HEALTH MONITORING OF SOLDIERS USING EFFICIENT MANET PROTOCOL

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***Abstract*— Information technology plays a key role in collecting, exchanging, and processing information from the disaster-prone areas like war field and international borders. One such significant role is to monitor the health condition of the soldiers in the war field remotely to ensure their safety. The data transmission in these areas is not reliable over wired connections. This paper focuses on designing a health monitoring system which transmits the data such as health parameters of soldiers like temperature, pulse rate, blood oxygen level and Electro Cardio Gram (ECG) over a Mobile Ad hoc Network (MANET) with an efficient routing protocol through nRF24L01 to the control room. The efficient protocol is identified by comparing the different MANET protocols simulated using OMNET++. The body parameters are sensed using different bio-sensors attached to soldiers' body and the data is transmitted to the control room through the mobile nodes in the route (i.e., the soldiers' nodes act as mobile nodes to transfer the data). Since the sensed body parameters are transmitted via offline, it ensures secure communication. The proposed system is also provided with an SOS (Signal on ship) facility, to alert the control room during an emergency via cloud service.**

Keywords*— *MANET, nRF24L01, OMNET++, SOS signal, mobile nodes, bio-sensors.

I. INTRODUCTION

One of the most challenging issues faced by the Indian Armed Forces is the lack of proper communication between the soldier and the control room. This is due to the inappropriate use of routing protocol and wireless technology. The International Institute for Strategic Studies launched the military balance report in 2014 and it confirmed that the causalities caused in the battlefields are more from injuries than direct physical attacks [1]. This can be eliminated by designing a system with an efficient wireless technology and routing protocol.

There are currently numerous wireless communication technologies implemented in health care monitoring systems. Of those existing technologies, ZigBee, Bluetooth and GSM are the most commonly used wireless communication technologies [2-3] in WBAN which have their own inevitable disadvantages like low data rate [4], short distance communication [5-6], and interference [7] respectively. Cognitive Radio (CR) is an enabling technology used for military communication [8-9]. CR utilizes the spectrum efficiently and thereby increasing the data rate.

The health monitoring system for soldiers in the war field requires a wireless communication technology that is capable of communicating over long distances and it should also be able to communicate with several nodes simultaneously. Gui Wu et al. analyzed that nRF24L01 has the best communication range for a full-duplex communication and low power consumption with high data rate compared to GSM and ZigBee communication module [10]. Hence in this paper, the proposed system communicates the sensed parameters from the bio-sensors attached with soldiers' body to the control room over a Mobile Ad hoc Network (MANET) with the help of the nRF24L01 module.

MANET is a group of mobile nodes capable of wireless communication. This network can configure itself dynamically depending upon the position of wireless nodes. So, the implementation of MANET in these disaster-prone zones ensures self-configuration, self-organization and flexibility [11].

The remaining sections of the article are structured as follows. Section II discusses the literature survey. The detailed architecture of the proposed system is explained in Section III. The results and inferences are discussed in Section IV. Finally, Section V concludes the proposed work.

II. LITERATURE SURVEY

In this section, the various MANET routing protocols that are proposed in the recent literatures are discussed. In [12], a comparative study of the Wireless Sensor Networks and their routing protocols is presented by Debnath Bhattacharyya. The performance of the different types of routing protocols like pro-active, reactive and hybrid was compared and concluded that the performance of the protocol depends upon the application of the sensor network. A detailed study on the different types of mobile ad hoc networks (MANET) was carried out by Zakir Hussain et al. due to the disadvantages in the existing technologies for health care monitoring [13]. Shaik Shabana et al. discussed the effect of the routing protocols on the characteristics of MANET like multi-hop communication, power consumption, and so on was analyzed [14]. S.S Jadhav evaluated the performance of the Dynamic Source Routing (DSR) protocol by applying varying network conditions like normal network condition, disaster condition and disaster prevention condition and concluded that the performance deteriorates during the application of disaster condition [15]. Micheal Sung et al. suggested a Destination Sequenced Distance Vector (DSDV) algorithm to transfer the data from the soldier to the control room through an accelerometer. But this protocol causes flooding leading to data duplication [16]. In order to find an efficient protocol for the health monitoring of soldiers in the war field, we have compared the performance metrics of the various MANET protocols simulated using OMNET++.

