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Software Defined Radio for WSN in Real-Time Healthcare Monitoring System

Veeraprathap V, Ashish Hegde, Supriya V Kurpad, G NarendraKumar

Research Scholar, Department of Electronics and Communication Engineering. U V C E, Bangalore University, Bangalore, India.
Graduate Student, Department of Electronics and Communication Engineering. U V C E, Bangalore University, Bangalore, India.
Graduate Student, Department of Electronics and Communication Engineering. U V C E, Bangalore University, Bangalore, India.
Professor, Department of Electronics and Communication Engineering. U V C E, Bangalore University, Bangalore, India

ABSTRACT: Radio communication platform that has major part of the functionalities executed in a personal computer or embedded system is called a Software Defined Radio (SDR).This design prototype allows the users to implement a wide range of protocols, configurations and modulation techniques on a single hardware platform. Wireless Sensor Network (WSN) refers to interconnection or a web of dedicated and spatially separated sensors that monitor various environmental factors to store them at the server which are infrastructure-less networks consisting of mobile nodes that have the ability to communicate together without any centralized unit.

An improved Ad-hoc On-demand Distance Vector (AODV)routing protocol is implemented for route discovery and data transfer between the SDR nodes that reduces latency, avoids collision and has efficient use of bandwidth. Additional features like adaptability to different modulation schemes, fast switching between various protocols, security, frequency hopping and low latency are applied on each of the nodes. SDR plays a dual role that establishes interoperability between wireless medical sensors devices present at the hospital due to its reconfigurability feature. Simulations are carried out in MATLAB and NS2 to prove their networking capabilities and the SDR is coded with GNURadio.

KEYWORDS: Software Defined Radio, WSN, AODV, GNURadio, Adhocnetworks,NS2, MATLAB.

I. INTRODUCTION

Communication system plays a vital role in transferring data from Wireless Sensor Networks (WSNs). Considerable flexibility and security to the user is an integral part of any communication technique. In hospital environments, its applications include the seamless interoperability of wireless medical devices and WSNs in a common communication platform for medical environmental surveillance.

VeeraprathapVetal.[1],have proposed a Medical Sensor Network-based system that includes a health care system to monitor activity and physiological parameters of elderly people suffering from various chronic diseases that help them make an accurate diagnosis for better treatment and also enables communication for the person having a speech disorder. Remote Healthcare monitoring is provided for old age and paralytic patients that enables them to stay at their comfortable homes instead of being in expensive healthcare facilities. The proposed system is an extension of the above-described work.

J.Mitola coined the term “software radio” first and characterized some of its architectural concepts[2].The characteristics of SDR including the aforementioned waveform flexibility make it an apt solution for communication issues present in health monitoring systems and in-hospital environments. Interoperability of medical devices due to their operation at different frequencies and communication protocols are creating new challenges in WSNs employed in medical practice [3]. Hence, SDRs can help bridge this gap and contribute to more seamless interoperability between these devices by employing its features like communicating at any preferable bandwidth, frequency, transmit power, modulation technique and data rate by corresponding software update [4].

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WSN is an infrastructure-less wireless network that employs several sensors in an ad-hoc fashion to track the system, physical or environmental conditions. Considerable improvement can be achieved in the way the patients are monitored in an infirmary or a hospital by employing WSNs in healthcare systems. They collect, send and monitor patients' health parameters such as blood pressure, body temperature, pulse rate, wirelessly to remote monitoring systems. The ability to let hospitalized patients move around is vital to promote their quality of life and also enables them to seek immediate medical attention.

In the AODV routing protocol, the arbitrarily generatedrouteimplementsaroutedeterminationprocess,Fig.1. Three control packets viz. RREQ, RREP, RERR. While a message needs to be sent from originator node to the destination node, RREQ control packet is broadcasted to its neighboring nodes during the absence of a predetermined route. Routing tables of these nodes are verified and updated after receiving the packet,followed by setting a backward pointer towards originator node along with a forward pointer to the destination node in their routing tables. An RREP message is sent back to the originator node on successful reception at the desired destination node,else RREQ message is rebroadcasted to the other corresponding nodes. A fresh enough route is selected by the node for determination of the route.

