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IoT-based Healthcare Monitoring System for War Soldiers using Machine Learning

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Abstract

In today's world, warfare is an important factor in any nation's security. One of the important and vital roles is played by the army soldiers. There are many concerns regarding the safety of soldiers. So for their security purpose, many instruments are mounted on them to view their health status as well as their real time location. Bio-sensor systems comprise various types of small physiological sensors, transmission modules and processing capabilities, and can thus facilitate low-cost wearable unobtrusive solutions for health monitoring. This paper gives an ability to track the location and monitor health of the soldiers in real time who become lost and get injured in the battlefield. It helps to minimize the time, search and rescue operation efforts of army control unit. This system enables to army control unit to track the location and monitor health of soldiers using GPS module and wireless body area sensor networks (WBASNs), such as temperature sensor, heart beat sensor, etc. The data coming from sensors and GPS receiver will be transmitted wirelessly using ZigBee module among the fellow soldiers. Furthermore, LoRaWAN network infrastructure has been proposed to be used between the squadron leader and the control unit in high altitude warzones where cellular network coverage is either absent or does not allow data transmission. The collected data will be uploaded on the cloud for further data analysis and predictions using K-Means Clustering algorithm.

Keywords: ZigBee; LoRaWAN; IED Bomb Detector; GPS Tracking; Biomedical Sensors; Navigation; WBASNs; Monitoring; Data Analytics

1. Introduction

The soldier must be integrated with advanced healthcare monitoring, real time GPS (Global Positioning System) and data communications to send and receive information to/from the control unit. For that Soldier might need wireless

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networks not only to communicate with control unit but also with side by side military personnel. Apart from the nation's security, the soldier must need safety by protecting himself with advanced weapons and also it is necessary for the army control unit to monitor the health status of the soldier. To serve this purpose, in this paper bio medical sensors and monitoring devices are integrated with the soldiers. The integrated components must be light weight package and must provide desired result without requiring much power. One of the fundamental challenges in military operations lies that the soldiers are not able to communicate with control unit. In addition, the proper navigation between soldiers plays an important role for careful planning and co-ordination. So, the proposed work focuses on tracking the location of soldier which is useful for control room station to know the exact location of soldier and accordingly they will guide them. Control unit gets location of soldier using GPS. It is necessary for the base station to guide the soldier on correct path if he lost in the battlefield. This paper will be useful for the soldiers, who involve in special operations or missions. Smart Bio medical sensors including Heartbeat sensor, ECG module, Temperature & Humidity sensor, Vibration sensor, bomb detector, etc are attached to the jacket of soldiers. These are implanted with the soldier for complete mobility. This system will provide connectivity to the server at the base station using a wireless connection. The data collected at the base station can be used for further prediction using K-Means Clustering algorithm. This may help the control station to know about the situation at the mission field.

2. Literature Survey

The authors[1][2][3] had discussed on various wearable, portable, light weighted and small sized sensors that have been developed for monitoring of the human physiological parameters. The Body Sensor Network (BSN) consists of many biomedical and physiological sensors such as blood pressure sensor, electrocardiogram (ECG) sensor, electro dermal activity (EDA) sensor which can be placed on human body for health monitoring in real time.

In this paper, we propose a methodology to develop a system for real time health monitoring of soldiers, consisting of interconnected BSNs.

The authors[4] had introduced a system that gives ability to track the soldiers at any moment. The soldiers will be able to communicate with control unit using GPS coordinate information in their distress. It is able to send the sensed and processed parameters of soldier in real time. It enables to army control unit to monitor health parameters of soldiers like heartbeat, body temperature, etc using body sensor networks. The parameters of soldiers are wirelessly transmitted using GSM.

The authors[5][6][7][8] had presented an idea for the safety of soldiers using sensors to monitor the health status of soldiers as well as ammunitions on them. GPS module has been used for location tracking and RF module has been used for high speed, short-range data transmission, for wireless communications between soldier-to soldier that will help to provide soldiers health status and location data to control unit[9][16].

The authors[10][15] had investigated for the care of critically ill patients. This paper is based on monitoring the health of remote patients, after they get discharged from hospital. This system enables the doctors to monitor health parameters like body temperature, heartbeat and ECG of patients from their clinic or hospital. The health parameters of patient are measured continuously and transmitted wirelessly through ZigBee[12][13][14] transceiver.

The authors[17] have proposed a "Soldier Health and Position Tracking System" using Barometric pressure sensor, GPS, GSM and WBASNs (heartbeat sensor, temperature sensor). Microcontroller ATmega328p has been used for their prototype. Simple conditional statements have been used to identify the health of the soldier without any machine learning or training. GSM has been used as the means of communication which will not be useful at places with high altitude where network connectivity would be a big challenge. A message is sent after regular intervals containing the health status of the soldier using GSM.

