NXTGeUH: LoRaWAN based NEXT Generation Ubiquitous Healthcare System for Vital Signs Monitoring & Falls Detection

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***Abstract*— The challenge for deployment of low-cost and high-speed ubiquitous Smart Health services has prompted us to propose new framework design for providing excellent healthcare to humankind. So, there exists a very high demand for developing an Internet of Medical Things (IoMT) based Ubiquitous Real-Time LoRa (Long Range) Healthcare System using Convolutional Neural Networks (CNN) to agree if a sequence of frames contains a person falling. To model the video motion and make the system scenario sovereign, in this research, we use optical flow images as input to the networks. Right now hospital and home falls are a noteworthy medical services concern overall on account of the aging populace. Current observational information, vital signs and falls history give the necessary data identified with the patient's physiology, and movement information give an additional utensil in falls risk evaluation. The proposed framework utilizes Real-Time Vital signs monitoring and emergency alert message to caregivers or doctors. In this context, we introduce "*LoRaWAN based Next Generation Ubiquitous Healthcare System* (NXTGeUH), an intelligent middleware platform. In addition, this proposed method is evaluated with different public hospital datasets achieving the state-of-the-art outcomes in all aspects.**

Keywords—Internet of Medical Things(IoMT); Healthcare; ZIGBEE; Wireless Sensors Network; CNN; Remote Health Monitoring; Vital Signs; Body sensor networks; Telemedicine; Emergency Alarm; LoRaWAN; ECG; Ubiquitous computing; Fall Detection

I. INTRODUCTION

IoMT based Healthcare because, “Harnessing IoMT for Value-Centered Care” which covered the increasing role of internet-connected devices in medical care, as it has been predicted that in the following decades, the way healthcare is currently provided will be transformed from hospital-centered, first to hospital-home-balanced by 2020th, and then ultimately to home-centered in 2030th [1]. The global population of elderly people has been growing rapidly over the past few decades [2]. According to the statement of the World Health Organization (WHO):

> *“The delivery of health care services, where distance is a critical factor, by all healthcare professionals using information and communication technologies for the exchange of valid information for diagnosis, treatment, and prevention of disease and injuries, research and evaluation, and for the continuing education of health care providers, all in the interests of advancing the health of individuals and their communities” [1]*

The objective of the IoMT- LoRaWAN is to empower an assortment of Medical things/items to exhibit in the surroundings to be associated order to interact and cooperate interface to coordinate "at whatever time, wherever, with anything and anybody, in a perfect world utilizing any way or organize and any service".

LoRaWAN is a Low Power Wide Area Network (LPWAN) technology which empowers low cost and low power IoT based device communication even also in big urban areas. LoRa modulation has the capability of extracting data from a weak signal in noisy environments. This very advanced modulation technique can be very useful for the delivery of critical medical data in a noisy environment. [43]

There are such significant number peoples on the world whose well-being may persevere in light of the way that they do not have appropriate or easy access to doctor’s facility and HealthCare. Due to the latest innovation, small wireless networks which to be connected with IoMT can make it possible remotely to monitor patients without the visit to the hospital or health care center. An extensive collection of wearable sensors which are attached to the body of a patient; It can be used to get wellbeing information securely, and the assembled data can be dismembered with the utilization of some significant algorithms and sent to the server using particular transmission media like 3G-4G with base stations or high bandwidth Wi-Fi which are connected to the Internet. All the medical experts, caregivers or doctors can get to and see the received data, take decision properly to diagnose remotely to the patient.

This paper organizes as follows. In Section II we contrary about the Related Work and Motivation to our proposition. In Section III we describe NXTGeUH Modules and Functionalities where all proposed modules and functionalities are described. In Section IV we describe the Results of Propose System and Validation for finding interconnections between procedures of various organizations, through the events analysis. We also provide a case of emergency alert warning to the doctor, and we discuss the Future work and Conclusion in Section V.

II. RELATED WORK AND MOTIVATION

There have been numerous endeavors in planning gateways for one or a few particular applications and architectural layers. For example, the breathing rate observing (BREMON) framework has been proposed in [19].