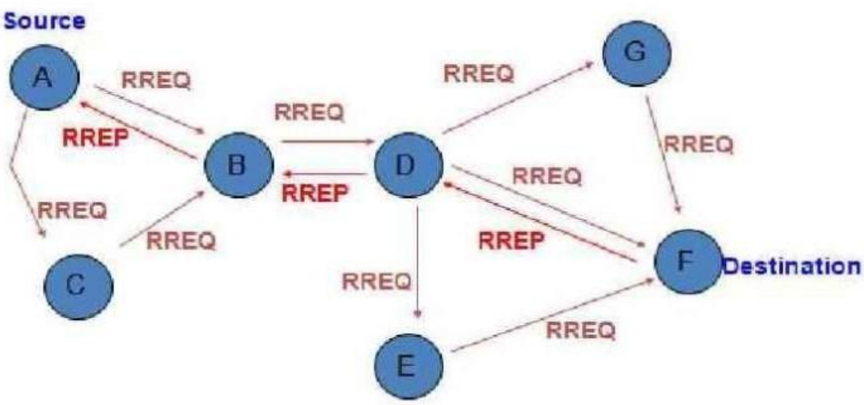

Fig 1: AODV protocol network diagram

II.RELATED WORKS

SDR being a rich field of interest in the wireless communication domain has attracted a good number of researches involving SDR-based mobile ad-hoc networks.

Chávez-Santiago et al. [5], have implemented an SDR-based WSN in hospital environment. Here, SDR serves as a gateway that is responsible for collection of data from different protocols such as Bluetooth, ZigBee, Wi-Fi, etc.

Oduolaetal.[6],have implemented the collection of data from sensor nodes with an USRP cluster-based topology. The SDR functions as a bridge that helps in storing data and transmitting it to the ground station. The protocols employed in their work areZigBee and Wi-Fi.

S. Hassayoun et al. [7], have developed the SDR Bridge for WSNs that adds a layer of AES security over the sensor data. They employ LoRa for transmission and reception of sensor data and hence they have introduced two SDRs that act as a bridge between the LoR a transmitter and receiver.

IrumNosheen et al. [8], have proposed a system for multihop, self-healing and self-forming ad-hoc networks employing TDMA-based cross-layer MAC protocol (CL-TDMA).Reservation-based MAC protocols utilize the empty slots of CL-TDMA technique. Efficient route calculation is done along with the call setup phase of SDRs in cross-layer architecture that reduces the network layer route calculation overhead, call setup delay and latency.

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Aforementioned articles depict the integration of various communication technologies within the same network can be achieved through the combination of IoT Technologies and SDR. LoRa protocol is simulated with the help of open source simulator developed in MATLAB[9].

III. SYSTEM DESIGN.

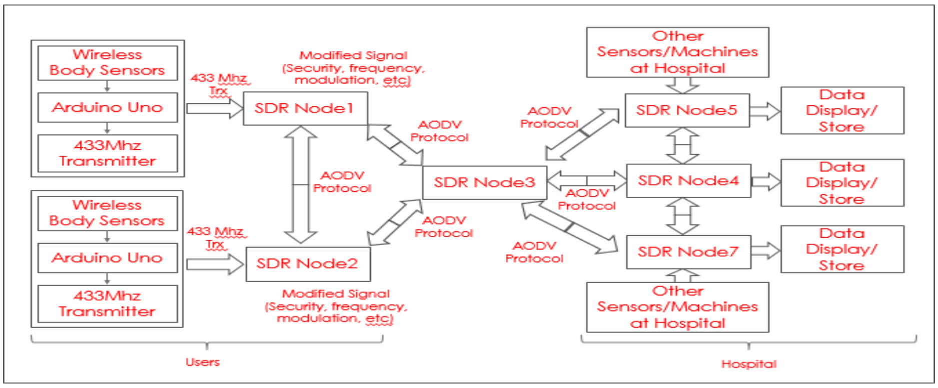

Fig.2.Block diagram of system setup

The entire system with SDRs is implemented in 3 phases for the ease of carrying out simulations at 3 different areas are considered, Fig.2. First, the SDRs at the user end that collects the data from sensors via Arduino microcontroller. Second, that form and maintain the ad-hoc network and finally at the hospital that takes up an additional job of interoperability along with being a part of the ad-hoc network.

A. Communication between sensors and SDR

The working of the health monitoring system typically depends on the sensors that monitor the parameters. Every monitoring system consists of a fall detection sensor, temperature sensor, eye blink sensor, moisture sensor and heart rate sensor. Each sensor system uses a group of sensors for collection of required data for the desired application and it's transmitted into an Arduino microcontroller as digitalbits.A433MHz transmitter connected to the Arduino is employed to transmit the sensor data to the SDR,Fig.3.

