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ORIGINAL CONTRIBUTION

Automatic Location Tracking and Health Monitoring by System Based on Mesh Network

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Abstract The safety of soldiers is one of the main concern of defence department of every nation. However, the location and health status of soldiers are communicated over the radio line which is not an efficient method for tracking or communicating. Thus, a system is developed in this paper for automatic tracing of location using Global Positioning System coordinates and monitoring of vital body parameters based on private mesh network for a secure communication. SOS feature is also available in this system which can assist soldier in case of emergency. A portable device is made that consists of all the required sensors for health monitoring and SOS feature. Further, an application is developed to maintain the record of all the data at the base.

Keywords Mesh network · Global positioning system (GPS) · Sensors · NodeMCU

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Introduction

There is rapid growth in science and technology as a result of new discoveries, breakthroughs, and innovations along with their advanced implementation levels in everyday life. The defence services adopt these emerging advanced technologies for the safety and security of soldiers. It is required to integrate the soldiers with real-time Global Positioning System (GPS), advanced healthcare monitoring, and data communications for maintaining the communication with control unit [1]. However, it might require wireless networks for communicating with the military personnel as well as control unit. Thus, the main challenge in such military operations is that soldiers are unable to send and receive information from the control unit. Moreover, army control unit also needs to perform the monitoring of the health status of soldier [2]. Thus, there is a need that base stations should have an embedded wireless system through which the health status of soldiers can be monitored using sensors in addition to their location by tracking them through GPS to guide them to any safe area. This can be achieved by integrating the soldier with our healthcare tracking system, which uses real-time GPS and data communications for receiving and sending the data to and from the control unit. This can be done by integrating the monitoring devices and biomedical sensors with soldiers which should have lightweight in addition to providing the desired result at low power. In order to monitor the human physiological parameters, several portable, wearable, small-sized, and lightweight sensors have been developed such as heart rate sensor, electrodermal activity (EDA) sensor, electrocardiogram (ECG) sensor, blood pressure sensor to monitor health in real time by placing them on human body [1, 3, 4]. Besides, it is crucial to have proper navigation between soldiers as it is required for coordination and planning [5]. So, tracking a soldier's location helps the control room determine their precise location, which is useful for directing them in the event that they become lost on the battlefield. With a wireless connection, connectivity is provided by this system to server present at the base station. In [2], a system is introduced for tracking every movement of soldiers. Thus, in distress, soldiers can communicate with the control unit by utilizing the GPS coordinates. It can send the obtained coordinates of soldiers in real time along with monitoring of health parameters of soldiers by body sensor networks, for instance heartbeat, body temperature, etc., by using Global System for Mobile communication (GSM). However, the system based on RF and GPS had been used for location tracking and high speed as well as short-range transmission of data for monitoring the health of soldiers and ammunition on them using sensors [5–8]. In [9], barometric pressure sensor, GPS, GSM, and wireless body area sensor networks (WBASNs), for example heartbeat and temperature sensor, are used for tracking the health as well as position of soldiers along with Microcontroller ATmega328p while [10] utilized PIC16F877A and piezoelectric film as an alternative to the costly sensors. Generally, GSM is used for communication but it cannot be utilized at high-altitude places due to issue of network connectivity. To avoid such issues, LoRaWAN (long-range wide area network) is used for sending the data to an analysis module [8]. The collection of data done at the base station can be used for future prediction. This may also assist the control station to have information regarding the scenario at mission field. Also, soldiers can enquire about their location from the army control unit while planning new strategies against the rivals or in case they get lost. Despite being efficient in terms of low-power, secure communication, it has certain range limitations.

In [11], Zigbee is used for wireless transmission of the data obtained from GPS receiver and sensors via microcontroller to the army control room. In addition to an alphanumeric LCD display for displaying the health parameters and location of soldiers, a panic switch and buzzer is present. In case of emergencies, soldiers can utilize the panic switch for seeking help from fellow soldiers or army control room in the wireless range. When panic button is pressed in emergency conditions, the buzzer of fellow soldier will sound. However, ESP-8266 and GPS module are used along with temperature and heart sensors in [12] for receiving the data from the transmitter. It is more efficient than GSM, ZigBee, Raspberry pi due to wide range and signal availability. In [13], WBASN is used in combination with GPS module for sending the real-time recording of sensors to base station. In [14] and [15], Internet of Things (IOT) is used for tracking the health status and location of soldiers by mounting it on the body of soldiers for real-time tracking for appropriate action in the time of crisis. A millimeter-wave soldier-to-soldier communication is proposed in [16] for covert communication that needs to develop the bespoke directive medium access layer. The directional communication will be enabled by numerous adjustments to IEEE 802.11 distribution coordination function. The portable and miniaturized sensor framework along with other transmission units is integrated by utilizing GPS which is then mounted on soldiers in war zone in [17]. It continuously monitors their health and transfer the obtained data obtained to central base station using IOT. Even in [18], wearable technology using IOT is presented for monitoring the soldiers health on battlegrounds along with their locations. The gathered information is transmitted to base station by Mobile Ad hoc NETwork (MANET) and long-range radio (LoRa) transceivers utilizing IoT in encrypted form. Despite being able of providing the information about the health status and location of soldiers, there is still need to improve the secure communication between base station and soldiers for the security purposes. Moreover, sometimes due to lack of network or internet, it is quite difficult to communicate the information which needs to be resolved. Furthermore, the design as well as implementation of the system along with performance enhancement is also a challenging task [19, 20]. The proposed system aims to address these limitations. The contributions of presented work are:

- A system is developed for automatically tracing the GPS coordinates of soldiers.
- A private mesh network is to be created for secure wireless communication between the soldiers.
- SOS feature is included that can send automatic distress signal in emergency situations to base station.
- An application is developed for the base in order to maintain the record of all the data.