The framework permits paramedics to screen the breathing exercises of patients by utilizing a cell phone. The framework uses the mobile phone-based accelerometer to screen the breathing exercises of a patient. The speeding up information is then handled to compute the number of breaths per minute (BPM). The information is then sent to the paramedics with the aid of a multi-bounce organize. The mechanism introduced in [37] propose LoRaWAN gateways to straightforwardly interface with various systems with different conventions with low power devices and sensors, for example, Bluetooth, ZigBee, and Ethernet. Then again, these gateways have constrained adaptability as they cannot be tweaked for various applications. In an alternate classification of related work, Mueller et al. [27] show a gateway called SwissGate which streamline and handles the operation of the sensor network. They particularly apply SwissGate on home robotization applications, for example, measuring warming, ventilation, and air conditioning control (HVAC) parameters. Bimschas et al. [28] proposed to give a few levels of insight to various portals by empowering them to execute application code. They propose a middleware for the entryway to offer three conceivable services: convention transformation, ask for reserving, and canny storing and disclosure.

So as to spare vitality and lessen the cost of the keen home, Bian et al.[30] introduce another sort of insightful home control framework, utilizing Android Phone as a transitory home entryway rather than the default home passage. Their point is to close down the right gadgets by foreseeing client conduct consequently. At last, in work introduced in [31], creators propose a model of a brilliant 6LoWPAN (IPv6 over Low Power Wireless Personal Area Networks) border router which settles on local choices of wellbeing states utilizing a Hidden Markov Model. Satyanarayanan et al. [32] suggest that cell phones can utilize modern algorithms, for example, facial recognition and language translation to enlarge human insight. Nonetheless, constraints in handling power and long WAN dormancy are unsuitable.

The way motivates our proposition that in a smart hospital or in-home healthcare therapeutic services, vital sign monitoring with emergency alarming and falls detection are major challenges and still there are extremely need to inquire about and build up a ubiquitous framework to utilize it in viable. This promising open door and the test can be exploited by various means such gathering wellbeing and setting data from those systems and giving various services in like manner.

III. NXTGEUH MODULES AND FUNCTIONALITIES

The diagram of the incorporated HealthCare framework outlines in Fig. 1, it comprises of LoRaWAN enabled real-time physical perceptions system, vital signs (remote medical gadgets), falls prediction and detection (movement information) and Emergency Diagnosis.

The remote medical devices utilized as a part of this exploration are: Zigbee[6], Temperature Sensor[7],PIC Controller[8], Bosomedicus notoriety BP monitor [8], Nonin's Onyx II finger clip heartbeat oximeter [9], Accu-Chek (Compact in addition to) blood glucose meter [10] and Omron's moment tympanic (ear) thermometer [11].

So in this proposed system, We implemented a three-way validation data collection approach: Initially, in the first phase, vital signs were assembled by remote medical devices depicted in figure.1 and transmitted it progressively to the base machine. Then in the second phase, the registered nurse performed physical manual readings of similar factors or parameters, utilizing standard ward strategies Lastly, every estimation generated by the medicinal devices was recorded physically by the analyst to check any remote transmission data loss, erroneous information transmission, and transmission delay time.

Fig. 1 demonstrates the generic framework design of proposed diagnosis and monitoring framework utilizing a tablet, with this it has a protected secure gateway which permits information network to the registered gadgets and connections them with the particular patient individual profile including devices' points of interest (MAC address and serial number). They got information at the clinicians' end must be gotten to by utilization of a unique user-name and secret key. We deliberately dodge any open system availability because of the likelihood of outsider access to the touchy restorative data. In this manner, portable 3G information has been utilized through the secure switch and firewall settings, which associates with the tablet and mobile workstation [2, 3].