Fig.3.Setup for transmission of sensor data via 433MHz RF transmitter

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Each of the sensor systems has a corresponding SDR connected wirelessly (in range) to it. All the data from the sensors being unsecure due to no data encryption are transmitted at regular intervals of time. Once the SDR senses the data being transmitted from the sensors, it receives the modulated data wirelessly from the sensor's 433MHz transmitter, demodulates and begins to process the information adding a layer of securityi.e.,AES encryption to the received data carried out with the help of GNU Radio as a flow graph followed up by having additional features like changing the sampling rate, operating frequency to avoid interference and frequency hopping (to avoid jamming) Fig.4.The SDR being a part of the Ad-hoc network, periodically scans the known frequency ranges during its idle state to check any data is being transmitted from other nodes operating in different frequency or modulation techniques. At any point in time, there comes are quirement of having demodulation of multiple communications standards like LoRa, Wi-Fi (2.4 GHz), etc., the flow graph can be updated in the GNU Radio software to accommodate the new additions very quickly. Finally, it retransmits the data to other SDR nodes present in the ad-hoc network with the help of the AODV protocol.

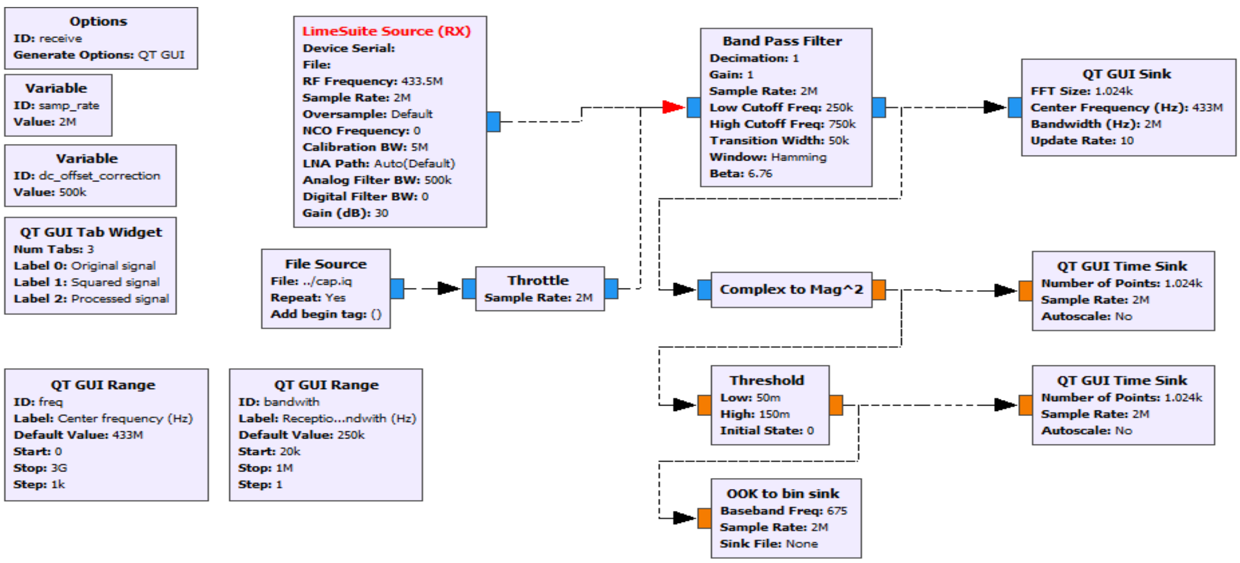

Fig 4.GNU Radio flowgraph of 433MHz OOK receiver

A. Communication in SDR based Ad-hoc network

The AODV protocol is implemented between the SDR nodes to provide a robust, fast, reliable routing and data transfer. Being a reactive protocol it begins to find the route only once there is a requirement to transfer the data between the source and destination. Each of the SDR nodes prepares the routing table and routes the data packets accordingly. A decentralized network of SDRs makes sure that even during the failure of any nodes the network will not collapse. This process of data transfer between the SDR nodes from the user (inhops) continues until the data reaches the destination SDR node(in hospital).Here ,the AODV protocol for the Network(NET) layer is simulated in MATLAB and NS2 simulator having the Medium Access Control (MAC) protocol being implemented with Time Division Multiple Access (TDMA).The empty slots in this method are reused and data communication is collision free.SDRs have multi-hop routing and low call setup time due to the implementation of Cross-Layer Architecture for MAC layer and Network (NET) Layer that makes sure that a bandwidth-efficient and collision-free communication is taking place. In Cross-Layer TDMA (CL-TDMA) and Slot Allocation (SA) algorithm, exchange of AODV control packets occur in the control phase followed by transmission of data and voice in data transfer phase.

