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Realtime Wireless Embedded Electronics for Soldier Security

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Abstract*— One of the important and vital roles in a country'sdefense is played by the army soldiers. Every year Soldiers get strayed or injured and it is time consuming to do search and rescue operations. In this paper, we present a WSN-based environmental and health monitoring approach in which sensor data is processed using robust and stable algorithm implemented in controller. These processed data are then sent to the base station via low-cost, low- power and secure communication links provided by a LoRa network infrastructure instead of cellular networks, since, they are either absent or doesn't allow data transmission in warzone or remote areas. We focus on monitoring environmental factors such as temperature, humidity, air pressure, air quality; physical factors such as motion, position, geographic location and health parameters like ECG (electro cardiograph), blood oxygen level, body temperature. Moreover, camera and microphone are used to monitor any undesirable situation of soldier. The aim of the system is to reduce the response time for any emergencies with the use of embedded system and WBASN, while being power efficient.

***Keywords*—WSN, NMEA, LoRa, Raspberry Pi, WBASN**

I. Introduction

The nation's security is monitored and kept by army, navy and air-force. There are many concerns regarding the safety of the soldier. Soldiers in battlefield often lose their lives due to lack of connectivity, it is very vital for the army base station to known the location as well as health status of all soldiers. To avoid life-threatening situations, it is helpful to continuously monitor soldiers suffering from harsh conditions. The Wireless Sensor Network (WSN) plays a crucial role in health monitoring, since it enables us to connect sensors to collect soldiers' health and environmental data and process it to prevent critical events. Major research is being done by some of the world's largest militaries like Russian and U.S. Army to build wearable embedded device which could monitor the physical and environmental factors of soldiers, like in TALOS Exoskeleton (Tactical Assault Light Operator Suit) project which involves 56 corporations, 16 governments agencies, 13 universities, and 10 national laboratory for research and development purpose [1]. In-depth analysis regarding smart wearable clothing has been provided by Scataglini et al. [2], about the application and importance of smart wearable clothing in the Army.

A comprehensive survey has been provided by Islam et al. [3] which provides information regarding the impact of IoT on e-health monitoring, monitored parameters and provided services. Existing IoT-based health monitoring systems suffer from three main constraints. First, they often make use of relatively high cost communication links, such as 3G/4G [4, 5]. Second, they typically do not deal with data privacy issues [6, 7]. Third, most of them do not analyze monitored health parameters to prevent critical situations [6, 7]. In this paper, we propose an IoT-based health monitoring approach that addresses above mentioned issues. Ahmed et al. [6] have proposed an architecture for e-health monitoring systems. The authors [8-10], had discussed about various wearable, portable, light weighted and small sized sensors that have been developed in order to monitor physiological parameters of the human. The Body Sensor Network (BSN) consists of many biomedical and physiological sensors which can be placed on human body for health monitoring in real time. GSM is used for communication which may not be useful at places with high altitude or in remote areas where network connectivity would be a big challenge. A message is sent after regular intervals containing the health status of the soldier using GSM. In paper [11], authors implemented monitoring system including data privacyusing blockchain which is an important factor, but the use of GSM can be troublesome in the war-field. Another IOT-based system is described in the paper [12] which uses the Wi-Fi module to communicate with control room, which can be costlyin terms of power consumption.

Gondalia et al. [13] described the system that tracks the location and monitors the health of the soldiers. The data collected from sensors will be transmitted wirelessly using ZigBee module among the fellow soldiers. Furthermore,