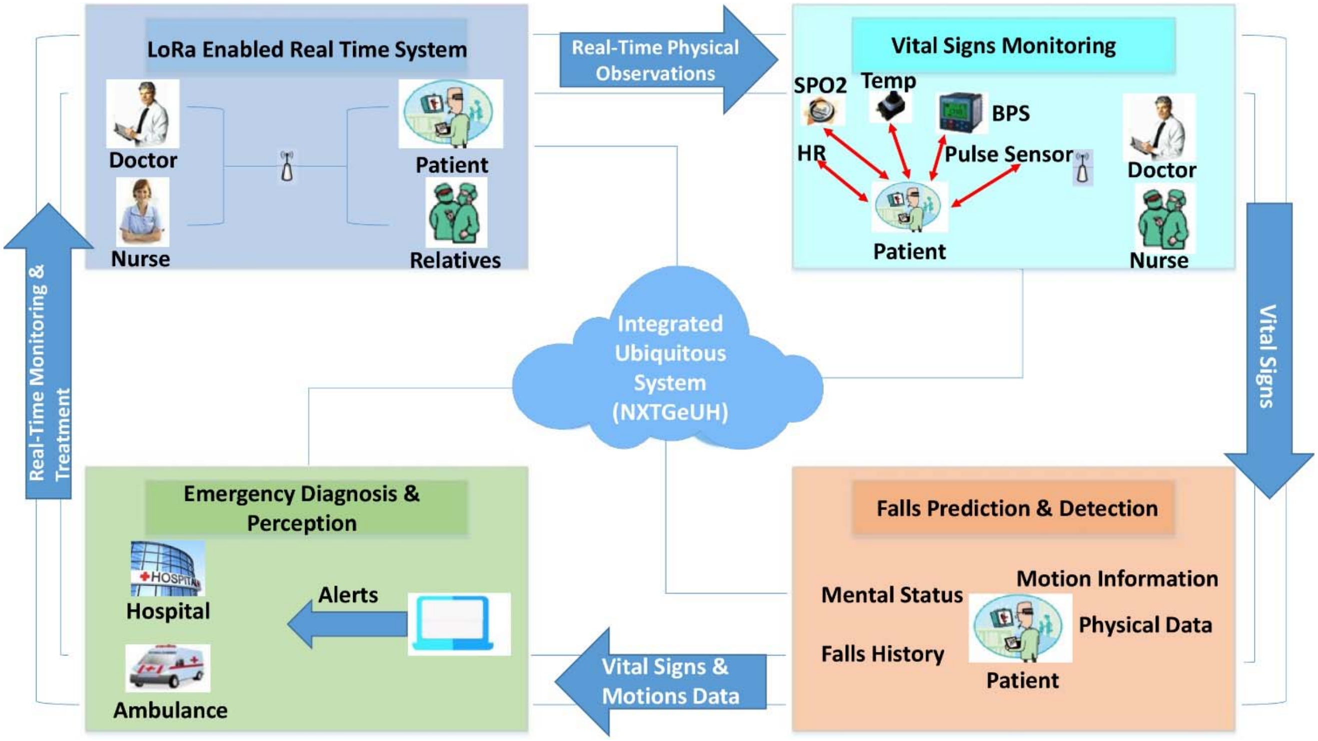

Fig. 1. Proposed System Architecture of LoRaWAN based Healthcare System (NXTGeUH)

a) Vital sign monitoring: This alludes to the monitoring of patients' vital sign parameters, for example, body temperature, pulse rate, blood oxygen immersion, blood pressure, blood glucose, cardiogram, and sweat level. This usefulness fundamentally takes a shot at an on-request premise, since some available sensors, for this reason, can't be worn for all time or can't work consequently, e.g. the glucometer. At the point when the deliberate essential signs surpass predefined edges, an alarm is accordingly sent to assigned carers, therapeutic services professionals, and the telemonitor focus (took care of by emergency tele-experts) through instant message, a video telephone, web applications, and electronic correspondence, for example, email. Subject to time accessibility and functional limitations, just the last two strategies were actualized in this examination.

b) Security monitoring: Its fundamental capacity is constant human fall recognition with alarms automatically sent to assigned carers, medicinal services professionals, and the telemonitor focus using the same technique from utilized for vital sign monitoring. Once exchanged on, this capacity is performed consequently and round the clock.

