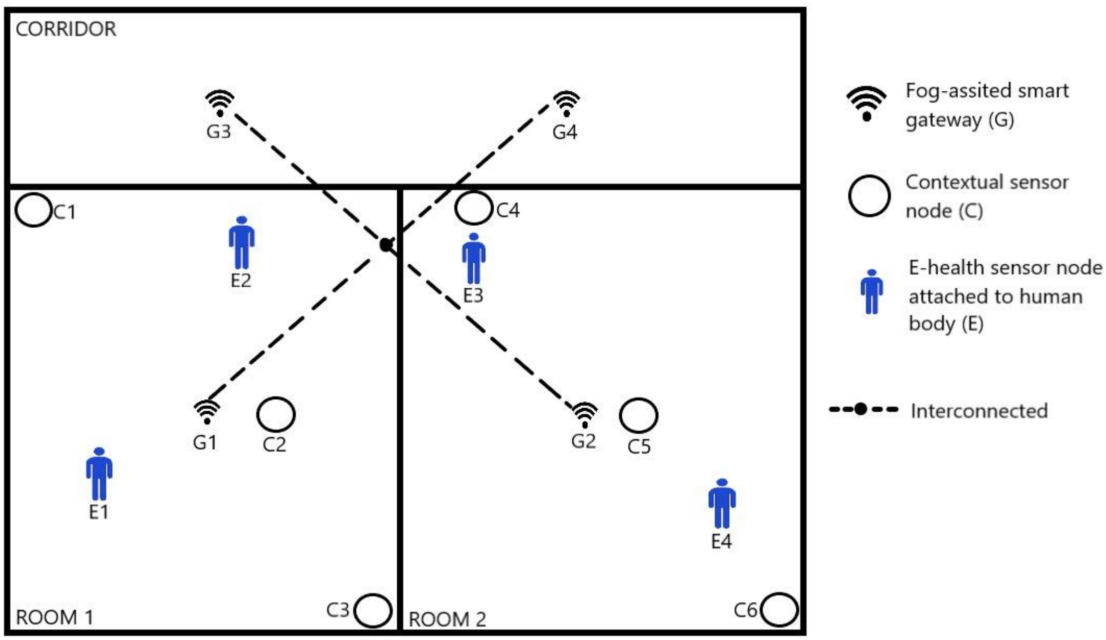

Figure 4: Scenario of test-bed implementation

5.2 Smart gateway and Fog services implementation:

Pandaboard which has a 1.2 GHz dual-core Arm Cortex microprocessor and 1 GB low-power DDR2-RAM has been used to build a smart gateway of the system. Various communication interfaces has been supported by Pandaboard that includes Wi-Fi, Bluetooth, and Ethernet by built-in components. , a 32 GB SD-card which can be used for installing embedded operating systems has also been supported by it.

A lightweight version of Ubuntu based on Linux is used in the execution. Various services including information decompression, information handling, information examination, and security have been based on the working framework or the OS (operating system). To provide interoperability many wireless communication components has been joined with Pandaboard. Sensor nodes which are equipped with nRF, an nRF24L01 chip have been connected to Pandaboard via SPI in order to get data. The nRF24L01 chip in the entryway is indistinguishable to the nRF24L01 chip utilized in sensor nodes with the exception of that it has some additional circuits and uses an enormous outer receiving wire. The quality of collected signal is increased but also large antenna costs higher energy consumption. For supporting

6LoWPAN, a composition of a CC2538 module and a SmartRF06 board is added into Pandaboard. These various parts have been connected to Pandaboard through Ethernet and USB ports due to the reason that high transmission bandwidth can be made available by Ethernet. The smart gateway has been provided with BLE components (CYBLE-202007-01 provided by Cypress Semiconductor) in order to support several BLE sensor nodes. The number of added BLE components based on the available UART ports of Pandaboard. So because of the above reason these UART ports are finite. In order to conquer this problem an FTDI chip and an ATmega328P microcontroller has been joined to Pandaboard. These segments can encourage BLE parts which are associated through programming based or equipment based UART. [22]

AES algorithm has been run by Sensor nodes for encrypting transmitted messages and also the same is used by the smart gateway for decrypting the received messages. For various services to get cooperative the AES algorithm has been run in the smart gateway is executed in Python. The smart gateway's database which has been built from MongoDB and JSON objects are used to store decrypted messages. The database has been combined with various languages such as HTML5, XML, Django, CSS, and JavaScript so as to provide a local host with user interface.