The remaining paper includes: The components utilized for the system are discussed in Sect. 2 while Sect. 3 presents the mesh network-based system to track health and location of soldiers. Section 4 discusses the results of the implementation of developed system. Eventually, the conclusion is provided in Sect. 5.

Prerequisites

The prerequisites of the proposed work are as follows:

- NodeMCU (ESP-8266): It is an open-source Lua-based firmware and development board which particularly targets IoT-based applications. It has ESP-12 module-based hardware and firmware which runs on ESP-8266 Wi-Fi SoC from Espress as depicted in Fig. 1.
- GPS module (NEO-6M): It is a well-performing GPS receiver having a built-in ceramic antenna of

Fig. 1 ESP-8266 board

Fig. 2 GPS module

Fig. 3 Heart rate sensor

$25 \times 25 \times 4$ mm that has a capability of strong satellite search. Signal and power indicators are used for monitoring the status of module. The GPS module (NEO-6M) is shown in Fig. 2.

- Heart rate sensor (MAX30102): This biosensor module has an integrated heart rate monitor and pulse oximetry. Figure 3 shows the heart rate sensor which involves photodetectors, optical elements, internal LEDs, and low-noise electronics having ambient light rejection.
- Organic light-emitting diode (OLED): SSD1306 model is used in the presented work which is a monocolor having 0.96-inch display (128×64 pixels) as shown in Fig. 4. It does not require backlight that provides better contrast in dark environments. Moreover, energy consumption is less in OLED as compared to other displays as the energy is consumed by its pixels only when they are on.

Fig. 4 OLED

- Pushbutton: It performs the task of connecting two points in a circuit upon pressing.
- Lithium-ion battery: It is rectangular prism having round edges along with the polarized snap connector at its top. The terminal which is large having hexagonal/octagonal shape (female) is the negative contact and the smaller circular (male) terminal is positive.

Proposed System

As IOT is gaining popularity, so it is utilized for healthcare applications along with the sensors such as medical dispensers, patient telemonitoring, and soldier health tracking [21–23]. In this system also, the location as well as body vitals of a soldier will be continuously tracked such that each soldier will be provided with a device that is capable of tracking their location and monitoring their health using GPS and different sensors. A mesh network will be created to connect all soldiers together in the absence of any internet service, for secure communication. Additionally, each soldier may be provided with an android device with a tracking app that will be able to connect to the mesh network which helps to locate injured soldiers by using navigation feature. If a soldier is injured or in need of help (SOS), the device will automatically broadcast a help message (if vitals falls below a threshold value) to each and every soldier's device. Each soldier's device will show a notification displaying injured soldier's location and body vitals. As there is a field squadron leader for each operation who is continuously communicating with the control unit, he/she will receive the notification about the injured soldier's data on the device which will be automatically transferred to the base camp using available military networks like satellite phone etc.