c) Movement Pattern monitoring: This worries, for the most part, the following of the continuous development of the patient at home with information on his/her constant area automatically sent to the telemonitor center.

d) Emergency call-for-help toolbox: This refers to the arrangement of a portable alarm; once squeezed by a patient, it would convey an alarm to designated carers, human services professionals, and the telemonitor focus.

e) HealthCare dashboard, Service portal, and administration support: The Service portal and authenticated patients, carers, medicinal services professionals, and telemonitor focus workforce to set their inclinations and administer to human services monitoring and to survey/upgrade/remark on individual wellbeing information or potentially finding by means of a health awareness dashboard.

f) LoRaWAN Setup: LoRaWAN is an energy efficient low powered LPWAN innovation intended to address power utilization and coverage issues in IoT based applications [46]. The determination characterizes security strategies and localization services administrations. Subsequently, LoRa modulation keeps running on ISM groups, it is conceivable to send private and open LoRaWAN systems. From a structural perspective, the framework has three fundamental segments; (I) nodes, (ii) gateways (GWs) and network system servers (or data centers). LoRaWAN systems are sent as a star of stars topology and GWs are the interface between network system servers and nodes. A custom LoRaWAN hub is created utilizing the equivalent LoRa bolstered RFM95 chipset over an Arduino Uno gadget. Our proposed system end node is adequate for transmitting LoRa frames with predefined frequency in addition to SF (Spreading factor) values.

B. Vital signs transmission and Monitoring

The teleconferencing module of the proposed framework is tested for the audio and video conferencing of up to four simultaneously. This module of the proposed framework is not tested in a clinical environment due to the ethical and policy issues limiting the utilization of video in a hospital. Moreover, this module is tested in non-healing facility settings just to check the working and reconciliation of the entire framework (different modules). The handheld ubiquities gadget (tablet) is able and in charge of vital information accumulation shape, all wireless Bluetooth (BT) connected gadgets. Also sound/video (discretionary) recordings and transmitting the information progressively to the clinician's PC specifically or using central processing framework where data examination and fuzzy logic analysis will be performed.

C. Vital signs interpretation

A fuzzy logic model is engaged to measure and interpret multiple physiological parameters using gathered vital signs like HR, BP, P, SpO2 and T as indicated in given Table 01. As well, it is also important to allusion that the standard or normal range in Table 01 represents the range of normality across the whole group of elderly people, but vital signs of each person will have different normal and abnormal levels. The system learns from standard parameters of each particular patient using adaptive neuro-fuzzy inference system modeling. The relation between physical signs and vital signs is established by consulting with doctors or physicians (Table 01).

H = high, L = low, N = ordinary and N/A are Not appropriate The linking and mapping of various vital signs for identifying a separate event utilizing fuzzy model [22] give great exactness with the reliable sign of health events. For a case, hypotension is described as a 'low blood pressure,' regardless of interchange parameters.

The hypotension is of any clinical significance will depend on upon interchange parameters measured. At the point when the proposed system fuzzy model arranges a wellbeing event as hypotension, it is because of giving high significance and additionally high weight to blood pressure. Rather than considering just blood pressure as one of the likelihoods of hypotension we consider High-level heart rate and in addition High-level pulse rate as other conceivable clinical significance of hypotension from the clinician's perspective.

- High HR (Hghr); Low BP (Lwbp); and High Pulse rate (Hpr) for need 2 Hypotension,
- Very High HR (VrHhr); Very Low BP (VrLbp); and Very High heartbeat rate (VrHp) for need 1 Hypotension.