III. PROPOSED METHODOLOGY

This section deals with the methodology proposed to monitor the health condition of soldiers in the war field from the control room.

A. Block Diagram

The block diagram of the proposed system is shown in figure.1. The system architecture consists of three units. They are:

- The soldier unit
- The substation
- The control room

The soldier unit contains sensors to measure the heart rate, blood oxygen level, ECG and the temperature of soldiers' body. Substations are camps at every few kilometers in the warzone for the storage of soldier's necessities. In the war field, there will always be a substation which is in continuous communication with the main control room. The control room consists of a PC connected with a nRF24L01 to monitor the health parameters. The instantaneous values of health parameters sensed by the bio sensors attached to soldier node 1 are sent to the control room through the substation 1 and from soldier node 2 are sent to the control room through the substation 2 for regular monitoring. The SOS button provided in this unit, when pressed helps the soldier in emergency to send their health parameters to the control room through a cloud for fast communication and immediate action. The data from a single soldier's node will be sent to the substation via multiple nodes in the path between the soldier and substation wirelessly using nRF24L01. The data transmission between the substation and the control room also takes place in a similar manner. The red arrow mark in the figure 1 indicates the path of the data packets between the soldier nodes and substation.

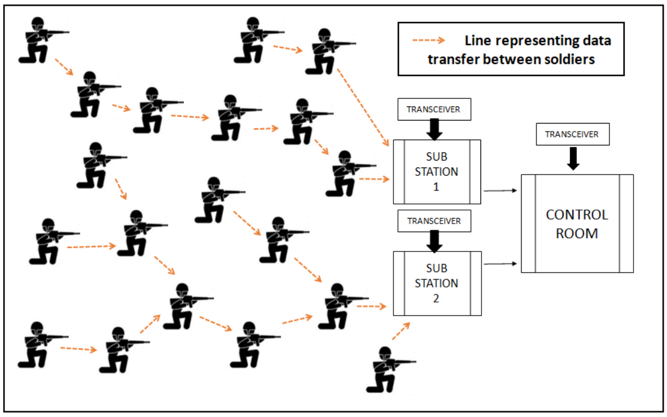

Figure 1: Block diagram of the proposed method

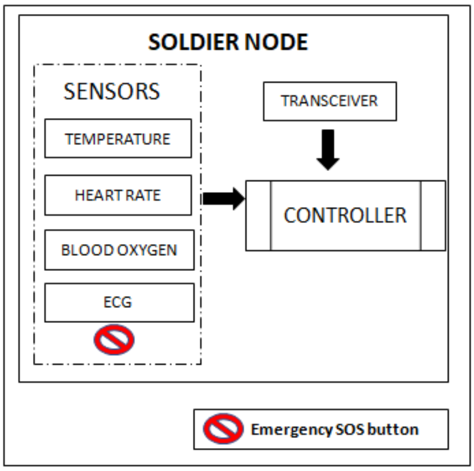

Figure 2: Single soldier node

B. Hardware Components with Specifications

- Pulse Oximeter (MAX30100)
- Temperature sensor (NTC thermistor 10k)
- ECG module (AD8232)
- Transceiver module (nRF24L01)
- Wi-Fi module (ESP8266)

Pulse oximeter sensor measures the heart rate and the blood oxygen level when it is in contact with the finger, earlobe or toe. NTC thermistor is used for measuring the body temperature (-55□ to 125□). AD8232 sensor outputs an ECG signal by sensing the electrical activity of the heart. The nRF module is a single chip radio transceiver for wireless control. ESP8266 Wi-Fi module is a self-contained SOC (System on a Chip) with integrated TCP/IP protocol stack that gives Wi-Fi access to any microcontroller. WIFI module consumes less current between 15uA and 400mA. Arduino board can be used between 6V and 20V DC to power a number of components. The operating temperature range of the ESP8266 is between -40□ to +125□ whereas that of the nRF24L01 and the microcontroller is -40□ to +85□. These are the temperature of the modules, not the ambient air. Therefore, the modules will function normally in the regions of temperature between -40□ to +75□. In the regions of higher temperature, the prototype can be wrapped up with insulating material like silicon polymers in order to protect its functionality from the environmental heat. The synthetic polymers also help in preventing the prototype from external damages.