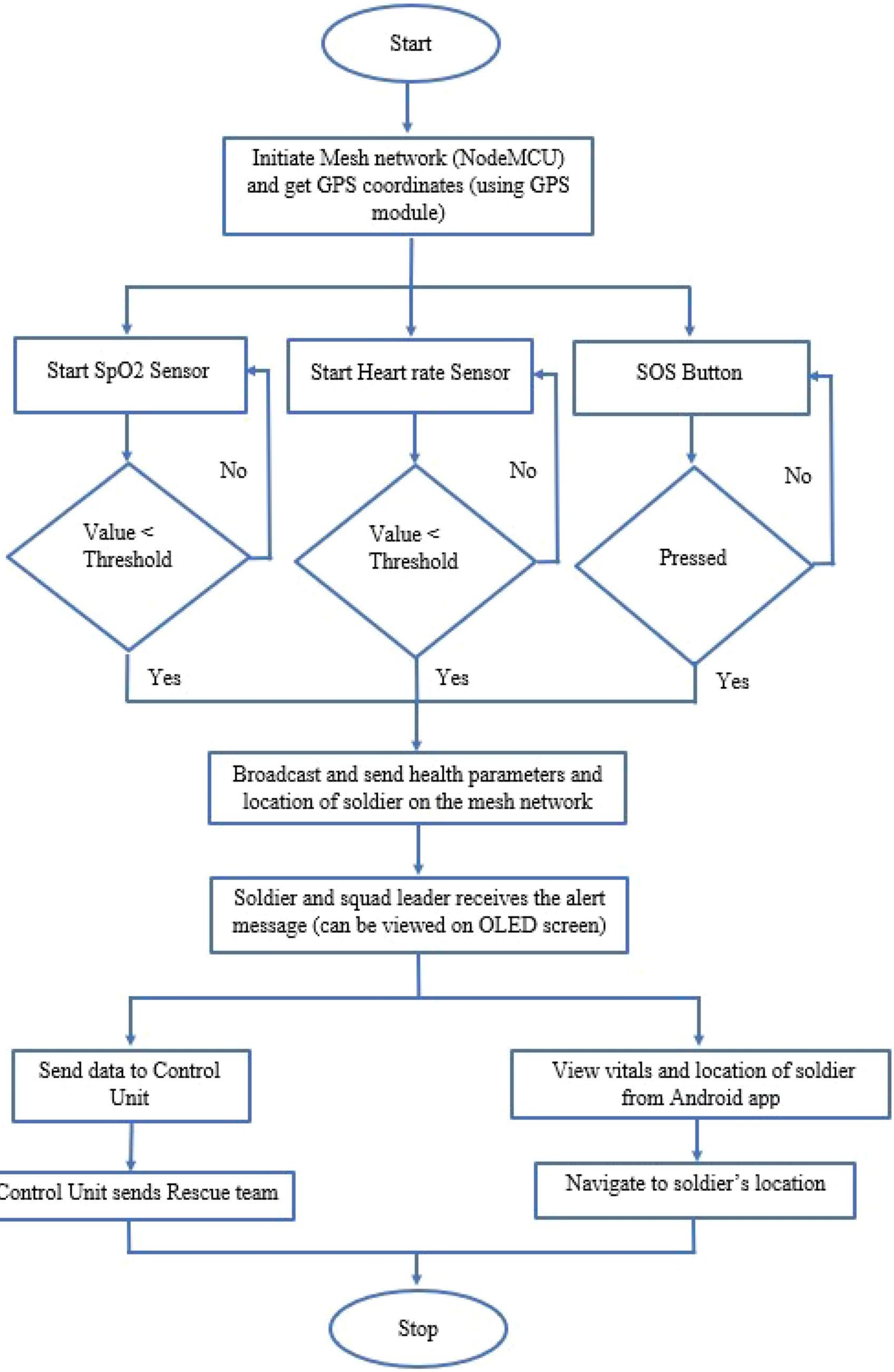


Fig. 5 Flowchart of proposed system

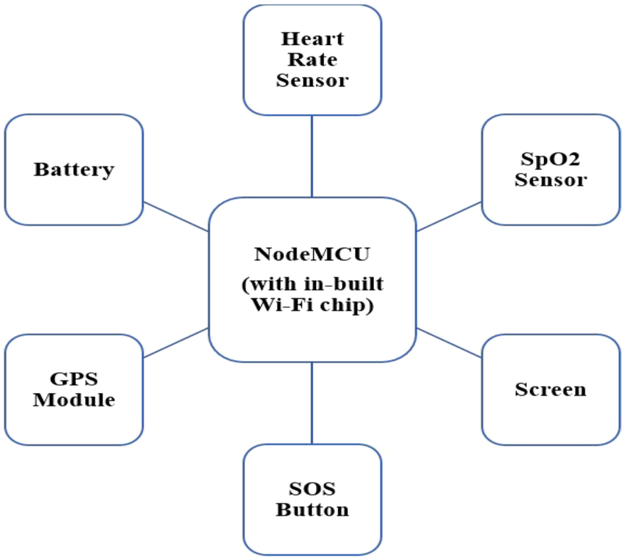


Fig. 6 Block diagram of device

so that they can send rescue teams to help injured soldiers. Squadron leader will also have an android tablet with that tracking app installed so that he/she can guide rescue teams or other soldiers to locate injured soldier and also he/she can disconnect a device from the network for security concerns. And also, because each soldier has been provided with that tracking application, he/she can also navigate directly to the injured soldier without seeking any help from the squadron leader. That tracking app will show the nearest injured soldier on the top of the list so as to fasten the rescue operation. And after locating and rescuing a soldier, the rescuer can broadcast a success notification. This system can also be used for locating a missing soldier. Figure 5 presents the flowchart of proposed work.

System Architecture

The system includes the device used for tracking and monitoring, android device with the tracking app, and unit of squadron leader or sub-master.

- Device: It is based on NodeMCU (ESP-8266) board with inbuilt Wi-Fi chip which assisting in interfacing all different types of sensors like GPS (NEO-6M), heart rate sensor(MAX30102), etc. as shown in Fig. 6. It also facilitates communication between soldiers by utilizing Wi-Fi in mesh topology to create a secure private network. This device also has a small screen to display the notifications and a SOS button. It is powered by a small rechargeable battery. If body vitals fall below a threshold value, an automatic message including GPS coordinates and body vitals will be sent to all soldiers including the respective squadron leader. The message will be visible on the screen connected to the device.
- Android device with tracking app: This app enables each and every soldier to locate other soldiers using offline navigation independently. Moreover, internet connection is not required as every android device has a GPS receiver in it. Using this, soldiers do not need to ask