TABLE I. THE RELATION OF PHYSICAL SIGN WITH VITAL SIGS

Physical Sign	HR	BP	P	SpO2	T
Tachycardia	H	N/A	N/A	N or L	N/A
Normal Range	60-90 bpm	140/60-80 mm/Hg	60-100 bpm	94%-99%	36.5-37.5
Hypoxemia	N/A	N/A	N/A	Often L	N/A
Fever	H or N	N/A	H or N	N/A	H
Hypothermia	L	N or L	L	N/A	L
Bradycardia	L	N/A	N/A	N/A	N/A
Hypotension	N/A	L	L or N	N/A	N/A
Hypertension	N/A	H	Usually N	N/A	N/A

D. Fall detection Algorithm

The fall detection administration is utilized to recognize a patient fall. To recognize a fall, one of the accessible potential outcomes is the utilization of tri-pivot accelerometers. This component permits an accelerometer connected to the body of a man to quantify the speeding up of the individual generally to the gravity, utilizing the condition (1).

$$|f| = \frac{(fx)^2+(fy)^2+(fz)^2}{9.8} \qquad (1)$$

The utilization of spinners can enhance the fall recognition frameworks accuracy. Spinners can identify the introduction of a man by figuring his rakish speed through the condition (2).

$$|\rho| = (\rho x)^2 + (\rho y)^2 + (\rho z)^2 \quad (2)$$

On both circumstances, the qualities are contrasted and thresholds by the patient, or dynamically characterized by the framework. There is some work distributed that utilization this approach to distinguish falls. On the work displayed in [20], a fall recognition framework is tested utilizing a tri-hub accelerometer and a tri-pivot whirligig. By gathering information through a few tests in the various day by day life exercises, the creators characterized upper and lower limits for both increasing speed and correct speed. At that point, utilizing these edges, falls could be identified through increased speed and rakish speed values measured progressively. In [21], the creators used the 3-hub accelerometer and magnetometer of a cell phone to distinguish falls.

A. ALGORITHM:

Input: ρ is ECG sensor where x is patient & y is

Doctor, N is Normal Case,

C is Critical Case,
A is Available.

Output: Approving of given data whether correct or not. **Begin,**

1) Start using ECG sensor for Monitoring Patient's Health Condition.
2) If the ECG sensor shows Patient's condition within the range, then-No action needs to be taken.
   If $\rho=N$, Then, No Actions required,
3) If ECG sensor shows Patient's condition Out of the range, then Sent Alert Message to the doctor with the exact number.
   If $\rho \neq$ N That is $\rho=C$,
   Then, Sent Alert Message to the physician with the Exact number.
4) Doctor Initiates the Task then.
5) If Doctor Available at the time, then they start the necessary treatment.
6) If $y= A$,
   Then, Start Treatment.
7) If Doctor will not Available at the time, then they Consult Other Doctor/ Caretaker to the Patient.
   If $y\neq A$,
   Then, they Consult Other Doctor/ Caretaker to the Patient & start the treatment then.
8) Update/ Add above info to the Database.
9) END

Once more, limits were characterized for both accelerometer and magnetometer information, describing an algorithm ready to recognize falls when certain qualities beneath lower edges and values above upper edges were developed.

IV. NXTGEUH SYSTEM WORKING MODEL

The proposed system model uses every patient information separately for the understanding which can be expressed as an individualized examination as well as for the entire populace information data just fills in as the outline limit of the framework for the entire age group. The exceptional component of the individualized module is that all as far as possible will change all through the checking stage. Each tenth record or 08 minutes, the machine of this working model updates the cutoff points and contrasts that and the past one with the goal that any critical variations or changes can be distinguished.

In this section, we first present the design of our framework demonstration and evaluate the framework characteristics including more high-level functions developed. In the proposed architecture, the framework implementation is to consider the Emergency Alerting System. Our intelligent NEXT generation Healthcare system, called NXTGeUH, collaborates with different sensor nodes, remote server, and clients using like ZIGBEE.

Figure. 2 depicts the proposed system general workflow of vital signs associated with falls detection model. The first step is to connect the mobile application and LoRaWAN and the wearable device. Then, the wearable device runs the fall detection algorithm. Once a fall is detected, the wearable devices send an alert message via LoRaWAN. This fall detection algorithm is set with the 30 seconds timer in order to allow the user to cancel an emergency call. If the person does not cancel the call, the emergency protocol is started which contains a call, and SMS messages to preset contacts.