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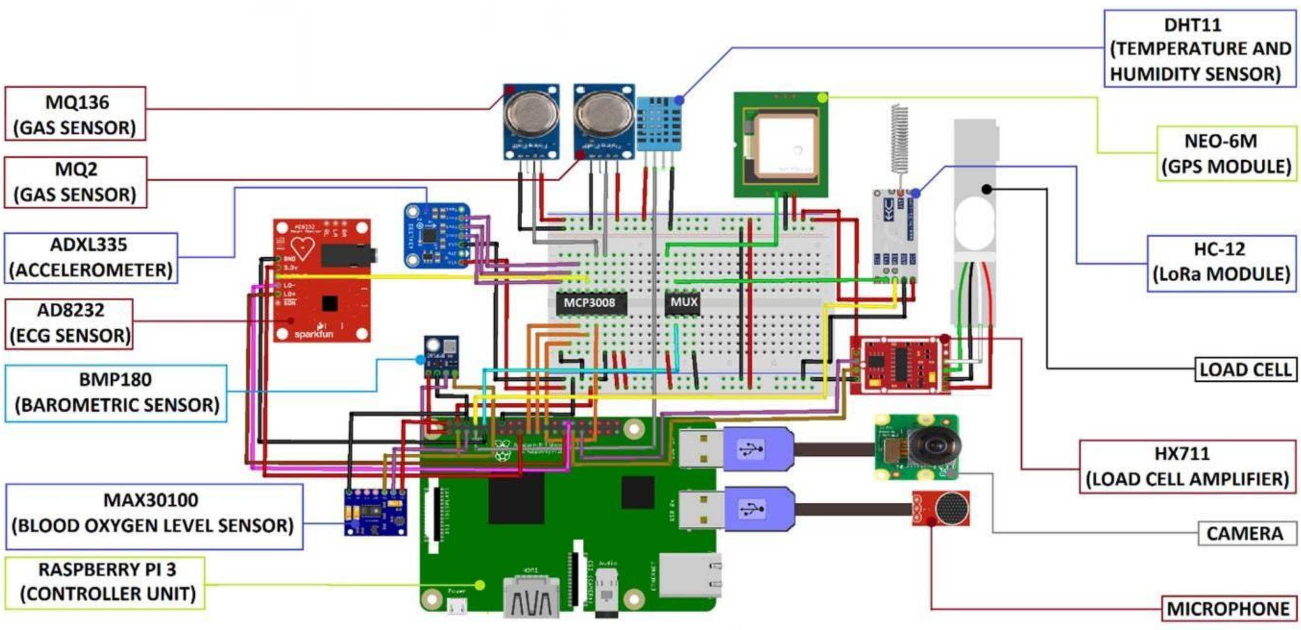

Fig.1. Circuit diagram of soldier's unit showing health and environmental sensors connected to Raspberry Pi controller

LoRaWAN network 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. Mdhaffar et al. [14], has proposed, IoT-based Health Monitoring via LoRaWAN in which collected medical sensor data is sent to an analysis module LoRaWAN (Long Range Wide Area Network) network infrastructure. Power consumption of their monitoring system is claimed to be ten times lower than other long-range cellular solutions, such as GPRS/3G/4G.

Previously, similar work has been done by our group using Arduino [15], but due to limited processing power of Arduino and lacking USB port for camera and microphone connection, we have used Raspberry Pi to overcome the above-mentioned controller constraints. In our model, the collected data is processed by Raspberry Pi and then sent to the base module by a low-cost, low-power, long range and secure communication links provided by a LoRa communication. The transmitted data is analyzed to detect, predict and prevent crisis situations by generating and executing adequate treatment plans. Base module receives images and audio recording clip whenever emergency situation is detected by robust and stable algorithm on the bases of data acquired from the sensors. All this will help the base station to get a better understanding of the situation and will help to create more informed and efficient strategy to overcome the situation.

II. Proposed Model for Soldier's Health and Environmental Monitoring System

The system consists of two units viz, Soldier's unit and Base station unit. Soldier's unit can be integrated to the soldier's vest as shown in Fig. 2.