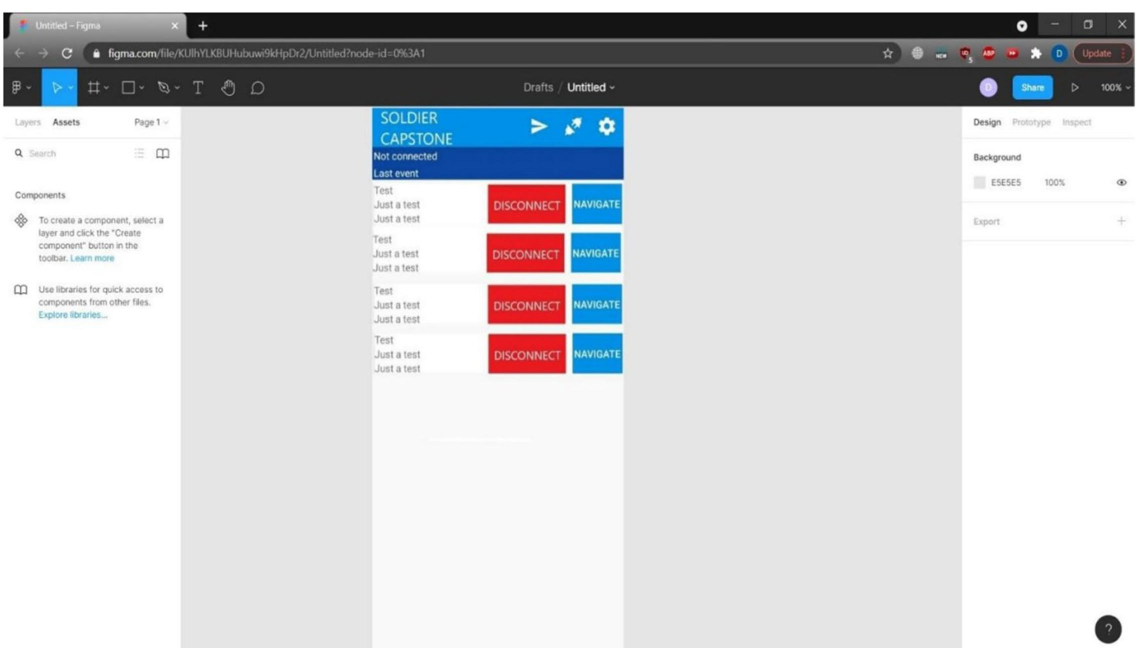


Fig. 7 Frontend design layout on Figma software

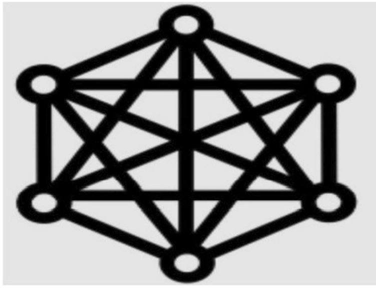


Fig. 8 App icon

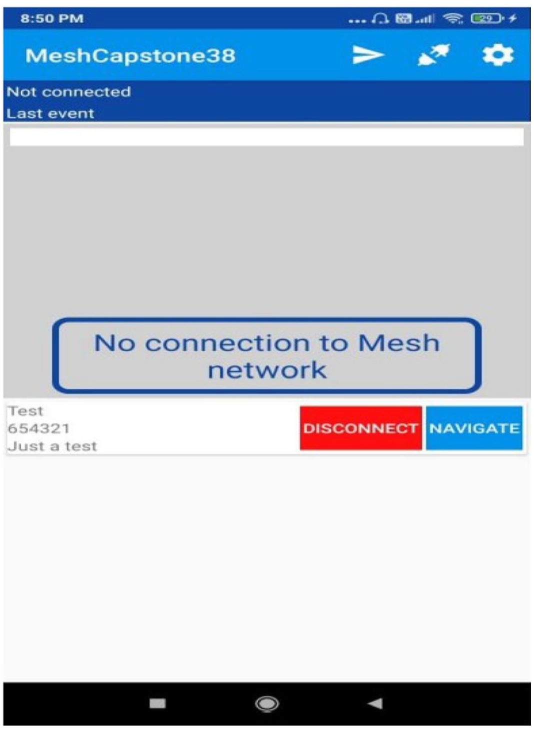


Fig. 9 Android app user interface

directions from the squadron leader. Also, this app shows the body vitals of the injured soldiers to other soldiers, so that they can rescue injured soldier as soon as possible.

- Squadron leader's unit or sub-master's unit: An on-field squadron leader is always available for continuously communicating with the base camp or control unit. Leader is equipped with an additional device capable of connecting to an existing military network such as satellite communication etc. that will help to send the entire report including number of injured soldiers with their body vitals and GPS coordinates to the control unit or the base camp, if the control unit is out of range of mesh network. The squadron leader also has an android tablet with the same tracking app that is installed in soldier's android device but with extra features such as squadron leader can block a device from entering into the mesh network in the case when that device is compromised, i.e., seized by enemy.

Stages of Development of Proposed System

There are various stages involved in the development of this system:

- Design the front end of the android app: The front end is designed using the Figma software as shown in Fig. 7.
- Updating the app icon: The app icon along with different sizes is illustrated in Fig. 8.
- Android app user interface: The user interface of android app is shown in Fig. 9.
- Code files uploaded on Github: The code files are uploaded on the Github as illustrated in Fig. 10.
- Creation of code for mesh network: The code created for mesh network is shown in Fig. 11.
- Hardware Setup: The setup of hardware is done, and output is received from NodeMCU as shown in Fig. 12.
- Layout design using Fritzing software: The layout is designed using the fritzing software. The design for the proposed work is shown in Fig. 13.
- Implementation of circuit: The circuit implementation is carried out on the printed circuit board (PCB) as depicted in Fig. 14.
- Android app development: The android app is developed for the communication. Figure 15 shows the screenshots of app showing message received from different nodes and mesh network credentials while Fig. 16 shows the screenshots of sent messages and selection of node ID to which message is to be sent.

Results and Discussion

After the implementation on the PCB, the individual modules are tested on the basis of simulation as well as hardware. The testing was successful as NodeMCU transferred data using the Wi-Fi protocol as all the sensors were working simultaneously and GPS module also showed accurate