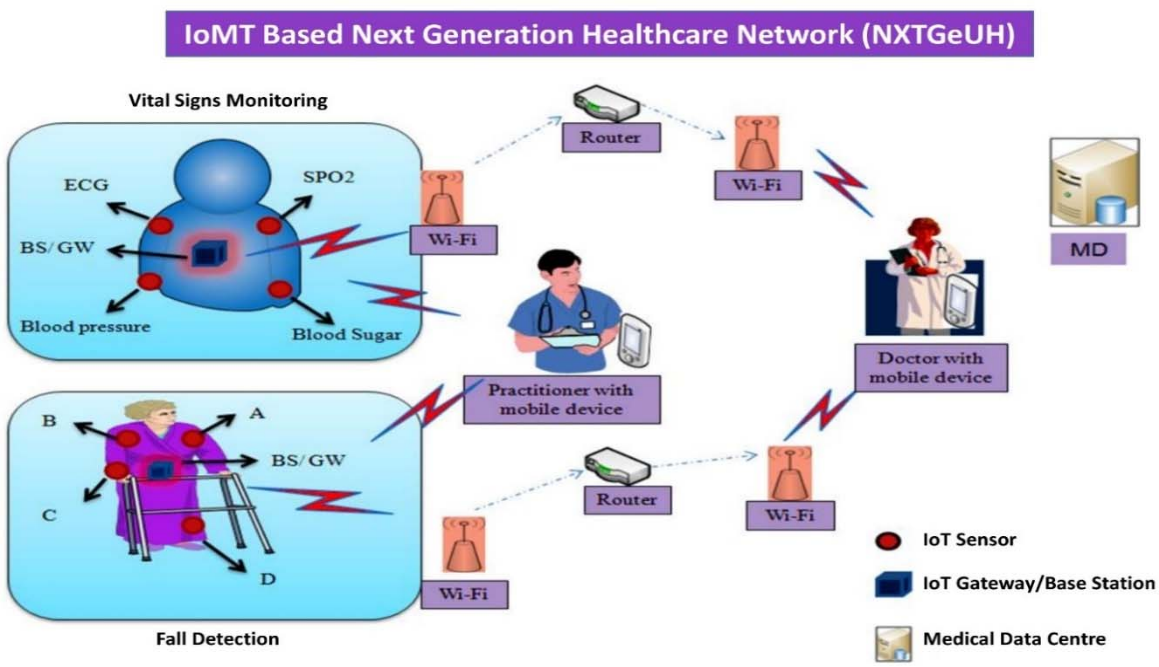

Fig. 2. Block diagram of vital signs association with falls detection model

As appeared in figure 4, the extracted vital intelligence, if there should arise an event of an emergency, is transfer to the server. The picture which is currently spare in the server is consequently sent to the mail address of the specialists shown in figure 5. If there is the occurrence of an event of an emergency, the trigger gives to PIC controller which sends the instant message to the specialist utilizing GSM modem.

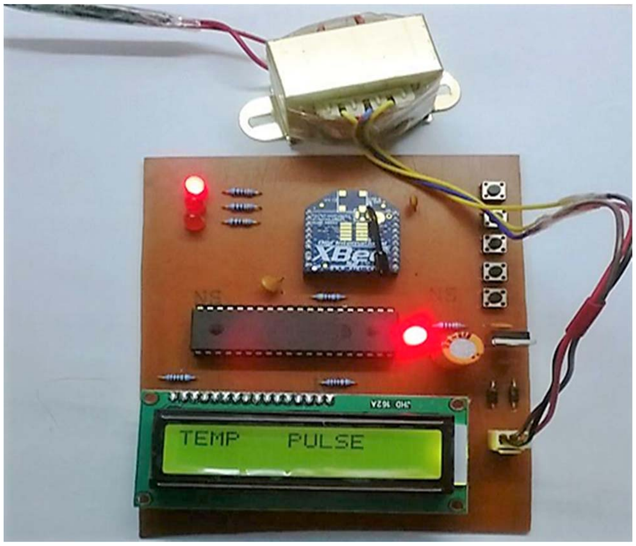

Fig. 3. Actual Hardware showing start screen

From the server, the underlying ECG picture is sent to doctors' and caregiver's predefined email address and mobile number. For the module creation, Microsoft Visual Studio 2010 is the IDE been utilizing. The programming dialect utilized here is C#.