C. Network structure

The nRF24L01 transceiver module can send and receive data through a channel with the ISM frequency band of 2.4GHz. There are 125 possible channels through which the nRF can communicate and each nRF module is capable of listening to 6 other modules. Thus, this module can create a network of 3125 modules. The nRF module uses a packet structure known as Enhanced Shock Burst. This structure sends each data packet with a packet ID. This new packet structure helps the receiving device to identify whether the packet is new or retransmitted and thus discards the multiple copies of the same data.

This communication is done using MANET with DYMO protocol. The type of MANET implemented is a tactical MANET which is specific and effective for military applications as war zones have no access for fixed infrastructure. The DYMO protocol is a hybrid type of MANET protocol and can behave as both proactive and reactive protocol. In this type of protocol, the routes can be discovered only when there is a necessity for the transmission of data. During an emergency, the data is sent directly to the control room through the Wi-Fi module (ESP8266).

i) Data transmission using DYMO

When a node needs to transmit data, it broadcasts an RREQ (Route Request) message and this message keeps an ordered list of all nodes it passes through. When the RREQ arrives at the destination node, it replies with an RREP (Route Reply) message containing the route information from the origin of the RREQ message. Whenever the data reaches the control room, the RREP will be sent as an acknowledgement to the source node. Once the data is collected in the control room, the monitoring can be done to analyze the soldiers' health condition. In case when the source node does not receive the RREP, it retransmits the RREQ.

ii) Cloud Architecture

ThingSpeak remotely monitors the data from various devices like sensors, transceivers and instruments. In this work, the ThingSpeak cloud service is used as an IOT based Cloud platform to indicating the emergency. This enables the military personal to analyze the health parameters of the soldiers who are in emergency irrespective of the soldier's current location. The online and offline analysis of the data and retrieval of data is very easy since all the data is stored in one central location in the cloud using the ThingSpeak.

IV. RESULTS AND DISCUSSION

To design a better Mobile Ad hoc Network with an appropriate routing protocol, different routing protocols were simulated using the OMNET++ simulator and their performance metrics were compared to opt for the efficient protocol. To determine the best transceiver module, the various parameters like the communication range, power consumption, and data rate were analyzed. In this section, the results of both the hardware implementation of the proposed system and software simulation of the several MANET routing protocols are discussed.

A) Hardware Analysis:

The component setup of the proposed system is shown in Figure 3. The quantitative metrics like Communication range (in meter), Power Consumption (in mA) and Data rate (in bps) of blue tooth, GSM, ZigBee and nRF24L01 are compared and given in table 1.

The data rate and the power consumption of a transceiver module are inversely proportional to each other (i.e.,) higher the data rate, lower will be the consumption of power. Usually, higher data rates are used to reduce the air time of the packet, which helps in reducing the power consumption of the module. From the table, it can be observed that the nRF module has the highest data rate and hence the power consumption is very small. Whereas, the other mentioned communication technologies like Bluetooth, ZigBee and GSM have low data rates and high-power consumption compared to nRF technology.

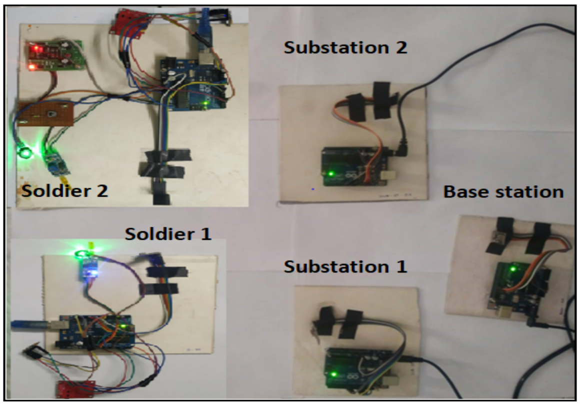

Figure 3: Component setup

Though GSM has a wide range of communication, it consumes more power which is contradictory. Thus, nRF has all the favorable characteristics needed for war field communication and was found to be more suitable for this application.