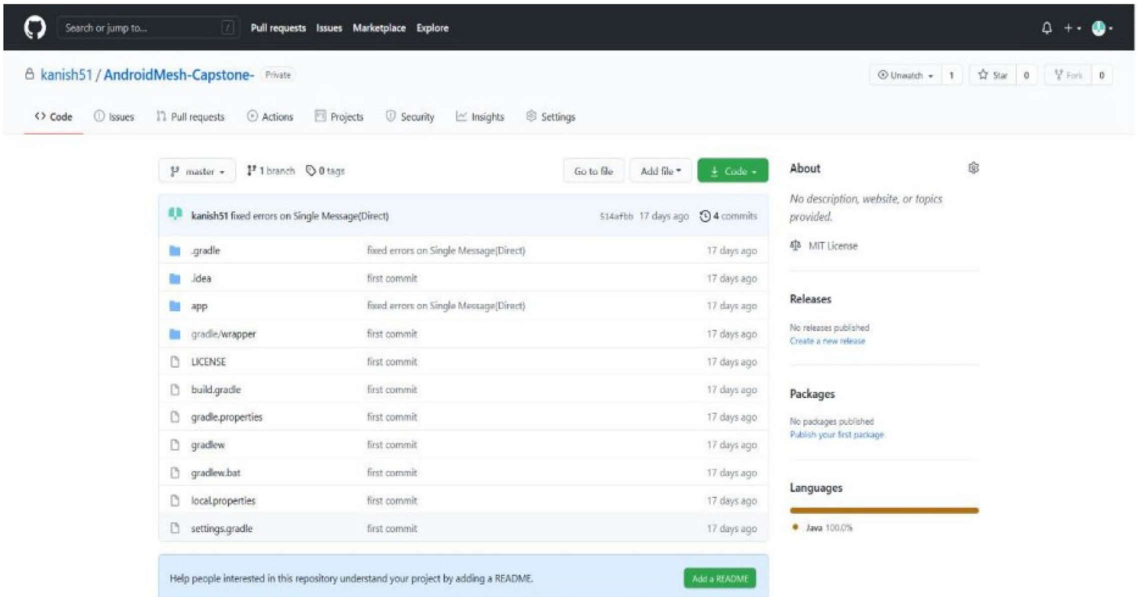


Fig. 10 Code for the mesh network

```
#define   MESH_PREFIX     "Capstone_Network"
#define   MESH_PASSWORD   "somethingSneaky"
#define   MESH_PORT       5555

Scheduler userScheduler;
painlessMesh  mesh;

// User stub
void sendMessage() ;

Task taskSendMessage( TASK_SECOND * 1 , TASK_FOREVER, &sendMessage );

void sendMessage() {
  String msg = "Hello from node '1' ";
  msg += mesh.getNodeId();
  mesh.sendBroadcast( msg );
  taskSendMessage.setInterval( random( TASK_SECOND * 1, TASK_SECOND * 5 ));
}

// Needed for painless library
void receivedCallback( uint32_t from, String &msg ) {
  Serial.printf("startHere: Received from %u msg=%s\n", from, msg.c_str());
}

void newConnectionCallback(uint32_t nodeId) {
    Serial.printf("--> startHere: New Connection, nodeId = %u\n", nodeId);
}
```

Fig. 11 Code for mesh network

location via geographic coordinates. The heart rate sensor and OLED screen were also successfully tested as shown in Fig. 17. The mesh network was successfully created and tested using two NodeMCUs as shown in Fig. 18. Figures 19 and 20 illustrate the output received on the serial monitor and the screenshots of mesh network credentials and received messages on the android applications. Thus, the system works successfully in locating the GPS coordinates