Iptables and a part of our advanced security methods have been executed in the framework in order to protect the smart gateways. The part of these methods has been applied for the protection of connection between the smart gateways and Cloud. Many parts have been not employed due to the reason of increase in latency and energy consumption of sensor nodes. The implementation of smart gateways is in python because it remains consistent with other services.

5.3 Cloud servers:

Google Cloud workers, API, and Cloud's administrations are utilized in the implementation of the framework for putting away, preparing information and offering progressed types of assistance. For example, the message pop-up help of the framework is fundamentally executed at Cloud. Like local host in Fog, Cloud workers have the worldwide pages which can show both constant information and the verifiable information in text based and graphical structures. For getting to information, end-clients can utilize the worldwide web pages or a versatile application. This application is worked by PhoneGap in order to support the two IOS and Android.

6. Experimental results

Gathered information at Fog-assisted entryways or gateways like angular velocity, acceleration and ECG is prepared with 3 essential steps which includes filtration of information, detecting baseline, and wander removal of baseline. As referenced, crude information is separated to take out commotion from general climate. In the greater part of the cases, the information which is filtered has different baseline in comparison to the reference baseline which is 1 g, 0 deg/s, and 0 voltages for increasing speed, angular speed, and ECG. Therefore, two processes i.e. detection of baseline and baseline wander removal are utilized for moving the signal's baselines into the normal ones. Two distinct techniques are applied for identifying the standard of various signals. A mean value is applied for identifying the baseline of acceleration and angular velocity.

On the other hand, Daubechies d4 wavelet transform is applied for distinguishing the standard of ECG. The information which is processed has the equivalent size and waveform as the separated information and is utilized as contributions for calculations, for example, fall discovery, pulse figuring and QT frequency extraction discussed in Section 4.1. The experimented parameters of room environment are shown below in the table.

Table 2: Parameters of room environment

Parameters (experimented)	Value

Temperature	22 degrees Celsius
Humidity	31%
CO	0.6 ppm
NO_2	8 ppb
$S0_2$	6 ppb

From the values given in the above table, we can see that the room environment is pretty good. Internal heat level and glucose are gathered yet it isn't utilized for the correlation since its worth only marginally changes during various exercises. For example, the gathered internal heat level and glucose of a volunteer are around 37 degrees Celsius and around 100 mg/dL for all exercises aside from preparing (e.g., running), individually. At the point when a volunteer seriously runs, the center temperature increments. The blood glucose level is different and changes with the monitoring time. For example, the glucose level toward the beginning of the day is less than in the early evening and after lunch. The glucose level of that individual vacillates around 90-98 mg/dL for all estimation cases in our experiments.

There are various waves such as P wave, Q, wave, R wave, S wave and T wave associated with ECG waveform. These waves are required for calculations (e.g., pulse estimation and QT's length extraction). On the off chance that of lying and standing, consequences of the calculations show that pulse is 59 beats per minute, the length of QT is around 390 and QTcB is 387 approximately. Some variations are expected to be encountered when the user slightly moves his body two times during lying in bed. Luckily, it is discovered that the ECG waveform in those minutes stays stable (e.g., ECG previously and during those minutes is comparative as far as the quantity of waves, and state of the waves.