It is critical to monitor the patients' body temperature and heartbeat rate of those as of now getting a few types of surgical treatment. So the prepared gadget will be valuable for them. This gadget is additionally safe for use in the hospital, and this gadget will have the capacity to:

- That a patient's body temperature and heart rate is distinguished as strange. It has the arrangement to set the extents relying upon the age gathering of the patient as well as it will alert; if critical reaches have accomplished.
- It eliminates delays in accepting medical treatment as the patient can observe remotely.
- Optimize HealthCare services to at hazard populace Enhances nature of living and Saves lives.
- It provides early detection of heart attacks by cautioning healing center staff/specialist on the off.

As shown in figure 5, the point when the deliberate vital signs exceed predefined threshold limits, an alarm is accordingly sent to assigned caretakers, doctors, and the telemonitor focus (take care of by emergency tele-experts) through instant message, a video telephone, web applications, and electronic correspondence, for example, E-mail, SMS notification.

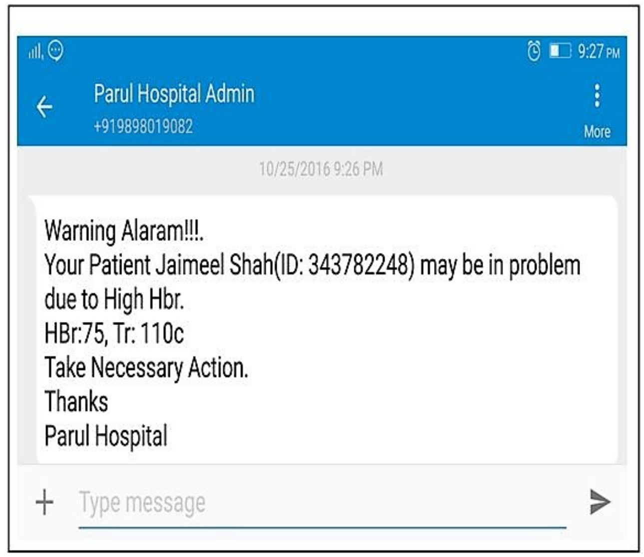

Fig. 4. Patient's Heart rate and body temperature readings

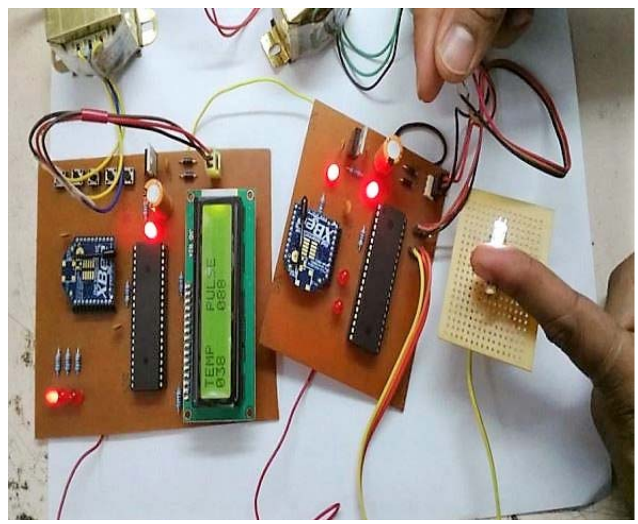

Fig. 5. Screenshot of Alarm notification on doctor's handset

V. System Results And Validation

Integration of vital signs into the falls risk assessment system gives an enormous advantage to the proposed model in the assimilation, detection, and classification of falls risk.