TABLE 1: COMPARISON OF SPECIFICATIONS OF TRANSCEIVER MODULES

Transceiver modules	Communication range(m)	Power consumption (mA)	Data rate (bps)
nRF	1100	~17	2M
Bluetooth	100	<30	1- 2M
GSM	Not limited	<480	56 - 114K
ZigBee	100 - 150	<40	250K

The radiation exposure from the components are low (less than 1000mSv) that will not affect the human health. Devices such as dosimeter, Geiger counter can be connected to detect the radiation level.

B) Simulation analysis:

Mobile ad hoc network with one routing protocol from each type (proactive, reactive and hybrid) i.e., DYMO, GPSR, AODV and DSDV is simulated in OMNET++ environment. OMNET++ is Objective Modular Network Testbed in C++. The same network conditions were chosen for the simulation of every routing protocol. A network size of 10 router nodes has been considered for the simulation. The packet size and bit rate were set to the default values in the simulator i.e., 64 bytes and 2Mbps respectively. Figure 4 shows the simulation environment of the routing protocols like DYMO, GPSR, AODV, and DSDV respectively.

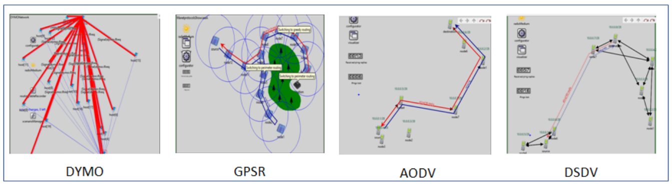

Figure 4: Simulation environment of various protocols in OMNET++

To compare the performance of reactive, proactive and hybrid protocols quantitatively, the metrics namely Packet Delivery Ratio (PDR), Throughput and Average Round Trip Time (RTT) described below are considered. Table 2 gives the collective comparison of the protocols.

Packet Delivery Ratio (PDR): Packet delivery ratio is the fraction of successfully delivered packets. The network with high PDR is said to be more reliable than the one with low PDR. Figure 5 shows the PDR of each network with various routing protocols. The reason for the high PDR of DYMO is due to its ability to quickly react to the changes in the network by updating the information of the node which is affected.

TABLE 2: COMPARISON OF AD HOC PROTOCOL PARAMETERS

Routing Protocol	Packet Delivery Ratio (%)	Throughput (Kbps)	Average Round Trip Time (ms)
DYMO	99.8	3.32	2.38
GPSR	95	2.96	12.19
AODV	58.7	2.29	13.71
DSDV	29	1.28	8.36

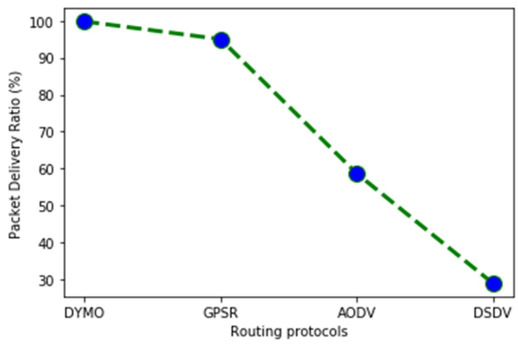

Figure 5: Comparison of PDR

Throughput: It is the average number of messages delivered per unit time and determines the speed of the network. A network with low throughput indicates packet loss. From figure 6, it is identified that the network using DYMO protocol has better throughput than others. Since throughput depends on time, the DYMO being an on-demand routing protocol does not take much time to deliver the packet compared to table-driven protocols.

Average Round trip time: Round trip time is the length of time it takes for a packet to be sent plus the length of time it takes for an acknowledgement of that packet to be received. The network will be fast and reliable when it has a lower RTT. Figure 7 shows that the network using the DYMO routing protocol has the lowest RTT compared to others.

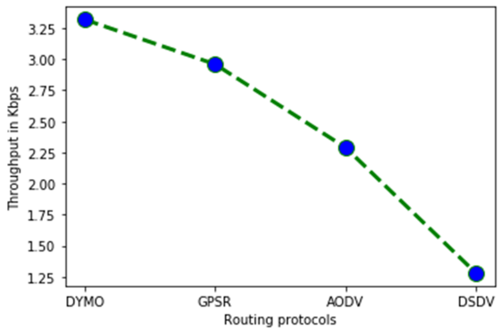

Figure 6: Comparison of Throughput

DYMO executes route discovery only when there is a need to establish a route between nodes for communication, thus reducing the pressure on the network overload. This helps in reducing the round-trip time.