A. *Soldier's Unit:*

In this unit, Raspberry pi 3 is used as a controller module at the node(soldier), which collects data from the different sensors, processes the data and send information to the base station via LoRa module. Neo 6M GPS sensor is used to gather geographical location of soldiers, which helps to track

Fig. 2. Placement of WBASN (Wireless Body Area Sensor Network) on soldier's body

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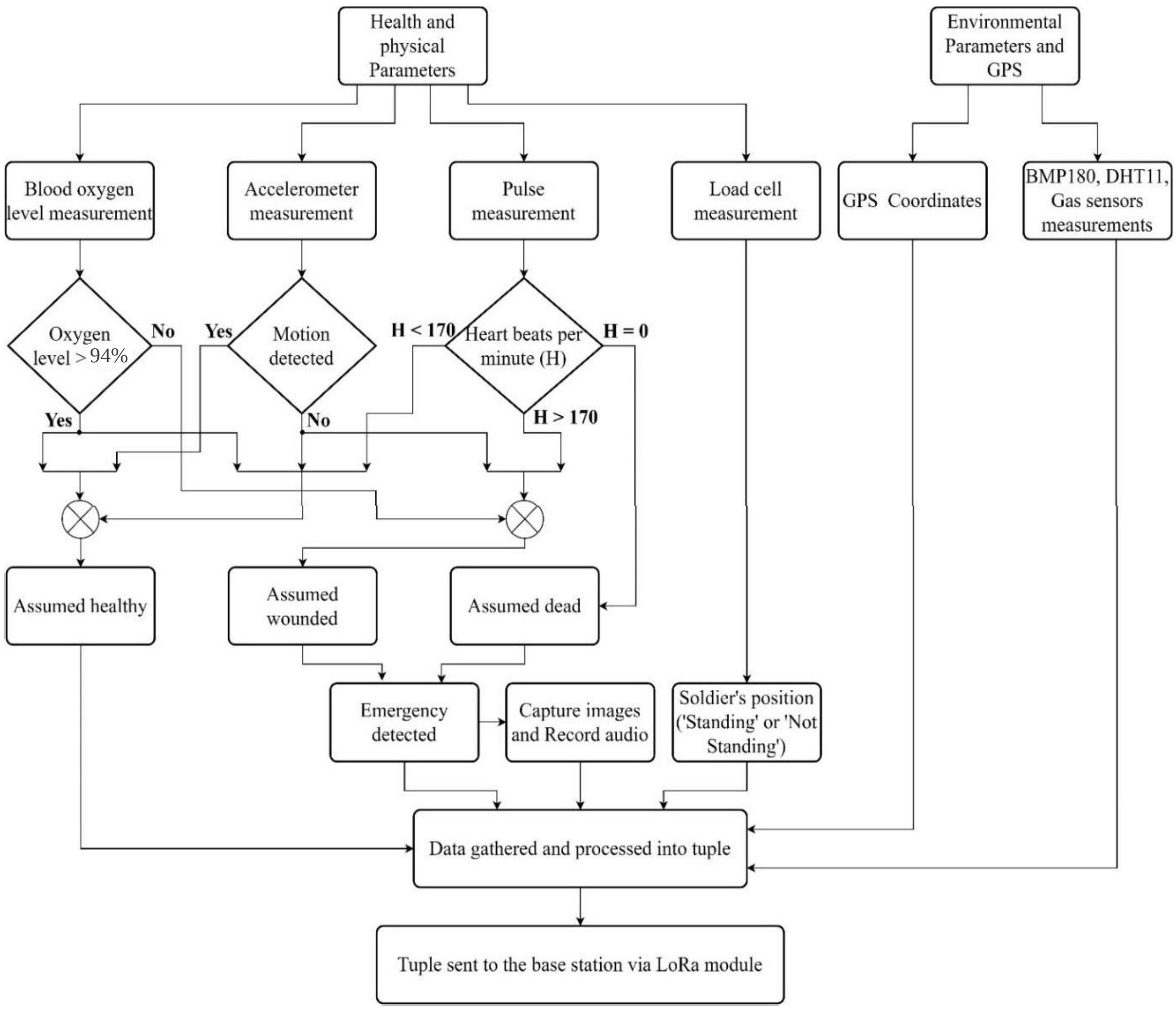