The authors[18] have proposed "IoT-based Health Monitoring via LoRaWAN" in which collected medical sensor data is sent to an analysis module via low-cost, low-power and secure communication using a LoRaWAN (Long Range Wide Area Network) network infrastructure. Blood pressure, glucose and temperature has been measured in rural areas where cellular network coverage is either absent or does not allow data transmission. The average area covered by LoRaWAN is found to be around 33 km^2 when the LoRaWAN Gateway is placed outdoor on a 12 meter altitude. Power consumption of this monitoring system is claimed to be at least ten times lower than other long range cellular solutions, such as GPRS/3G/4G.

The authors[20] have proposed a "Soldier Monitoring and Health Indication System" in which they have used GPS, Heart rate sensor, Temperature Sensor, Vibration sensor, Bomb Detector and a PIC16F877A Microcontroller for the prototype. This project uses polar heart rate transmitter and RMC01 receiver as a heartbeat sensor. This paper proposes the use of piezo disk vibration sensor using piezo-electric plate. Piezoelectric film is a lightweight, flexible, reliable, mobile and low cost alternative to expensive sensors.

Normal conditional statement are used to detect Hypothermia and Hyperthermia using the temperature sensor. The bomb detectors used are paper sensors which are also called as IED (Improvised Explosive Devices). It works by detecting the traces of chemical compounds in the atmosphere and also by directly detecting the type of IED without any additional systems.

In this paper, the aim is to combine the long range and low power consumption characteristics of LoRaWAN and ZigBee. We will be able to transmit and display the health data and the real time location which is sensed from remote soldiers to squad leader using ZigBee and onto the base station using LoRaWAN module as a wireless transmission device. GSM (Global System for Mobile Communication) or RF (Radio Frequency) are not proposed for communication due to some factors such as cellular connectivity at higher altitudes, weather and environmental conditions around the soldier's unit and long range capabilities. The collected data will be uploaded on the cloud for further data analysis using a K-Means Clustering algorithm.

3. Proposed System

3.1. Hardware Components with Specifications

- Arduino MEGA 2560
- Heartbeat Sensor
- Temperature Sensor and Humidity Sensor (DHT11)
- Accelerometer (ADXL335)
- Ethernet Shield (W5100)
- GPS Module (NEO-6M)
- ZigBee Module (XB Series 1)
- LoRaWAN Module
- Bomb Detector (IED i.e. Improvised Explosive Device)
- ECG Module (AD8232 i.e. Electro-Cardiogram)

3.2. Proposed Methodology

3.2.1 Real-time Data Sensing in the Warzone

Data collected from the war zone will be the indicator of soldier's health condition. Insights such as nearby bomb detection can be made accordingly. Appropriate sensors are proposed for deployment so the data analytics performed using K-Means helps the control unit in mapping the conditions around the soldiers.

3.2.2 Data Transmission

Data is transmitted from the soldier to the squadron leader using ZigBee. The squadron leader then collects this data and passes it to the control unit using LoRaWAN. Data can either be sent periodically after some fixed intervals or only when there is a significant change in the biomedical sensor readings of the soldier.

3.2.3 Data Analysis & Prediction

Instead of using simple conditional statements, K-Means Clustering algorithm has been proposed. Clustering is a type of unsupervised learning that can be used to visualize similar kinds of data and cluster them together. Due to the unavailability of real time soldier data, clustering has been proposed initially. K-Means Classification can be easily applied on the real time data that will be collected eventually.

The difference in sensor values will help us in clustering the data into clusters such as healthy, ill, abnormal and dead. Once the data has been collected and clustered, these clusters can be visualized for more instinctive summaries at the control unit.

3.3. Proposed System Architecture

3.3.1 Soldier's Unit

This unit consists of body area sensor networks such as temperature sensor, heart beat sensor, humidity sensor, vibration sensor, GPS and bomb detector. These sensors are used to sense the health parameters of soldiers, tracking their location and to detect if there has been a bomb explosion nearby by tracing explosive compounds in the environment. The sensed analog signals will be converted into digital signals using analog to digital converter and then compared with the normal conditional signals. If any discrepancy occurs between sensed signals and defined normal signals, then it will be considered as an emergency[4][10][11].

The use of a paper bomb detector has also been proposed in this paper to detect the presence of any explosive compound in the atmosphere nearby. The soldier's unit shall have a ZigBee module that will be used for communication between the soldier and the respective squadron leader.