During walking, the amplitude of the change in acceleration and angular velocity is small when compared with the already defines thresholds (i.e., 2g for acceleration and 200 deg/s for angular velocity) in the fall detection algorithm. The fluctuation however is helpful in identifying a walking status and in calculating the number of steps of a user. Activities like movement and non-movement can be distinguished by using angular velocity as a compliment parameter. The state of precise speed waveform can change contingent upon the walking or running style of the individual like swinging arms and hands during walking. ECG decently changes during walking. QT's length, QRS wave and T wave can be identified in the majority of the ECG cycles while P wave simply shows up in some ECG cycle (one for each every 6-8 ECG cycle). In this case QT's length is 35 ms and QTEB's is 392ms. ECG waves during walking are not as good as standing and lying-in bed with respect to stability. [23]

During running, there is drastic change in data when compared with the baseline. Here, acceleration shows number of steps of the individual (i.e., the top peaks have a lot higher amplitude as compared to the amplitude of acceleration baseline which is about 1g). The acceleration is higher than the predefined thresholds 2g in the fall detection algorithm, at the moment of 87-92nd sample. But the fall case here is not detected by the system due to two reasons. First, during the above-mentioned samples angular velocity is not more than angular velocity thresholds in fall detection algorithm. Second, it is observed in recorded information that none of the sensors is failed. The instance of precise speed (angular velocity) at 58-64th examples is higher than angular velocity threshold but fall event isn't identified. ECG during walking is not good as during standing and lying-in bed. Some of the ECG cycles do show P, Q, R, S and T wave (i.e., at 140-150th sample). It is not recommended to monitor ECG during intense activities like running or jumping as the value of QT's and QTeB's length varies dramatically. [23]

In some experiments, users tend to fall in random moments. They can fall forward, backward and sideways. In this chapter, fall cases are focused because people are more prone to falling when doing some activity rather than in static cases. Fall cases during activities as well as during static statuses can be detected successfully. The ECG, acceleration, and angular velocity of fall cases during walking shows that in most cases a person tends to sits or stands after falling, so the acceleration should reach to its peak values during such case.

Correspondingly it is expected that the falling peak with higher amplitude is compared with the other standing/sitting peak occurred in both acceleration and angular velocity waveform. These two peaks appear in collected data of all experimented cases. For example, in the fall forward case, two peaks of acceleration and angular velocity appear at 58-65th sample and 110-115th sample. Highest amplitude is often corresponded with the first peak which represents a fall moment while the amplitude of second peak varies depending on different situations like sitting, standing or crawling. Hence, second peak can be smaller or larger than the pre-defined threshold. Depending on the situations, the distance between both the peaks also varies. In fall aside, at a moment after falling there is no dramatic change in angular velocity at 125-1130th samples while acceleration reaches to a peak value. This is because the user slowly crawls and sits up after falling. Hence, it can be concluded that ECG fluctuates during fall moment while it remains good during other instants. [24]

Table 3: Area of gateway zones in various configurations in the event of a solitary nearby or adjacent gateway

Configuration	Conf 1_E	Conf 2_E	Conf 3_E	Conf 4_E	Conf 5_E	Conf 6_E	Conf 7_E	Conf 8_E
BME280					X		X	X
Samples/minute					1		1	1
Glucose sensor						X	X	X
Sample/minute(s)						1	1	1
MPU-9250			X	X				X
Sample/second(s)			50	50				50
AD8320	X	X	X	X				X
Sample/second(s)	60	120	60	120				120
Voltage (V)	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3
Current (mA)	1.65	3.15	4.58	5.76	0.22	0.45	0.61	6.35

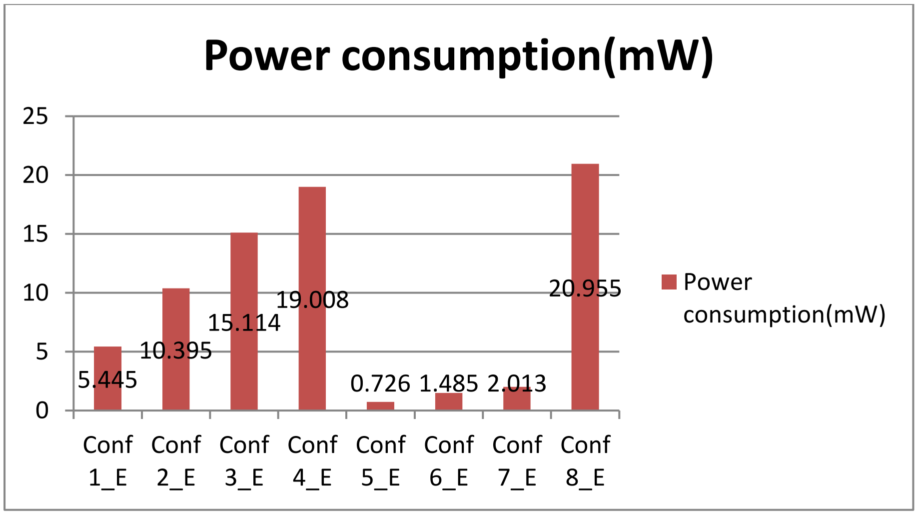

Figure 5: Power consumption in different configurations of e-health sensor nodes with a battery of 1000 mAh