Thus, DYMO protocol was found to have the best performance metrics compared to GPSR, AODV and DSDV.

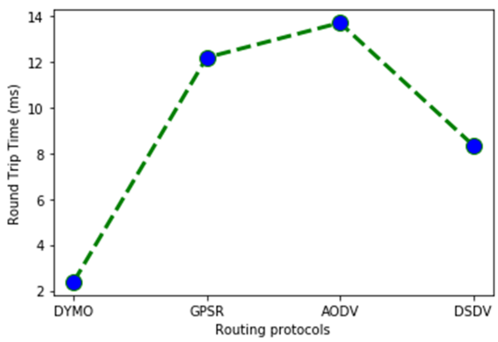

Figure 7: Comparison of RTT

C) *Hardware outputs:*

A Mobile Ad hoc Network using the DYMO routing protocol was designed with the nRF24L01 transceiver module. The sensed body parameters are received at the control room which can be viewed using the serial monitor of Arduino IDE. Figure 8 shows the serial monitor output and the ECG waveform viewed in the Serial plotter at Arduino IDE.

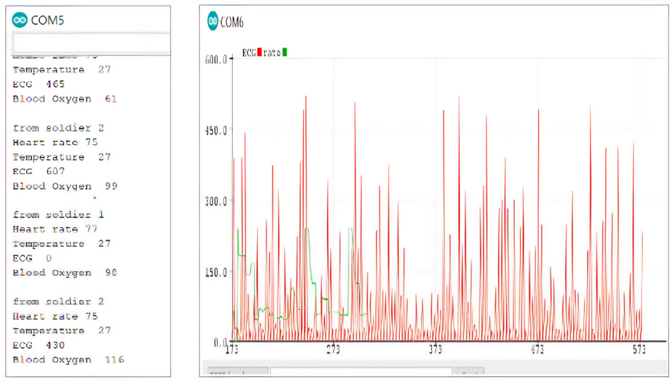

Figure 8: Output at the Serial monitor and Plotter of Arduino IDE

The emergency data during the SOS operation is transferred using the Wi-Fi module and the control room could view the data in the ThingSpeak cloud website as shown in figure 9.

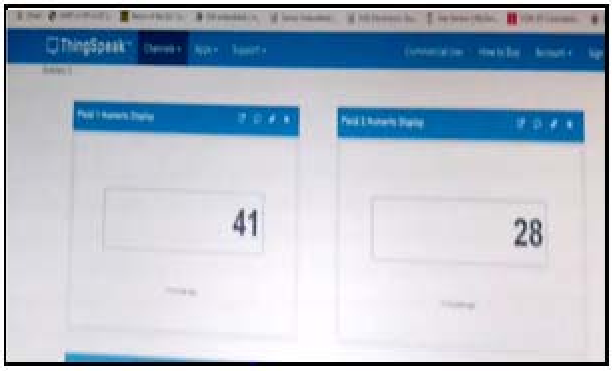

Figure 9: SOS Output

V. CONCLUSION AND FUTURE SCOPE

The proposed system was designed with bio-sensors like pulse rate sensor, temperature sensor, electrocardiogram sensor, and blood oxygen level sensor attached to the soldiers' body and the sensed values are transmitted to the control room through the intermediate nodes in Mobile Ad hoc fashion. The data is transmitted using the nRF module which has the best communication range and data rate compared to the other wireless technologies like Bluetooth, ZigBee and GSM. The simulation of various MANET routing protocols like AODV, DYMO, GPSR and DSDV using OMNET++ and their quantitative performance comparison showed that DYMO was found to have a better performance for the application like health monitoring. Hence a MANET is implemented with DYMO routing protocol in the proposed system. The SOS signal is transmitted to the control room through an ESP8266

Wi-Fi Module. This service would be of great aid for the soldier in the war field and during rescue operations.

In the future, the proposed system architecture could be extended in many ways. The health parameters of the soldiers can be communicated over the control rooms in different cities using LoRaWAN technology as it supports long-range and fast communication. This will help to get assistance in panic situations where the soldier cannot be treated with the medical facilities available in the control room located near to the war field.

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