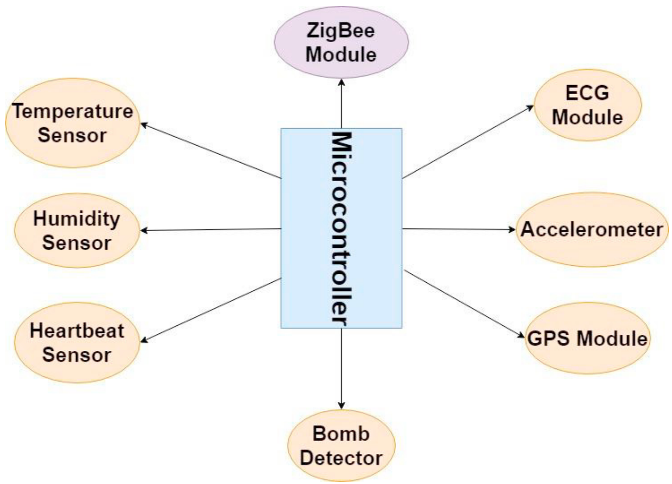

Fig 1: Soldier's Unit

3.3.2 The Squadron Leader's Unit or Sub-Master's Unit

For each and every field operation, there is always an on field Squadron Leader who is in continuous communication with the control unit. In the proposed methodology, this leader will be equipped with an extra LoRaWAN module which will be responsible of transferring data through the LoRaWAN to the control unit.

The sub-master unit will also be equipped with a ZigBee module to collect data from the other soldiers present in the area of operation. The sub-master unit and other soldier units would communicate using the multi-hop protocol. Thus, this sub-master unit acts as the cluster head for each and every squad that goes into the battlefield.

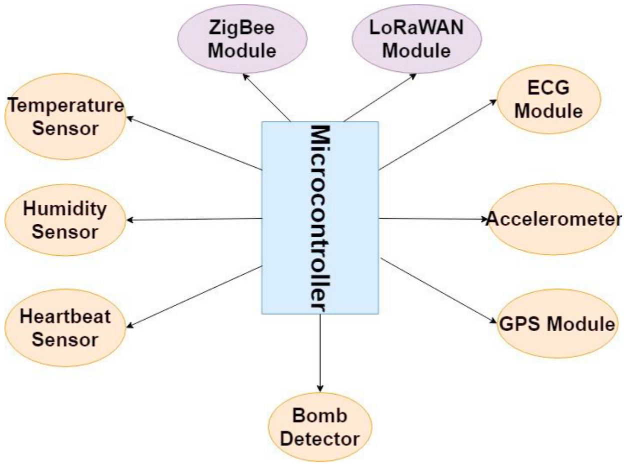

Fig 2: Squadron Leader's Unit

3.3.3 Control Room's Unit

The army base station unit or the control unit shall consist of a PC and a LoRaWAN transceiver module which will be connected with each other. The data coming from LoRaWAN module will be displayed on PC screen with the help of graphical user interface (GUI) or a web portal.

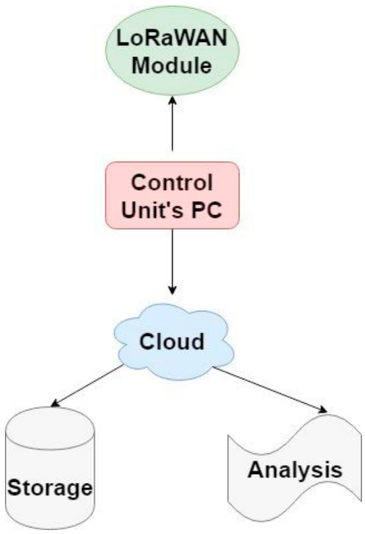

Fig 3: Control Room's Unit

3.4. Proposed Network Architecture

A ZigBee transceiver is used to transmit the data, coming from sensors and GPS receiver through microcontroller, to the squad leader using wireless communication [10] [11]. A ZigBee is low cost, low power, wireless mesh network standard especially designed and developed for long battery life devices in wireless controlling and monitoring applications. ZigBee devices have low latency which can further reduce the average current.

The squad leader is connected to the control unit using LoRaWAN which enables the communication between both ends. LoRaWAN can be used in high altitude warzones where cellular network coverage is either absent or does not allow data transmission.

This paper comes up with an idea of tracking the soldier as well as to give the health status of the soldier during the war, which enables the army personnel to plan the war strategies and predicting the war conditions using machine learning.