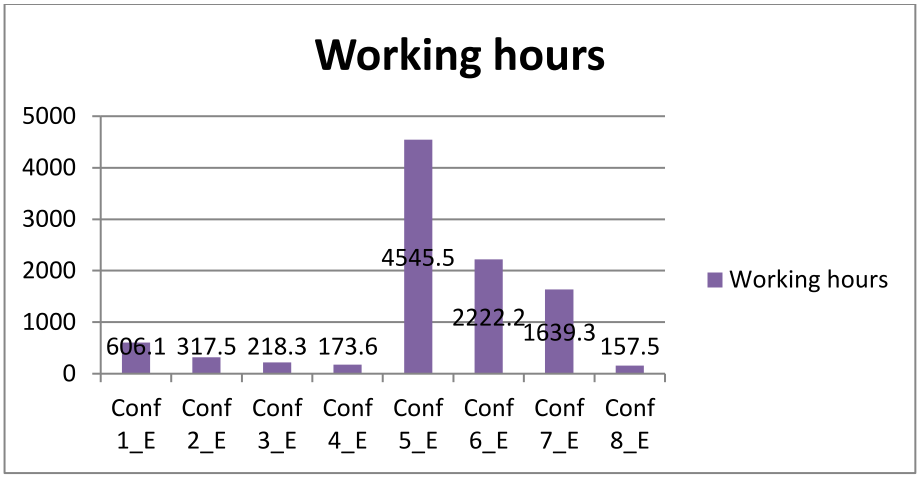

Figure 6: Working hours in different configurations of e-health sensor nodes with a battery of 1000 mAh

Power consumption of an e-health sensor node in different condition during different experiments is observed. A sensor or a group of few sensors has been combined into a sensor node in each of the given configurations. The information is collected from the sensor and is transmitted to a gateway through nRF. Results of power consumption and detailed information of the configuration are displayed in figure 5, 6 and table 3 respectively.

The first four configurations from i.e. shown in the table 3, Conf 1_E to Conf 4_E has the configuration of high data rate e-health sensor nodes and another three configurations (i.e., from Conf 5_E to Conf 7_E) has the configuration of low data rate e-health sensor nodes. The hybrid sensor nodes having low and high data rate sensors are for the last configuration (i.e., Conf 8_E). The motion sensor and ECG sensor which are the high data rate sensors consume a higher amount of energy compared to low data rate sensors consume according to the results. The low data rate sensor node (i.e., Conf 7_E) has been utilized up to 1639 hours whereas the high data rate sensor node (i.e., Conf 4_E) has been utilized up to 173 hours along with 1000mAh Lithium battery (a size of 60 x 32 x 7mm). With the same battery, the hybrid sensor node can be used up to 157.5 hours. [25]

In every second, data collected by contextual sensor nodes is sent to a gateway. Power consumption and configurations of the sensor nodes are showed in Figure 7 and Table 4 respectively. It is shown by results that sensors for collecting air related parameters (i.e., Mq2, MQ7 and MQ1250) use a large amount of power. Contextual sensor nodes can be operated up to 46 hours when applied the 10000 mAh battery having a size of 5 x 120 x 90 mm. As mentioned, contextual sensor nodes are fixed in a room. Hence, it is suggested that wall socket power is supplied to contextual sensor nodes. Only in case of electricity cut, the battery is used.