Collision-free transmission between SDRs is done in empty slot(s) that are computed by analyzing the information obtained from exchange of control packets between all communicating nodes in the vicinity by all the active radios.

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The simulation is done only at the NET layer implementing AODV protocol with 9 nodes:a-i,by selecting the sender and receiver nodes. This MATLAB program has a GUI structure for easier analysis and design that can be scaled to a higher number of nodes as per requirement,fig.5.Finally displays the number of hops, routing table and traffic statistics.

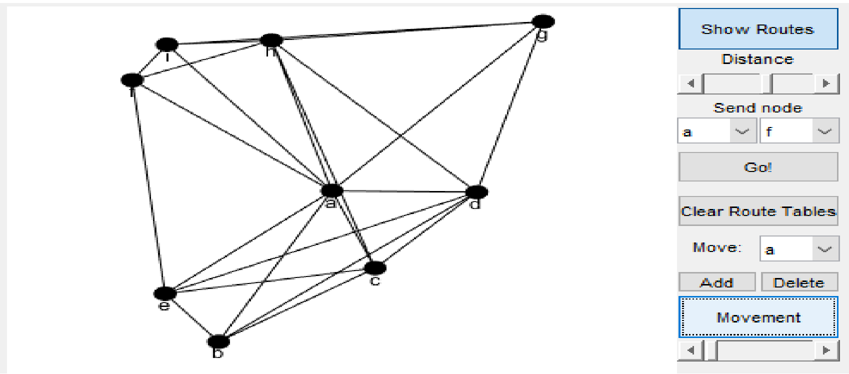

Fig.5.Setup for AODV protocol nodes(a-i) in MATLAB

B .Dual Role of SDR at Hospitals

In the hospital, the SDRs play another important role apart from being the nodes of the ad-hoc network and are responsible to make sure that the consultants receive the data from different sensors/ medical devices seamlessly without having a dedicated receiver or demodulator for each of the medical devices as they are having different modulation schemes and frequency of operation. Here,SDR serves as the mediator that singlehandedly receives the data from a varied number of wireless devices that operate on different protocol standards like ZigBee,Bluetooth,Wi-FiandLoRa.

This functionality can be achieved by having a single GNU Radio flow graph that is implemented on the SDR that has all the demodulation capabilities of all these 4protocols.The flowchart, describes the methodology that is proposed to carry out this objective, Fig.6. During the idle state, the SDR scans its complete frequency space to monitor the data traffic. The 4 protocols being transmitted at different frequencies can be used as a measure of identifying the right one at the SDR i.e.the protocol standard is identified at the SDR end based on the operating frequency and chooses the right flow graph to implement. Hence, with the help of a single SDR connected to the device, it can display/store the incoming data.

The simulation is carried out to receive all 4 protocols as mentioned above employing a single SDR in MATLAB. The Wi-Fi(802.11a) signal transmission and reception are simulated in Simulink with the complete transceiver model having 3 nodes. LLC layer generates data packets that have random arrival time at each node. Up to 4 data frames could present in each data packet.20Mbit/sec is the system bit rate and 126 bytes is the length of data frame payload. Two-path Rayleigh channel model is used as transmission medium with 50Hz Doppler frequency spread and 25Db (Eb/No)AWGN.

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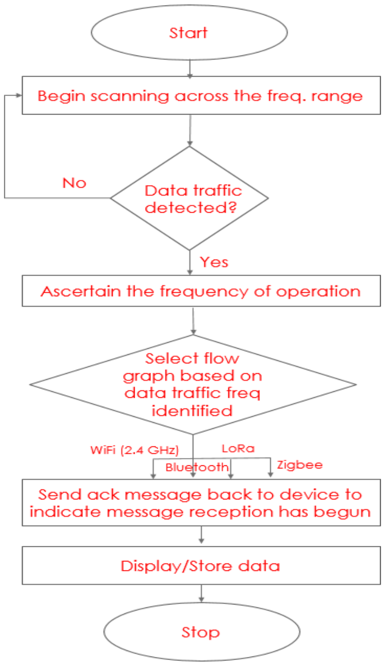

Fig.6. Flowchart for protocol selection in SDR

Next,a MATLAB simulation is carried out for the generation and reception of Bluetooth signals implemented with the help of the Communications Toolbox Library for the Bluetooth Protocol. Input for the Bluetooth LowEnergy(BLE) receiver can either be the simulated signals from the BLE Transmitter or real-time signals received from the LimeSDR with the following specifications:

- Range of transmission frequency:2.4-2.4835GHz
- Radio Frequency(RF)channels:40
- Symbolrate:1Msym/s
- Modulation: Gaussian Minimum Shift Keying(GMSK)
- PHY transmission mode:LE1M-uncoded PHY with the datarate of 1Mbps.