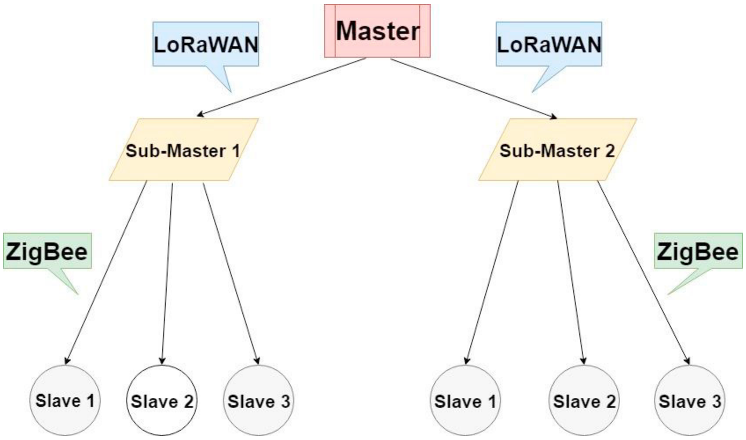

Fig 4: Proposed Master-Slave Network Architecture

3.5. Proposed Cloud Infrastructure

ThinkSpeak has been proposed to be used as the IoT-based Cloud Platform for the prototype model. It offers free data storage and analysis of time-stamped numeric or alphanumeric data. ThingSpeak library enables an Arduino or other compatible hardware to write or read data to or from ThingSpeak. It is an open data platform for the Internet of Things (IoT) with MATLAB analytics and data visualization. It enables sensors, instruments, and websites to send data to the cloud where it is stored in either a private or a public channel. Data is stored in private channels by default, but public channels can be used to share data with others. Once data is collected or uploaded in a ThingSpeak channel, it can be analyzed, visualized and shared on social media, web services, and other devices.

3.6. Machine Learning Algorithm

From the sensor data collected on cloud like – temperature, humidity, heartbeat sensor insights will be derived using K-Means Clustering. It solves the problem of unsupervised learning as any information or insights about the relations between different data that we are collecting is not available forehand. From the input data of different sensors, for different actions or events like running, walking, sitting, in case of bombing, injury; each cluster predicts these different events based on the data collected.
The following are the steps of K-Means Classification:

- *Data Assignment*

Each centroid defines one of the cluster. In this step, each data point is assigned to its nearest centroid, based on the squared Euclidean distance. More formally, if c_i is the collection of centroids in set C, then each data point x is assigned to a cluster based on:

$$\arg_{ci \in C} min\ dist(ci, x)^2$$

Eq 1: Standard Euclidean Distance Computation where, dist(ci,x) is the standard Euclidean distance. Let the set of data point assignments for each i^{th} cluster centroid be S_i.

- *Centroid Update*

In this step, the centroids are recomputed. This is done by taking the mean of all data points assigned to that centroid's cluster.

$$c_i = \frac{1}{S_i} \sum_{xi \in Si} xi$$

Eq 2: Centroid Computation

The algorithm iterates between both the steps until a stopping criteria is met (i.e. no data points change clusters, the sum of the distances is minimized, or some maximum number of iterations is reached).

Each cluster created represents different actions or events. After enough training data is collected, the model is classified based on clusters using K-Means Classification. It can be used to predict the type of situation the soldier is in. Therefore, K-Means Clustering is used for forming a model for prediction of events based on the input data, and appropriate actions are taken by the control unit or the base station.

3.7. Proposed Prototype

All the sensors such as Temperature sensor, Humidity sensor, Heart Beat Sensor, Accelerometer and GPS module along with either ZigBee Module or the LoRaWAN Module are integrated with the Arduino Mega 2560. Every soldier in the battlefield is provided with such model where various sensors' real time data along with the soldiers' location are sent to the squadron leader from the soldier using ZigBee module and the data received by the squadron leader is sent to the cloud through the LoRaWAN module as it supports long range communication and also fast communication. Data analytics using K-Means Clustering is applied on the collected data on the cloud to provide information about the soldier's unit such as if they are bombed, injured or if they have died. The current war scenario along with the health of the soldiers deployed on the battle field can be viewed through the web portal and thus it would also help the headquarters in decision making.