Table 4: Area of gateway zones in various configurations in the event of a solitary nearby or adjacent gateway

Configuration	Conf 1_C	Conf 2_C	Conf 3_C	Conf 4_C	Conf 5_C
Voltage (in Volts)	3.3	3.3	3.3	3.3	3.3
Current (in mA)	84.3	66.1	73.6	1.68	216.5
MQ2	X				X
MQ7		X			X

MQ135			X		X
DHT22				X	X

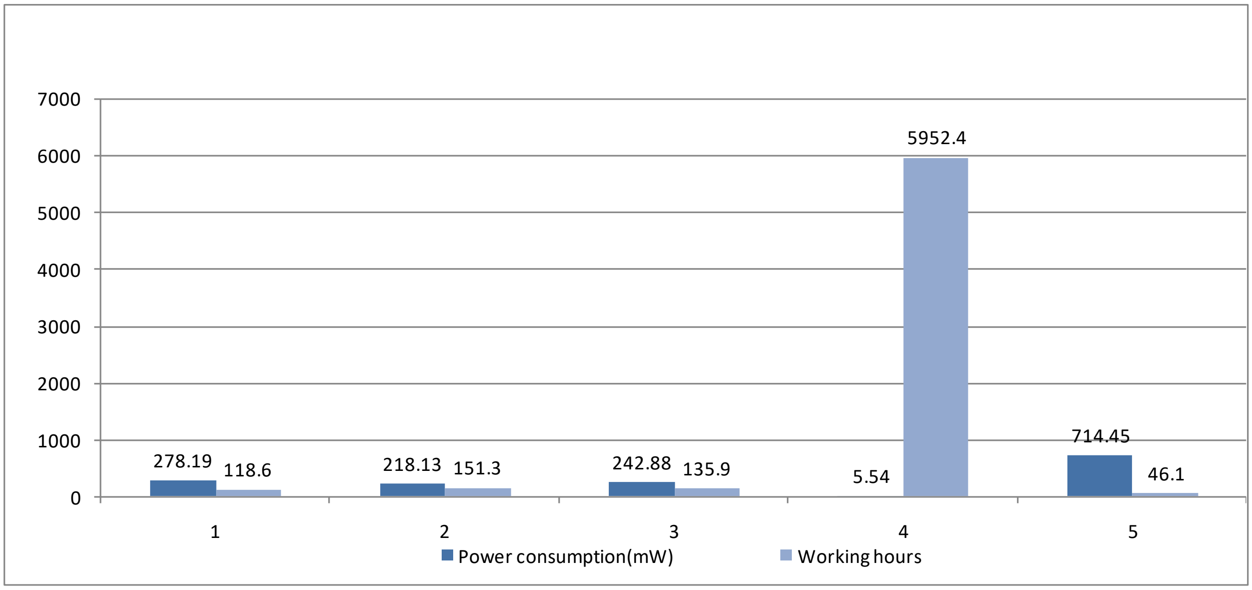

Figure 7: Power consumption and working hours in different configurations of Context-oriented sensor nodes with a battery of 10000 mAh