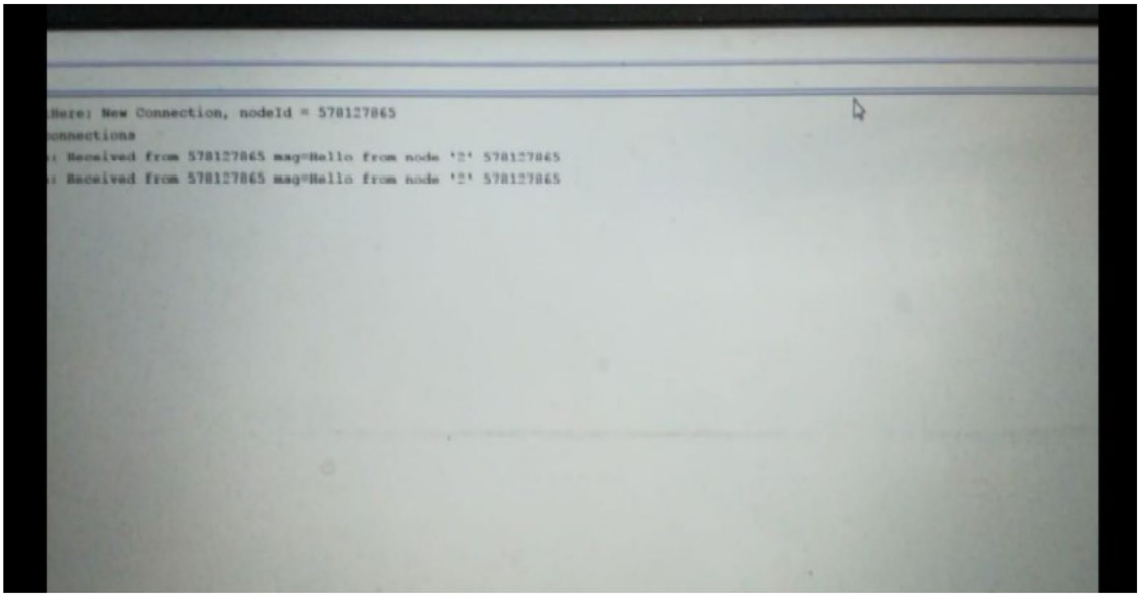


Fig. 12 Output received by NodeMCU

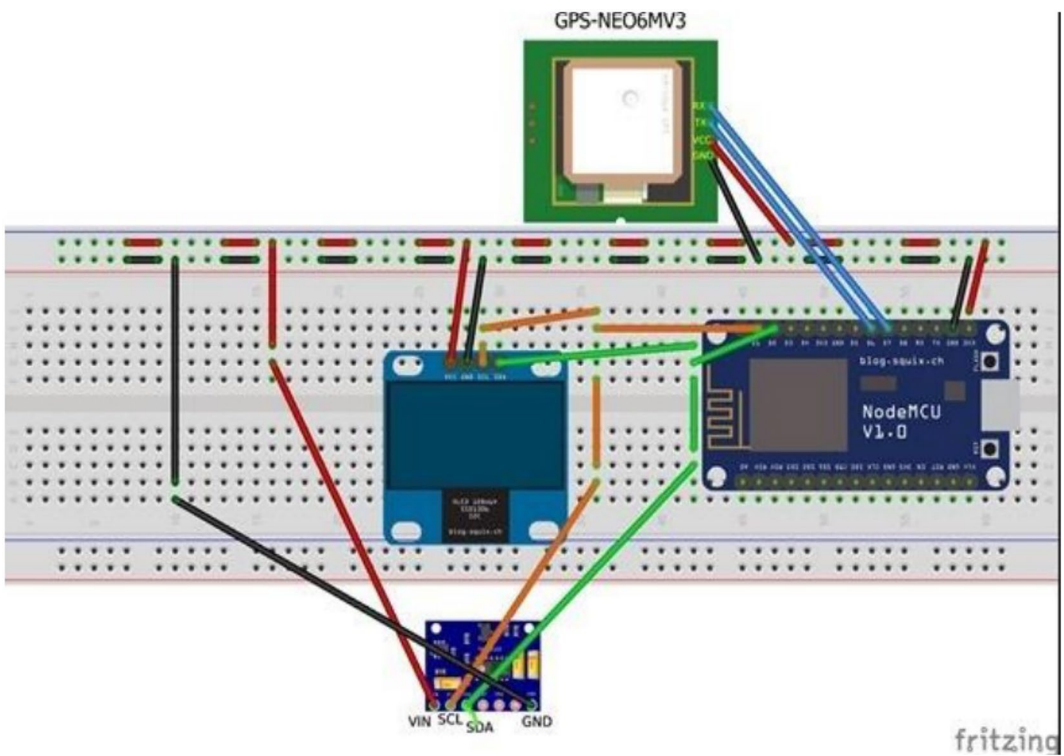


Fig. 13 Output received by NodeMCU

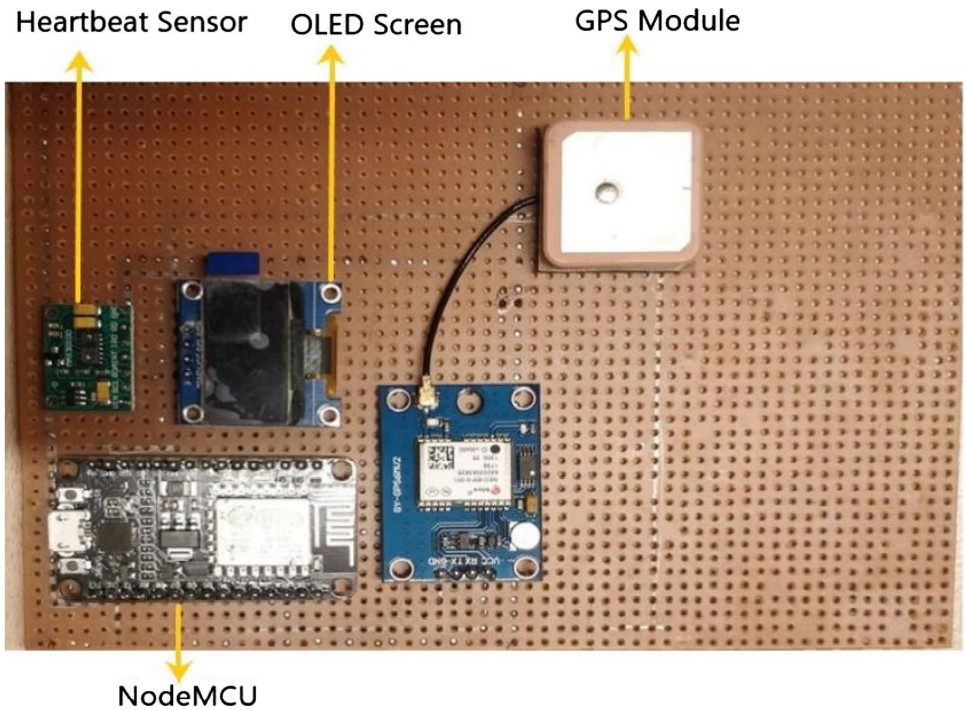


Fig. 14 Circuit implemented on PCB board

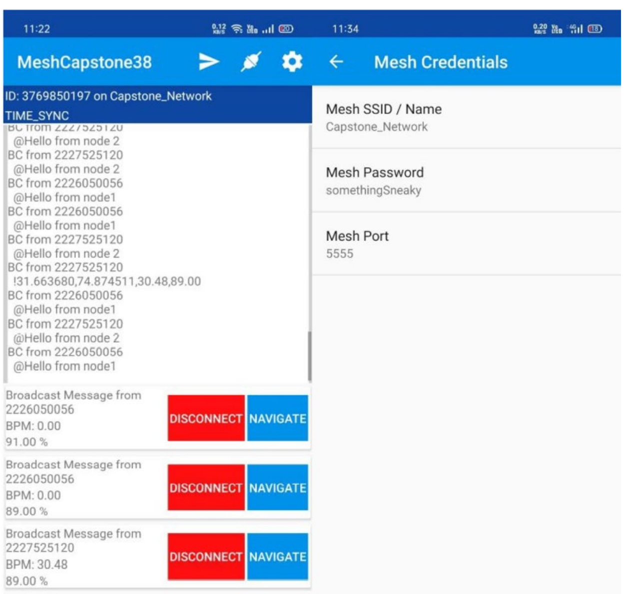


Fig. 15 Android app showing message received from different nodes and mesh network credentials