Furthermore, a simulation is carried out for the reception of ZigBee(801.15.4) signals in MATLAB. Here,a dataset of the transmitted raw ZigBee signal is taken from the repository and used as the input to the receiver. As the ZigBee communication protocol uses OQPSK(Orthogonal Quadrature Phase ShiftKeying)modulation scheme, the reception is simulated with the help of MATLAB Communications Toolbox. Lime SDR mini radio is employed as a practical receiver enabling this functionality in the 2.4GHz band and makes use of decoded signals recorded from commercial ZigBee radios(taken from the repository).

The final protocol is the Long Range abbreviated as LoRa and is also simulated on MATLAB using an open-source code. This simulation gives a very close approximation to the functionality of the LoRa device in real-time conditions. This network design incorporates LoRa modulation and coding scheme that makes the system resemble a typical LoRa transmitter or receiver. It can be utilized network designers to calculate the performance of the network

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prior to its physical deployment with the help of having more accurate tools that can emulate any propagation environment.

IV. SIMULATION RESULTS

The simulation is carried out in phases to test each component in the model described in the previous section.

A. Communication between sensors and SDR

To begin with,the reception of 433MHz RF signal wirelessly from the health sensors is done and the results are very pleasing. The SDR does a fine job in the reception of the OOK signal from the 433 MHz transmitters. Here, the SDR has to be tuned from the computer to first identify the precise frequency of operation. This is done by sweeping the oscillator of the mixer in the 433MHz range to obtain a spike in the spectrum analyzer followed by tuning of SDR to that frequency, Fig.7. Once the tuning is complete, the signal is received and is recorded as a .wav file for testing purposes .Finally, with the help of Audacity software ,the received ASK(OOK) modulated signals can be visualized,Fig.8.

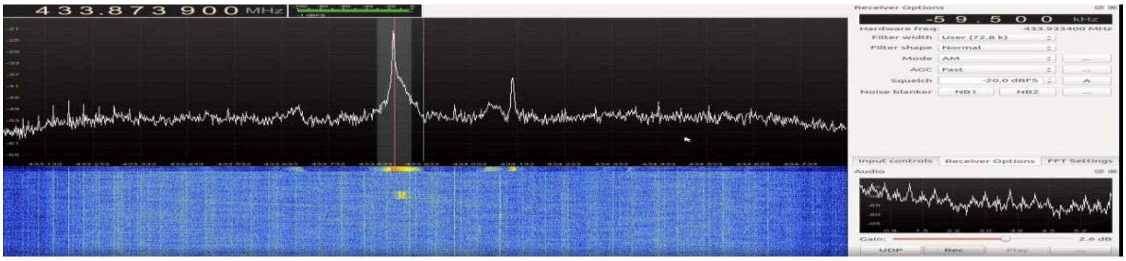

Fig.7.Spectrum Analyser showing a peak at 433.873 MHz

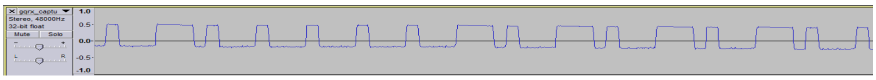

Fig.8.Received OOK modulated signals in the SDR

B. Communication in SDR based Ad-hoc network

AODV protocol is simulated on both NS2 and MATLAB to give visual understanding of the nodes present in the ad-hoc network, whereas MATLAB gives the set of parameters that is helpful for the performance analysis of the AODV protocol. The AODV network shown contains 22 nodes and the main node is acting as a server to send the data,Fig.9.The nodes are designed at specific coordinates that also act as mobile nodes that are specified during their application in the health monitoring system. Every node in the network applies the protocol mechanism to find its route to the destination node. The transfer of the data packets is seen in the simulation.