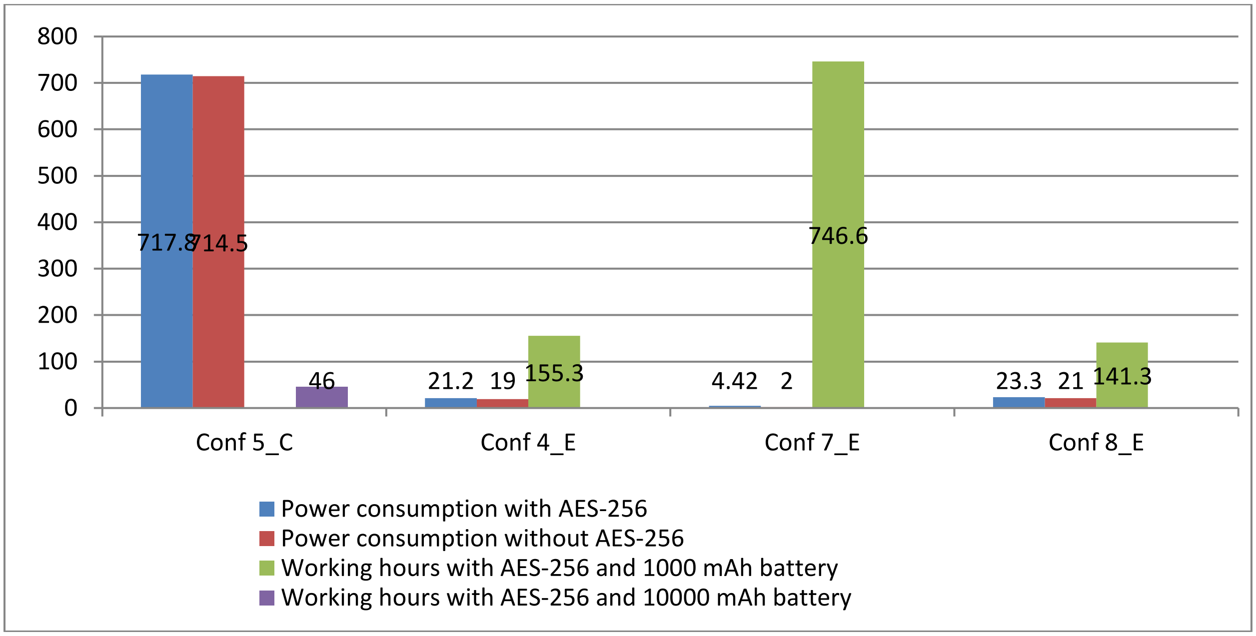

Figure 8: Power consumption and working hours in different configurations of sensor nodes with AES-256

The devices that we have used in our framework explained in this chapter i.e. the sensor node, smart gateways and cloud server works on AES-256 encryption, AES-256 decryption & AES-256 encryption both for smart gateways and AES-256 decryption algorithms respectively. The latency of these devices is shown below in the table 5.

Table 5: Area of gateway zones in various configurations in the event of a solitary nearby or adjacent gateway

Device	Latency (in microseconds)
Sensor node (AES-256 encryption)	1358
Smart gateway (AES-256 encryption)	43
Smart gateway (AES-256 decryption)	52
Cloud server (AES-256 decryption)	10

In the experiments, AES-256 is applied to sensor nodes in different configurations. Power consumption of the sensor nodes with and without is shown in Figure 8. The results show that when applying encrypting with AES-256, power utilization of the sensor node increments marginally (i.e., about 11% of absolute power of the e-health hybrid sensor node). The hybrid sensor can operate up to 183 hours in this case. Power utilization of nodes increment less than 0.01% in the case of context-oriented nodes. When they are supplied with the 10000 mAh battery, the contextual sensor nodes will still operate up to 46 hours. [26]

7. Future directions

There is a diverse field if we talk about the future directions of this work. As we have discussed in this chapter, the sensor node battery keeps going around seven days. Replacing the battery frequently is unfortunate particularly with wearable sensors as this would lead to inconvenience and even torment in the event of embedded sensors. Energy reaping of encompassing sources can be misused for re-energizing or broadening the time between re-energizing of wearable miniature force sensor nodes. It includes changing over the surrounding energy innate in the sensor node's current circumstance into electrical energy. [27]

Thusly, a sensor node will have the chance to stretch out its life to a reach dictated by the disappointment of its own parts instead of by its recently restricted force supply. A couple of sources have been explored in order to provide the energy to the sensors nodes. In past works, the attainability of RF energy collecting has been researched as a hotspot for fueling to the sensor. The focus on recurrence band was to collect 925 MHz GSM band, and due to their low edge voltage (0.2–0.3 V), Schottky diodes were used as correcting component. Regardless of this low turn-on voltage, the rectifier won't provide any power to the load aside from if a voltage of about 0.2 V or higher is accessible for driving the Schottky diode forward.