Fig. 3. Algorithm to determine soldier's health and environmental conditions

location of soldiers continuously. This sensor provides NMEA (National Marine Electronics Association) raw data, which is used to extract the coordinates of the soldier. Both the above modules (GPS and LoRa module) use UART (Universal Asynchronous Receiver-Transmitter) communication, while Raspberry pi 3 has only one UART port, i.e. it can communicate with only one device at a time. To overcome this, we have used MUX and time division polling has been done to communicate with both the sensors. BMP180 sensor is used to measure air pressure, surrounding temperature and altitude, which is useful to understand environmental conditions at the warzone and could detect the change in air pressure and temperature resulted from a bomb blast. BMP180 uses I2C communication. Similarly, DHT11 is used to get information about humidity in the warzone. Gas sensors like MQ-2 and MQ-136 are used to detect combustible gas, smoke and harmful gases like H_2S (Hydrogen Sulfide), which are usually present during chemical warfare. DHT11 and both gas sensors use one-wire protocol for communication.

ECG (Electro Cardiograph) sensor AD8232 has been used to monitor the heartbeat of the soldier and analyze whether soldier is healthy, wounded or dead. ECG electrodes can be placed at the chest or at the forearms of the soldier as shown in Fig. 2. Saturation of Peripheral oxygen (SpO_2) level is measured using MAX30100. MAX30100 uses I2C communication protocol and is placed on the ear lobe of the soldier as shown in Fig. 2. Accelerometer GY-68 is used to detect movement of soldiers. It uses one-wire protocol. Analog-to-Digital converter MCP3008 is used to convert analog data signals of the gas sensors and accelerometer into the digital data. Load cell is used to detect the position of the soldier whether he is standing or not, if soldier is not standing for a long period of time, that can be alert for emergency. It is placed at the sole of the soldier as shown in Fig. 2. An amplifier HX711 is used to amplify the signal of the load cell, which uses I2C communication protocol.Camera and Microphone are connected to Raspberry Pi via USB port, which are used to capture and record emergency situation which is triggered by algorithm, that can help to get better idea of situation. The circuit diagram of the soldier's unit is shown Fig. 1.