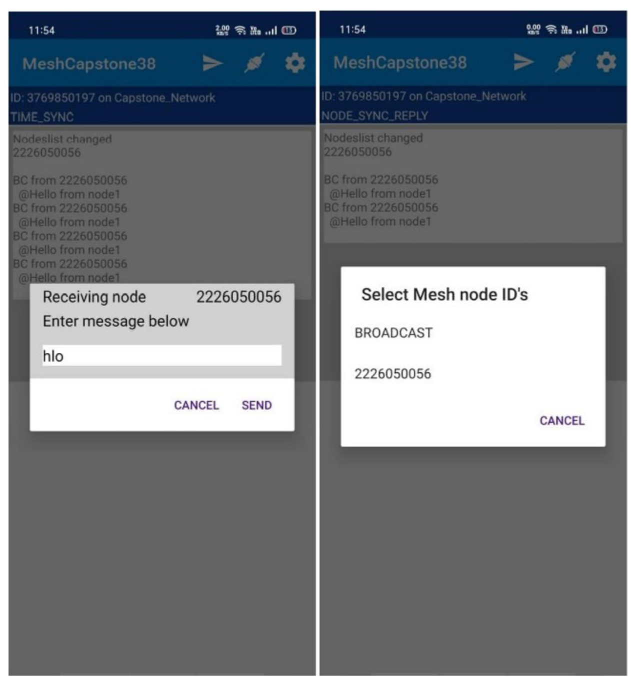


Fig. 16 Android app showing sent messages and selection of node ID to which message is to be sent

of the injured soldiers and can monitor their body vitals continuously.

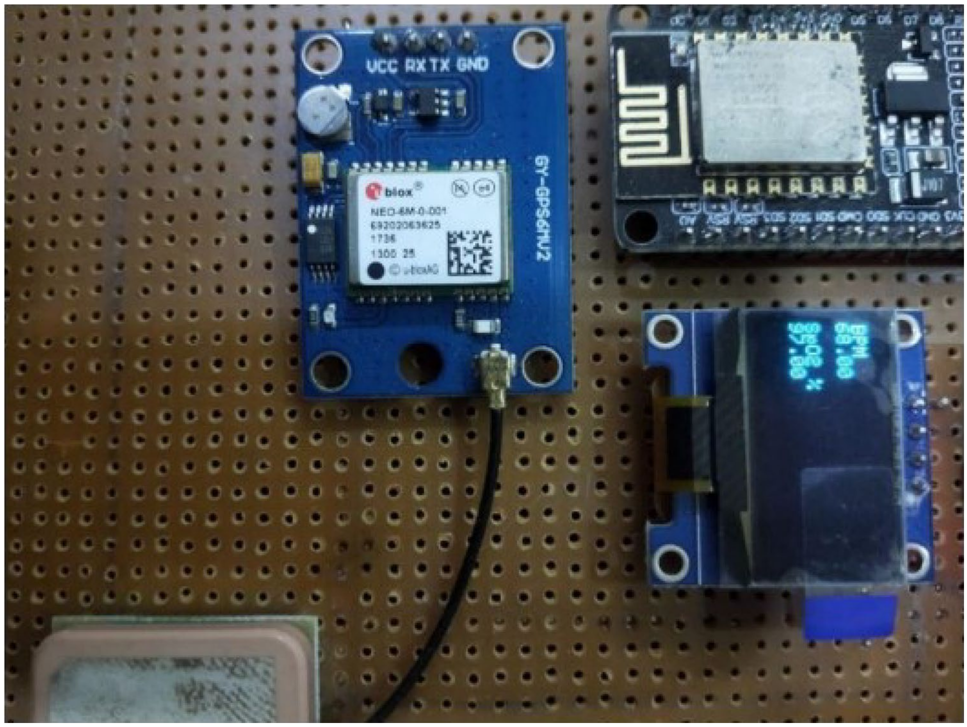


Fig. 17 Reading of heart rate sensor on OLED screen

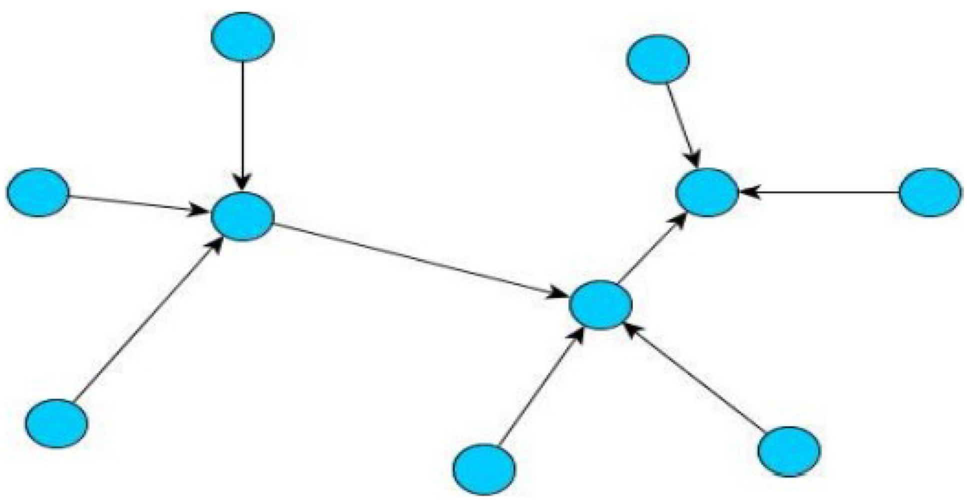


Fig. 18 Mesh network topology

Conclusion

This paper developed a system based on mesh network technology for the tracking of location and monitoring of body vitals of the soldiers in a secure manner. This system is capable of transmitting the data to the squadron leader as well as other soldiers which is obtained from remote soldier using the mesh network and from them to the control unit for saving the lives of soldiers. Moreover, it aids in monitoring the soldier's health, and in case of emergencies, it assists the soldier in getting assistance from other soldiers or army control unit by pressing the SOS button. It is beneficial during the operations of war and rescue because it can be used even in the absence of cell tower or internet. Thus, the presented system ensures the safety as well as the security of soldiers. This work can be expanded by utilizing accelerometer and gyroscope for recognizing the activities of human with the help of machine learning.