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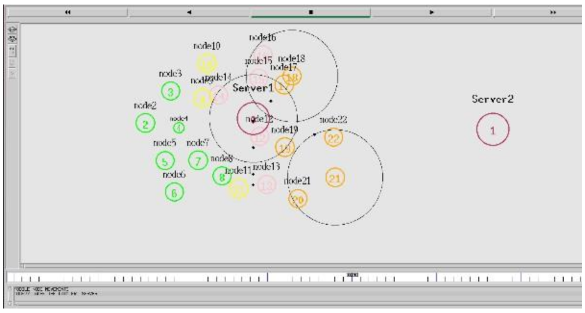

Fig. 9.NS2 simulation of AODV protocol

The MATLAB simulation gives the following results,Fig.10-12.The simulation inputs can be adjusted in the MATLAB code to include as many nodes as possible. The current simulation is carried out using 9 nodes. Based on the wireless range (the maximum distance that a node can establish communication) given in the inputs for each node, the routes are created with solid lines, Fig.5. Messages are exchanged for the establishment of routing between the nodes and it is recorded in the routing table, Fig.10. Finally, the propagation delay and the number of hops are calculated and plotted, Fig.11. The traffic statistics are also plotted which gives an idea to compare quantities like the number of hops, transmissions, and propagation delay,Fig.12.

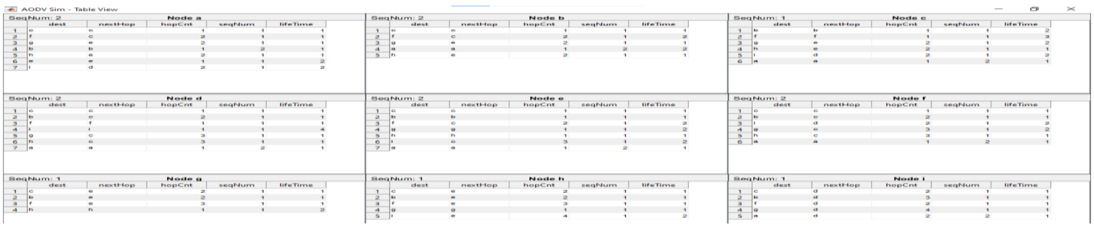

Fig 10.The routing table of AODV simulation for 9 nodes

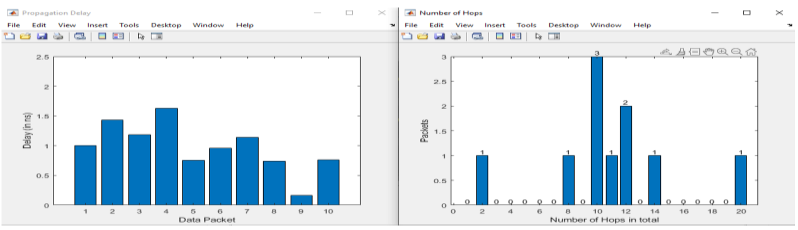

Fig.11.A) Propagation Delay and B) Number of hops

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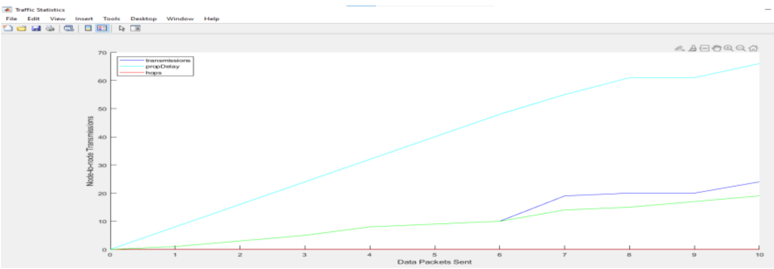

Fig.12.AODVTraffic Statistics

C. Dual Role of SDR at Hospitals

The first simulation is of the Wi-Fi communication protocol(802.11)carried out with 3 transceiver nodes. Traffic at the transmitter end and received signal power at the receiver end are plotted for analysis, Fig.13 and Fig.14. It is concluded that an Ack frame is sent to signify a successful transmission although among all three nodes or between any two nodes collisions are possible, high network throughput requires a short turnaround time and ALOHA-based MAC due to its use of carrier sense is less effiecient than CSMA/CAMAC.