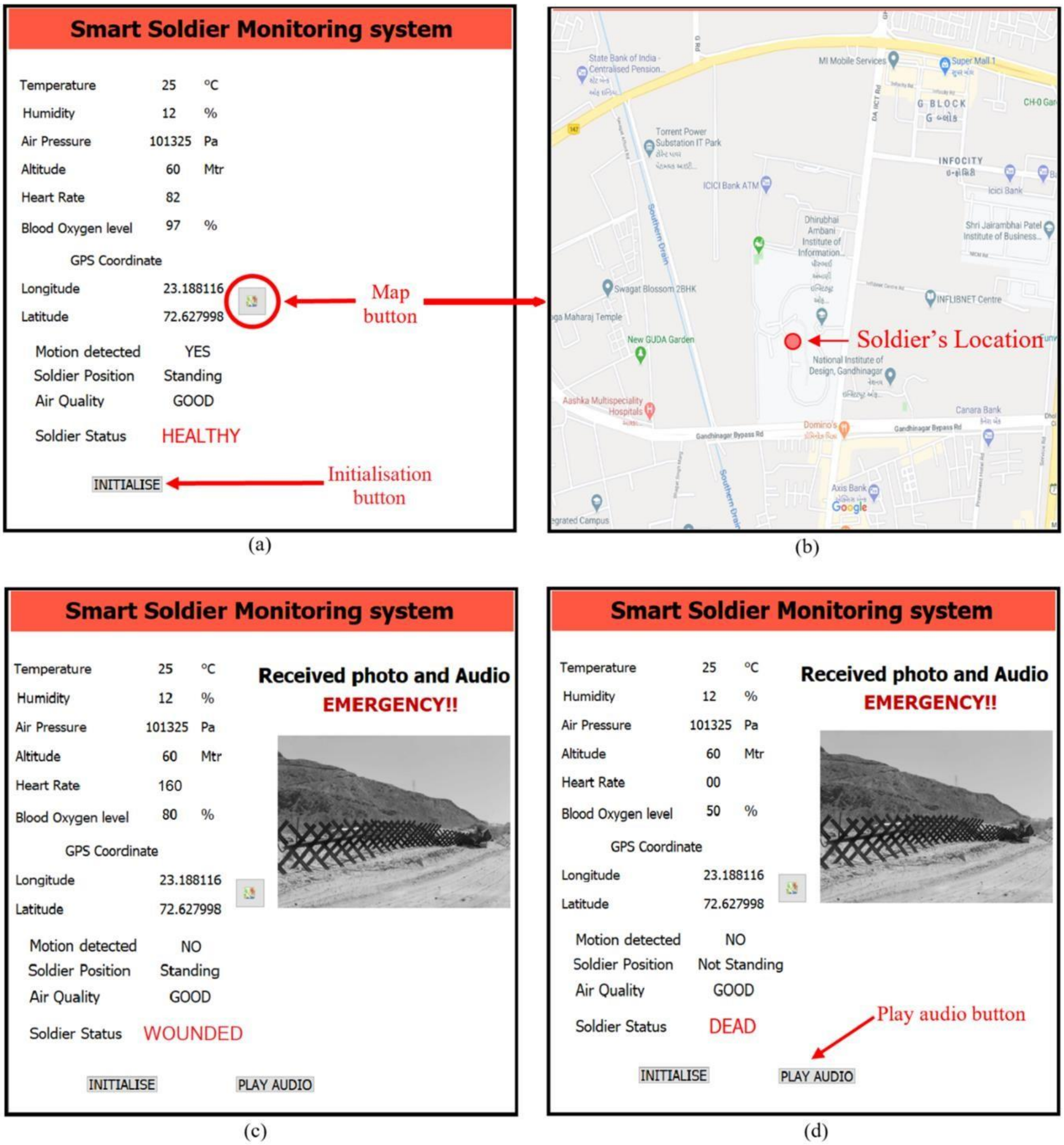

Fig. 4. GUI showing environmental parameters and soldier's health condition for different cases. (a) shows soldier is healthy, (b) shows soldier's location on map, (c) shows soldier is wounded and (d) shows soldier is dead.

The data transmission from one node (soldiers) to another node (base station) is done by LoRa module HC-12. In LoRa module, there is a tradeoff between over the air baud rate and range, i.e. in order to increase the baud rate for data transfer, sensitivity decreases and as a result range decreases drastically. So, depending on the application, optimal value of baud rate can be used for the transmission. Performing experiments at 9600 baud rate, we were able to get the line of sight distance approximately 200 meters, which could further be increased by decreasing the baud rate, if needed. The data includes all sensor data, image bits and audio bits.

B. Data processing and transmission:

Collected data from the sensors will be processed to find the soldier's health condition, using an algorithm as shown in Fig. 3, which compares data with different threshold values. The soldier will be declared dead, if the heartbeat is not detected and will be declared wounded, if heart beat rises above certain threshold which is set to 170 in our case, because heart beat can rise up to 85% of the maximum heart rate during intense physical activity or severe injury [16]. The approximate maximum heart rate of a person can be find using the formula [16],

Maximum heart rate = 220 – soldier's age (20 in our case)