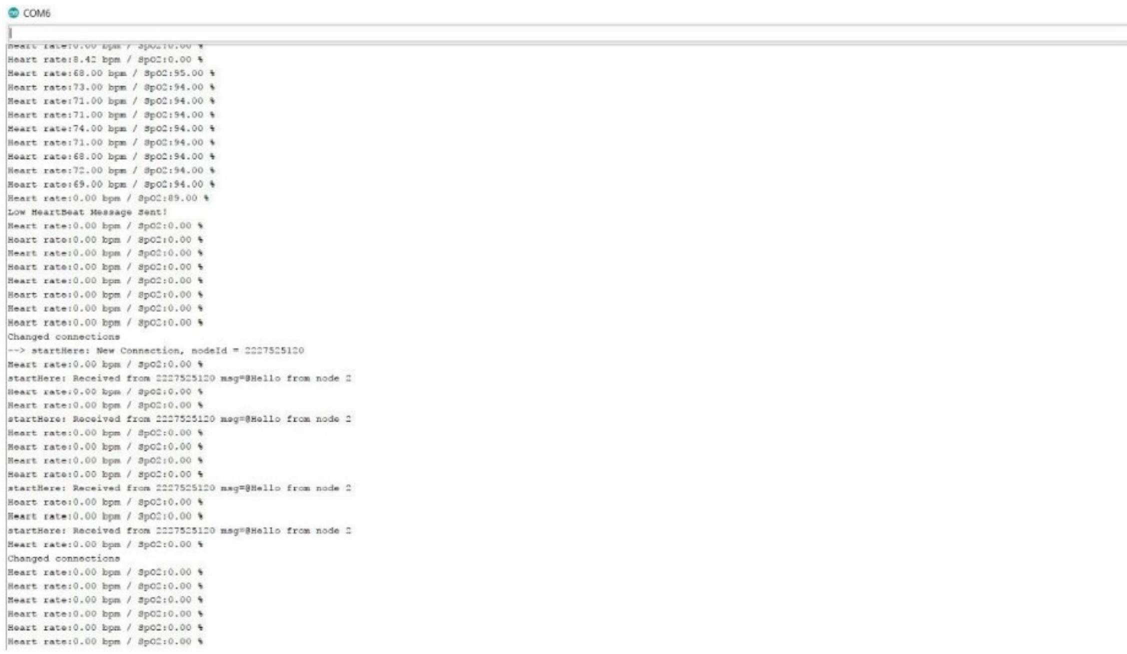
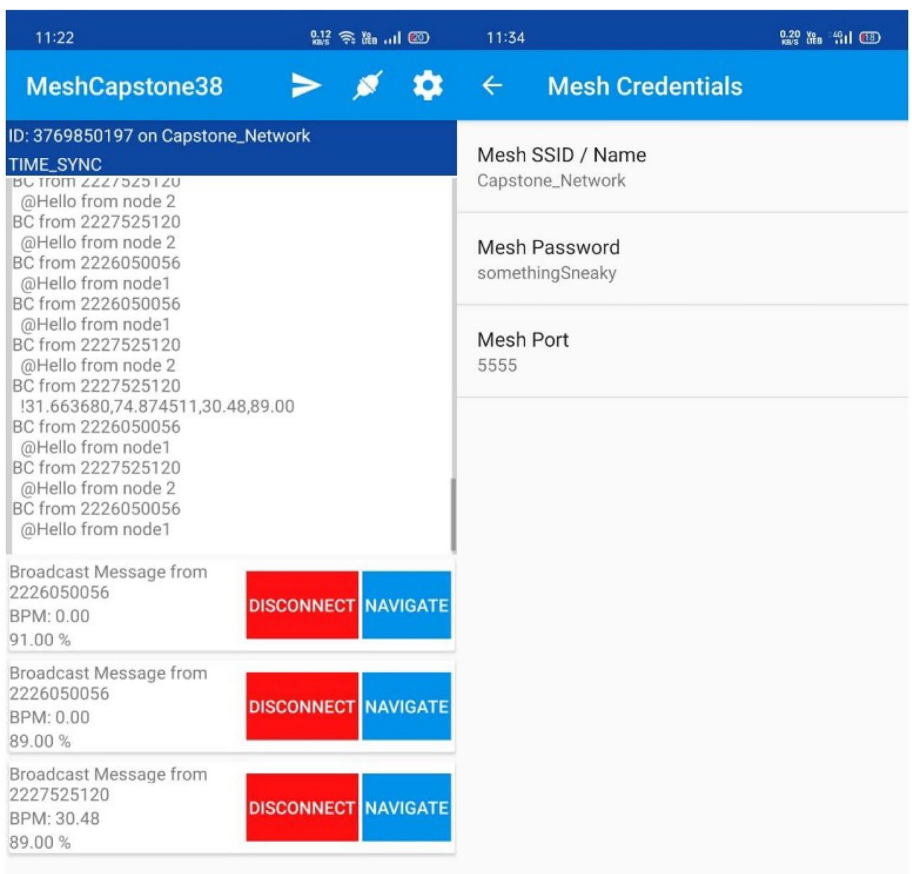


Fig. 19 Output received on serial monitor

Fig. 20 Android app screenshots showing message received from different nodes and mesh network credentials



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Declarations

Conflict of interest There are no additional data associated with this manuscript.

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