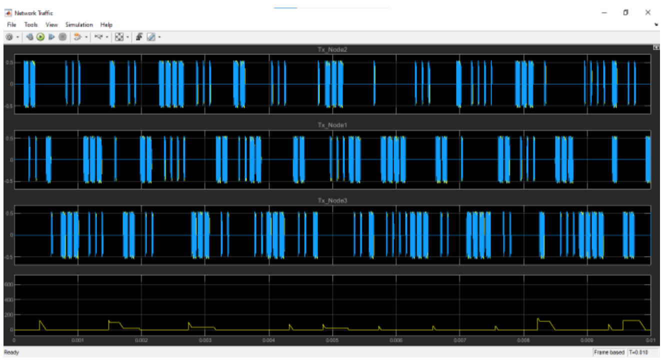

Fig.13.Network Traffic at the Wi-Fi transmitter end

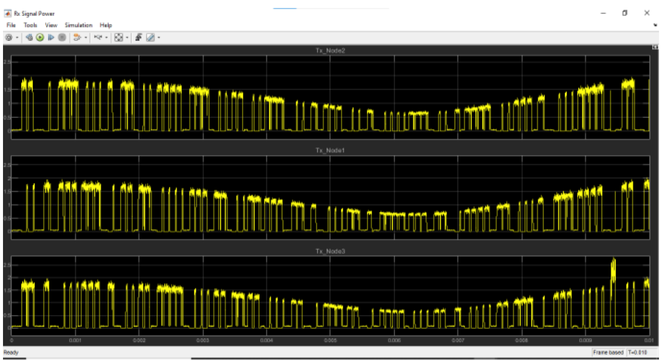

Fig.14.Wi-Fi Receiver signal power

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The second simulation is of the BLE Receiver in MATLAB that makes use of the data produced by the BLE Transmitter that is saved in a file, captures the data packets, processes and finally decodes. It can decode and plot real-time data by connecting an SDR to the computer. The received waveform is plotted and visualized with the help of Spectrum Analyser,Fig.15.The packet error rate is computed based on the decoded packet information.

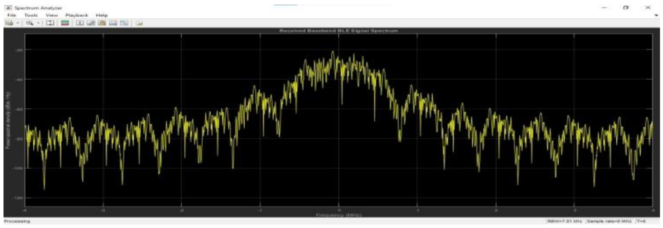

Fig.15.The waveform of the received signal in the BLE Receiver

The third simulation consists of the ZigBee communication protocol (802.15.4) in MATLAB. The raw signal transmitted by a ZigBee transmitter is saved in a file and is used as the input to the Receiver. All the operations are carried out to extract the error-free message from the signal and the final constellation diagram is plotted, Fig.16. It can be seen that the various OQPSK symbols are obtained with very little ambiguity that makes sure that the error in the received signal is minimal. As the symbols are clustered over the four regions, the detection is very easy and hence prone to fewer errors. The received symbols are mapped and decoded to get the original message.

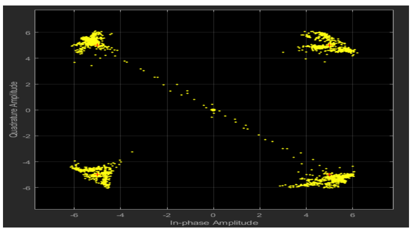

Fig.16.OQPSK Receiver signal constellation diagram

The final simulation consists of the LoRa communication protocol in MATLAB by making use of the open-source simulator program. The simulator uses the data collected from the SDR for interference calculation and even the modeling of the system. The final result received in the simulated LoRa receiver matches with the transmitter message in the screen shot, Fig.17.

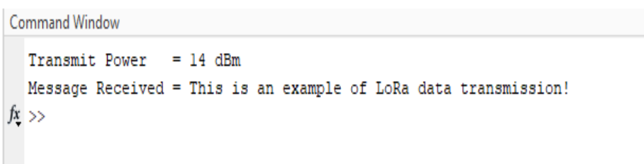

Fig.17.LoRa receiver message

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V. CONCLUSION

Proposed work examines the feasibility of establishing an ad-hoc network on an SDR that is integrated into the existing WSN. An overall robust, highly secured, adaptable, WSN system was designed and simulated with the help of SDR. The implementation of each phase is described in detail and is supported with necessary simulations carried out in MATLAB, GNURadio and NS2.

SDRs being portable and compact allows the rapid deployment of the system. The flexibility and reconfigureability feature implemented via software updates enhances the performance of the system. Updates can be periodically incorporated that prevents the system from being obsolete.