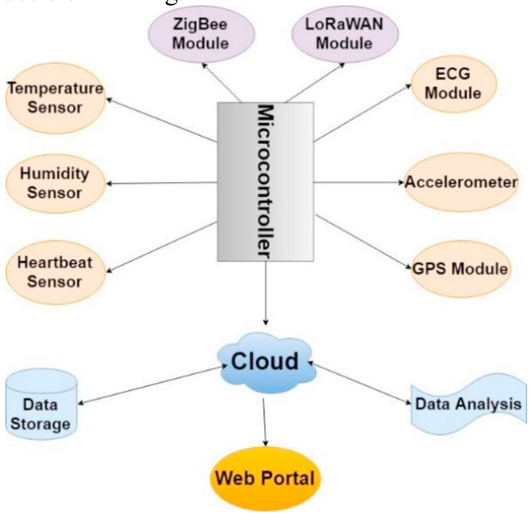

Fig 5: Block Diagram Implementation of the Prototype

4. Results

The sensors were subjected to the real world and the semi/unstructured sensory output data were recorded. These data were then processed and converted to structured data to fit the K-Means model. A total of 2000 instances of data were collected from various sensors. It was then clustered using K-Means Clustering algorithm and the following clusters were observed for different activities performed:

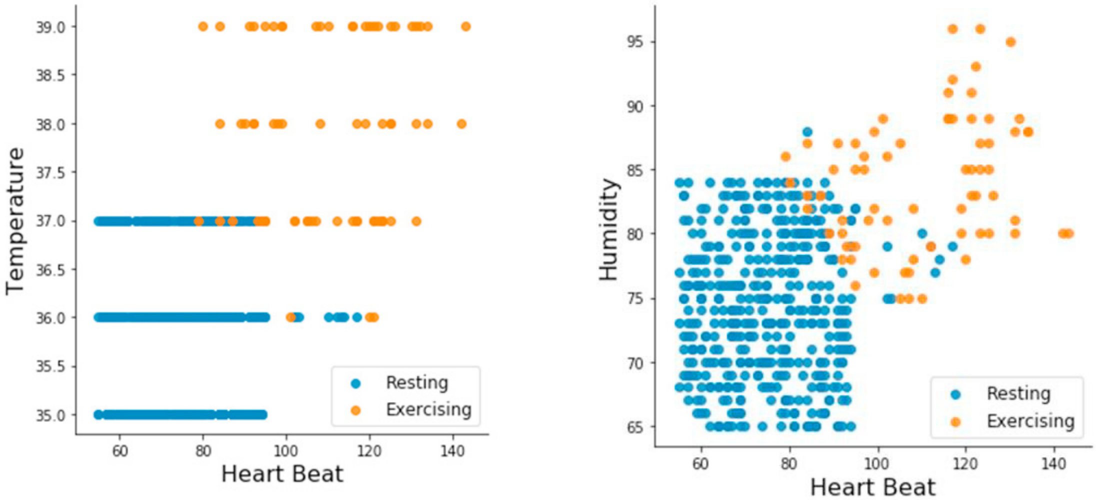

Fig 6: K-Means Clustering forming 2 clusters for Temperature Vs Heart Beat & Humidity Vs Heart Beat respectively

The data fits the model very appropriately because it distinctively created two clusters. The two clusters created signify the state of resting and exercising. The graph plots of the data make the picture very clear and give a deeper insight on how the different sensors' output contributes to the two states. Temperature vs Heart beat and Humidity vs Heart beat plots are great parameters to identify the above mentioned states and hence they were chosen for in-depth analysis. The graph shows that with low heart beat and low temperature amounts to the state of resting while the opposite signifies the state of exercising. The other graph also gives a similar insight wherein low heartbeat combined with low humidity amounts to the state of rest while the opposite amounts to the state of exercising. The model clearly aligns itself with the real world scenario and beautifully clusters the sensor data.

5. Conclusions and Future Scope

From the proposed system, we can conclude that we are able to transmit the data which is sensed from remote soldier to the squad leader and other soldiers using ZigBee transceiver and from the squad leader to the control unit using LoRaWAN as the wireless transmission technology. This system helps to monitor health parameters of soldier, track their position, detect nearby bombs and predict the warzone environment using various sensors and K-Means machine learning algorithm. The system helps the soldier to get help from army control unit and/or from another fellow soldiers in panic situation. It will prove to be very useful to military forces during war and rescue operations as it can be used without any network restriction combining the capabilities of ZigBee and LoRaWAN. Thus, this system provides security and safety to our soldiers.

The proposed work can be expanded in the future in many directions. Gyroscope and Accelerometer can also be used together for human activity recognition using machine learning. Blood pressure sensor and electro dermal activity sensor can also be implemented together to classify if the soldier is calm or is in distress. A suitable and better routing algorithm can be used to make this system more reliable and energy efficient. Ubiquitous computing will surround all the soldier's environment that merges physical and computational infrastructures forming a whole new integration. It will feature a proliferation of hundreds or thousands of computing devices and sensors that will provide new functionalities without being bulky. The selection of the squadron leader has been done statically in this paper while it can be done dynamically in the future using an appropriate and efficient cluster-head selection algorithm.

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