As shown in Table No. II, for the validation and testing of this novel system, we have collected almost 240 data sets based on mentioned categories in Table II from 20 hospitalized patients from Parul Sevasharam Hospital, Vadodara.

Kappa [34] analysis was utilized to measure the level of understanding/difference between the proposed system and a doctor. Kappa analysis is utilized as the proportion of how precisely the framework can emulate people's execution utilizing true negative (TN), true positive (TP), false positive (FP) and false negative (FN). As for experimental testing, from every hospitalized patient, we have gathered 20 datasets. Thusly, we gathered a sum of 440 datasets from 22 patients. The analytical execution of the framework was confirmed through a progression of (review) tests utilizing 440 datasets from 20 hospitalized patients. The framework has been prepared with all required information from 10 hospitalized patients (220 datasets) and tried with information from the rest of the 10 hospitalized patients (220 datasets). The testing and training datasets were chosen indiscriminately the entire 22 patients' information. Table 2 demonstrates the aggregate number of alerts created by the proposed framework as well as it also arranged into the related above mentioned vital sign. As Kappa esteems acquired from Table 2 are TP=54, TN=65, FP=04 and FN=0 from the aggregate of 220 datasets.

TABLE II. NXTGEUH SYSTEM AND THE MEDICAL EXPERT PHYSICAL SIGNS DETECTION

Results Comparisons		**Vital Signs**				
		Heart rate	***Tempe-rapture***	***Oxygen Saturation***	***Blood Pressure***	***Total Alert Genre-rated***
Recorded No. of alarms-Physical sign	***Proposed System (NXT-GeUH)***	Tachy-cardia (13)	Hypoth-ermia (09)	Hypoxemia (12)	Hypotension (10) Hypertension (14)	58
	Medical Expert/ Doctor	Tachy-cardia (11)	Hypoth-ermia (07)	Hypoxemia (12)	Hypotension (10) Hypertension (14)	54

So this proposed system successfully tested on real datasets and we found good values in results of generated alarm due to different emergencies found at the time of real-time vital monitoring of patients' compare to medical expert observation and detection of problems.

The proposed framework accomplished a general agreement and precision of 96% and Kappa rate 93%, i.e. the proposed framework and the Doctor agreed 94% of the recognized wellbeing actions. As mentioned in Table.02, there are four contradictions from the doctor side which are talked about here.

On two events framework identified 'possible tachycardia and hypertension' for every one of two specific hospitalized patients from their individual qualities. Blood pressure(BP) was somewhat on the higher side. As well as pulse and heartbeat were also high which demonstrated conceivable critical changes in the patient's vital sign values when contrasted and past qualities and in general standardized data trend.

On another two occasions 'possible hypothermia' was distinguished on the grounds that the recognized ear temperature esteem was underneath the typical incentive for that specific patient. The framework created a possible alarm yet the doctor differs and detailed that it was a marginal esteem and he would have held up to see next couple of esteems before really thinking about it as a possible emergency alarm.

VI. CONCLUSIONS AND FUTURE WORK

That is to say that, the performance values for the proposed system, NXTGeUH, has achieved the sensitivity of 100%, accuracy of 96.93%, specificity of 94.25% and predictability of 91.38%, these results seem to be reasonable compare to the aforementioned systems.

With the smart, intelligent analysis system, the indication of emotional condition and vital sign abnormality for the patient can discover early, and afterward, the patient can also get benefit from outside support in time, the sudden death of the patient can be retained some premeditated remote areas.

It is normal that the proposed composed alert framework creates warnings inside a short interim with the end goal to give the chance to clinicians, caregivers and medical experts to make a suitable move before an abnormal occasion happens. Then again, the framework should restrict its false cautions or alarm. To satisfy these mentioned criteria, the framework needs to recognize inclines and in addition screen edges with the end goal to alarm clinicians before the needy variable achieves a basic level. This research can be extended further with depth videos as well as with other datasets.

Our goal is to demonstrate that an embedded low cost adaptive system can have as good results as other more powerful and expensive healthcare IoMT systems.

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