So, to avoid false alerts due to intense physical activity, the heartbeat is measured only when there is no movement detected. Also, if the blood oxygen level falls below 94% soldier is declared injured because oxygen level in healthy human-beings lies between 94% [17]. The soldier is assumed to be fit in the rest of the cases as shown in Fig. 3. If soldier is found to be wounded or dead, then image will be captured and converted to grayscale to reduce the transmission data load to 1/3 of the original image. Capturing a video will lead to even greater transmission data load, since the frames per second(fps) for a video should be at least 24 fps. Since, transmission of image (size of 1 frame) takes almost 100 seconds to transfer, so transmission of video is not feasible in the time when soldier's life is on stake. Also, audio clip of 1 minute will be recorded at the sample rate of 44.1KHz which will further reduce in size by resampling at 8.82KHz, which is 1/5 of the original clip. The transmission of the data is done at the baud rate of 9600 bps by LoRa module. Furthermore, to secure the data communication end-to-end symmetric encryption is done which would help enhancing the security. The data is transmitted in a form of a tuple as given below:

['temperature', 'humidity', 'air pressure', 'altitude', 'latitude', 'longitude', 'blood oxygen level', 'air quality', 'motion', 'position', 'heart rate', 'status bit']

Here, the parameter 'air quality' is a Boolean which contains information regarding the presence of harmful gases like Hydrogen Sulphide and combustible gases detected using gas sensors. 'position' and 'motion' are also Boolean parameter which shows whether soldier is standing or not and soldier is in motion or at rest respectively. The 'status bit' has 3 values which shows the health status of the soldier i.e. healthy, wounded or dead. Rest of the parameters i.e. 'temperature', 'humidity', 'air pressure' and 'altitude' contains respected data collected from DHT11 and BMP180 sensors, which determines environmental conditions. If soldier is found wounded or dead, a new tuple of grayscale image and resampled audio clip are sent in the small packages. The packages consist of pixel value in case of image and sample data in case of audio clip separated by delimiter (','). These data packages are then reconstructed at the base station unit.

C. Base station Unit:

Base station Unit consist of LoRa module which is connected to the computer unit via USB TTL (Transistor-Transistor Logic) interface. LoRa module receives data signals sent by soldier's unit which contains data tuples that can be displayed on the GUI (Graphical User Interface). When emergency situation arises, soldier's unit sends picture and audio clip which will be saved locally and could be accessed directly from the GUI.

III. Results

The GUI of our system is shown in Fig. 4, which shows physical status of the soldier and environmental parameters. The system will start fetching data when 'Initialize' button is pressed. In Fig. 4(a), the health status is normal and there are no emergencies. The soldier's location can be directly viewed on map and will be highlighted by pressing the map button as shown in Fig. 4(b). Fig. 4(c) and 4(d) shows that the soldier is found wounded and dead respectively and system has received image and audio clip from the soldier's unit. After fetching the image and audio clip, it can directly be accessed from the GUI itself. The image is shown on GUI while audio can be played by pressing the 'PLAY AUDIO' button. The maximum energy consumption of the whole soldier unit is observed to be around 3.2 Wh. Using portable battery, it is possible to use it for several hours. For a commercially available 50,000 mAh battery, operating at 5 V, with the worst-case current drawing capacity of 90% and weighing around 1 kg, could provide power supply for around 75 hrs. The system could be implemented on low power Raspberry Pi alternative like Nitrogen8m mini to further decrease the power consumption.

IV. Conclusion

This paper presents a successfully implemented smart soldier health monitoring system, which has the potential to improve the military operations substantially. It helps to acquire the information from the warzone about each soldier's health condition and could detect biohazards with the help of vigorous algorithm. This helps to take swift decisions and can prevent causalities by providing backup or further assistance. Besides that, energy consumption of the system is only 3.2 Wh which is much less, due to the use of LoRa module for data transmission instead of high-power consuming GSM/GPRS modules. Therefore, it can be concluded that the use of the smart soldier health monitoring system improves upon the traditional methods of executing military operations considerably.

V. Future Work

More sensors like EDA (electrodermal activity), EEG (Electroencephalography) and biochemical sensors can be integrated with the system. The soldier's unit can be integrated to the wearable clothing using flexible electronics to make it more convenient for the soldiers.

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