CL-TDMA as MAC protocol along with AODV has significant improvement in the performance of WSNs in terms of call setup delay, throughput and latency.

This system plays a vital role in ensuring that the consultants do not need to have many wireless receivers connected to their computers to display/store the data, instead they can have a single SDR that carries out all these functions with ease.

REFERENCES

1. Veeraprathap.V et al., “Real-Time Healthcare Monitoring using MedicalSensorNetworkforMuteandParalyticPersons”Thirteenth International Conference on Sensr Technologies & Applications ,SENSORCOMM,Nice ,France October 2019
2. J. Mitola III, "Software radios: Survey, critical evaluation, and futuredirections," IEEE Aerosp. Electron. Syst. Mag., vol. 8, no. 4, pp. 25–36, April1993
3. B. Moorman, “Medical device interoperability: Standards overview,”ITWorld,pp.132–138,March/April2010.
4. T. Ulversoy, "Software-defined radio: Challenges and opportunities,"IEEECommun. Surv. Tutor., vol. 12,no.4,pp.531–550,2010.
5. R. Chávez-Santiago, A. Mateska, K. Chomu, L. Gavrilovska, and I.Balasingham,"Applicationsofsoftware-definedradio(SDR)technology in hospital environments," 2013 35th Annual InternationalConference of the IEEE Engineering in Medicine and Biology Society(EMBC),2013,pp.1266-1269,doi:10.1109/EMBC.2013.6609738.
6. S. Hassayoun, S. Lahouar, and K. Besbes, "SDR Bridge for a SecureWirelessSensorNetwork(WSN),"2020IEEEInternationalConference on Design & Test of Integrated Micro & Nano-Systems(DTS), 2020,pp.1-5,doi:10.1109/DTS48731.2020.9196201.
7. HarvaneetKaur, AmanpreetKaur, DhirajKhanna, “Benchmarking ofAODV Routing Protocol Implemented for Military Software DefinedRadio Waveform”, International Journal of Computer Applications(0975–8887),Volume120–No.2,June2015
8. IrumNosheen,ShoabA.Khan,andUmarAli,"ACross-LayerDesignforaMultihop,Self-Healing,andSelf-FormingTacticalNetwork",
9. HindawiWirelessCommunicationsandMobileComputing,Vol2019
10. B.AlHomssi,K.Dakic,S.Maselli,H.Wolf,S.Kandeepan,andA.Al-Hourani, "IoT Network Design using Open-Source LoRa CoverageEmulator,"inIEEEAccess.2021.LinkonIEEE:https://ieeexplore.ieee.org/document/9395074

AUTHOR’S BIOGRAPHY

VeeraprathapV has completed his graduation in electronics & Communication from visvesvaraya technological university,Belagavi Karnataka,Master of Technology in Digital Electronics from SriSiddartha Institute of Technology Tumkur And Currently Pursuing His PhD in field of WSN's at UVCE Bangalore University, Karnataka,India.

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AshishHegde, Undergraduate Scholar in Electronics and communication Engineering Department, University Visvesvaraya College of Engineering, Bangalore University, Bangalore, India. Interested in the application of wireless communication and DSP in real life scenarios. Experienced in working with SDRs, Ad-Hoc networks, Antenna design and various wireless protocols. Submitted proposal for IEEE - APS Design Contest on Direction of Arrival Estimation and Beam forming using Planar Microstrip Phased Array Antenna. Interned and incoming NCG at Texas Instruments India as an analog layout engineer.

Supriya V Kurpad, Undergraduate Scholar, Electronics and Communication Engineering Department, University Visvesvaraya College of Engineering, Bangalore University, Bangalore India.

Worked on literature survey on SARs, antenna design. Submitted proposal for IEEE-APS Design contest on Direction of Arrival Estimation and Beamforming using Planar Microstrip Phased Array Antenna. Electronics Hardware Engineer at Pravaig Dynamics.

Dr. Narendra Kumar G. Obtained Master's Degree in Electrical Communication Engineering, (Computer Science & Communication) from Indian Institute of Science, Bangalore, Karnataka, India in 1987. Was awarded PhD in Electrical Engineering (Computer Network) from Bangalore University, Bangalore, Karnataka, India in 2006. Currently Professor in the Department of Electronics & Communication Engineering, University Visvesvaraya College of Engg., Bangalore University, Bangalore, held the positions of Associate Professor, Lecturer and Director of Students Welfare. Research interests include Mobile Communication, Wireless Communication, Image processing, E-Commerce, Robotics and Computer Networks.