Consequently, in the ongoing work in advancement, low limit voltage diodes associated transistors are being prepared with smaller than usual solar panels joined to the transistors' entryways supporting in getting the necessary turn-on voltage for the transistor delivering the collecting circuit more delicate and ready to work even at extremely low RF signals accessible at its receiving wire. [28]

The sensor can be directly powered right now as the RF energy harvesting is currently able to in a standard alone situation, it very well may also be misused along with a proficient force or power management unit to re-energize the battery and furthermore, expand the existence of the sensor node. Then again, the context-oriented sensor nodes and passages can be totally fueled self-sufficient when being fueled by sunlight along with a much straightforward power management unit comprising of the following:

- lift converter

- buck converter
- voltage controller

The utilization of adaptable printed and wearable sensors is additionally being examined, other than low creation cost, better mechanical and warm properties, lightweight contrasted with inflexible non-adaptable sensors; they prove to be more helpful and agreeable while being utilized for observing on surfaces which are bendable such as arms and thighs.

Table 6: Area of gateway zones in various configurations in the event of a solitary nearby or adjacent gateway

Sensor node	Microcontroller (Mhz)	Flash (KB)	SRAM (KB)	Sensor(s)	Voltage (V)	Power consumption
O. Biros, et al., Implementation of wearable sensors for fall detection into smart household	ATmega32L (8)	256	8	Motion	5	Low
S. Z. Erdogan, and T. T. Bilgin. A data mining approach for fall detection by using k-nearest neighbour algorithm on wireless sensor network data.	ATmega128L (8)	128	4	Motion	3	Medium
P. Pivato et al. A wearable wireless sensor node for body fall detection. In Measurements and Networking Proceedings	MSP430F2617 (8)	92	8	Motion	3.7	Low
Y. Li et al. Accelerometer-based fall detection sensor system for the elderly.	MSP430 (8)	48	10	Motion	3	Low
F. Wu et al. Development of a wearable-sensor-based fall detection System	MSP430F1611 (8)	48	10	Motion	3.7	High
T. N. Gia et al. Iot-based fall detection system with	ATmega328P (8)	32	2	Motion	3	Low(36.38mW)

energy efficient sensor nodes						
T. N. Gia et al. Customizing 6lowpan networks towards internet-ofthings based ubiquitous healthcare systems.	Arm Cortex M3 (24)	512	32	ECG	3.3	Ultralow
R. Dilmaghani et al. Wireless sensor networks for monitoring physiological signals of multiple patients	MSP430 (8)	48	10	ECG	3.3	Low(36mW)
S. Mahmud et al. An inexpensive and ultra-low power sensor node for wireless health monitoring system.	ATmega328 (8)	32	2	ECG	3.3	Low
T. N. Gia et al. Low-cost fog-assisted health-care iot system with energyefficient sensor nodes	MSP430 (8)	48	10	ECG	3.3	Medium(64mW)
S. Lee, and W. Chung. A robust wearable u-healthcare platform in wireless sensor network	ATmega328PPU (8)	32	2	Motion, ECG, body temperature	3	Ultralow (21.3 mW)
in our work	ATmega328PPU (1)	32	2	Motion, ECG, body temperature,	3.3	Ultralow (23.4 mW)

In this chapter, we have compared the power consumption of our sensor node with other nodes used in various researches named in the above table. The results displayed in table 6 indicate that the sensor node which we have utilized is probably the most energy-efficient despite of the fact that the sensor node utilized in our framework is furnished with various types of sensors for performing various tasks such as gathering movement-related data, ECG, temperature of the body, and blood glucose level.

8. Conclusion

In this chapter, we have introduced a novel and savvy Fog-based framework for constant, distant observing glucose, ECG and different signals continuously. The total IoT framework comprising of sensor nodes, brilliant smart gateways with the technology called as Fog Computing and a back-end server was actualized. By concurrent checking various sorts of signals from bio-signals such as glucose, ECG, also, internal heat level to context-oriented signals (i.e., the quality of air, mugginess in the room and temperature), the exactness of illness investigation was improved. By utilizing keen passages and Fog processing in the framework, burden of sensor nodes was lightened while increased administrations (e.g., nearby information stockpiling, security, interoperability) were given.

Also, we proposed calculations for ascertaining the term of QT length, fall discovery, and movement status location, separately. These calculations joining with the pop-up message administration assisted with improving nature of medical care administrations. Results from the analyses depicted that the total sensor node for collecting glucose, ECG, movement related signals and internal heat level is perhaps the most energy-effective sensor nodes and it can work up to 157.5 hours with a 1000 mAh Lithium battery in a secured manner.

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