Energy Efficient Delay aware Routing Protocol for smart Ambulance Tracking System

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Abstract

The ambulance tracking system is a time critical applications using wireless sensor network to clear the traffic without much delay and allow the ambulance rush to the hospital. An Energy Efficient delay aware routing protocol for smart ambulance tracking system is proposed which efficiently route the information about the location of the ambulance to release the signal and pave way for the ambulance. Wireless sensor network is deployed and RFID tag is attached to the ambulance. The RFID reader is mounted on a lamp post or along the roadside buildings which is 800 meters away from the intersection signal. The RFID Reader senses the RFID tag, transmit the information to sensors. The sensors on receiving the data, route the packet to the sink node. The data is processed and the traffic signal is changed to green light. Smart Ambulance tracking system is simulated and evaluated with hardware as a prototype model. The results prove that the traffic signals are dynamically manipulated and time critical packets are transmitted with minimum energy consumption and minimum delay.

Keywords: *Ambulance, delay, energy, routing, RFID*

1. Introduction

Wireless Sensor Network (WSN) has become an outstanding domain and gained importance in recent days due to their potential for real time applications and also for time critical applications. WSN laid its foot prints in various fields such as military surveillance, environmental monitoring and health care applications. In these applications, sensors gather data or information and transmit to the sink node. Data collection from sensors can be continuous, event driven or query based. Routing of these sensed data to the destination is the one of the major challenging issues in wireless sensor network.

In day to day life, traffic congestion has become a major problem in metropolitan cities all over the world. There are various reasons for the growth of traffic. Today, due to modernization of the world, people are using personal vehicles for their journey which leads to growth of population of vehicles in cities across the globe. The tremendous increase in vehicle traffic leads to serious problem for special vehicles like ambulance, fire engine, etc. There is rapid growth in the technology and in lifestyle of human beings leading to automation and smart computing. The modern world, the era of Internet of Things (IoT) is the agglomeration of various technologies for interacting with a physical environment using sensors and actuators. The Ambulance tracking system is a time critical application wherein information needs to be transmitted with minimum end to end delay. A smart sensor based solution is proposed to clear the traffic for an ambulance in a city. An energy efficient routing protocol is developed which can be used in the ambulance tracking system for routing the sensitive data with minimum energy consumption and minimum delay.

2. Area of study

All printed material, Coimbatore, called as the Manchester of Tamil Nadu is an industrial hub and the second largest city of Tamil Nadu State. The city is an emerging hub for information technology and automobile industries. Coimbatore has a pleasant climate throughout the year due to western ghats. The city is situated at a center point connecting three states, Kerala and Karnataka with Tamil Nadu through three national highways. Coimbatore is the home of 2.3 million habitants. Its population is growing, but vehicle population is growing four times as fast. According to the current situation, vehicle traffic is expected for doubling as shown in Fig 1. This city is witnessing heavy traffic due two wheelers and four wheelers due to lack of high quality public transport system and non-motorist facilities. The existing system to reduce this traffic is focused on widening roads and building grade separators.

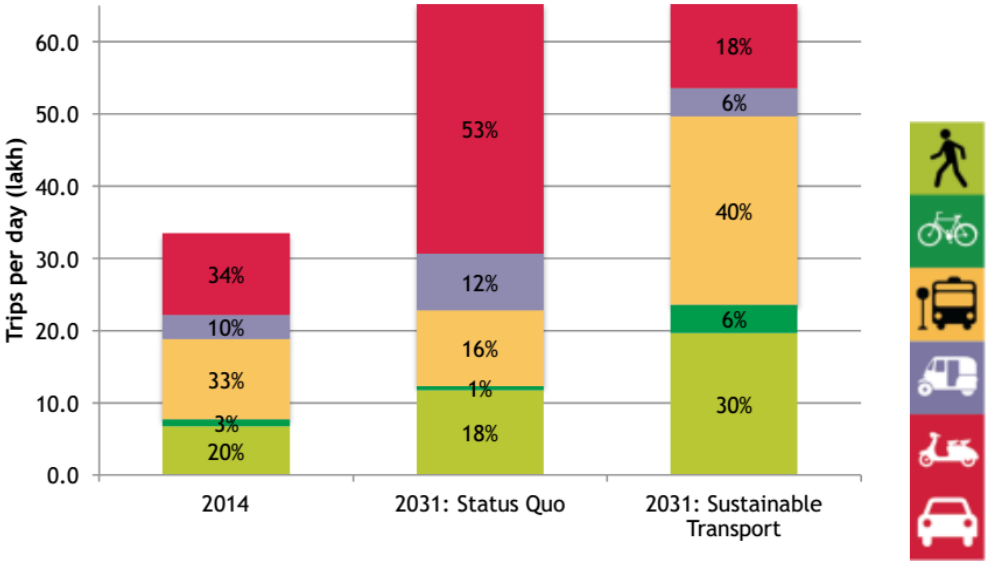

Figure 1. Prediction of Coimbatore traffic

The Figure 2 represents the road map of Coimbatore during the year 2013. Now projects are being carried out for widening the road and constructing new bridges to reduce the traffic in popular areas of Coimbatore.

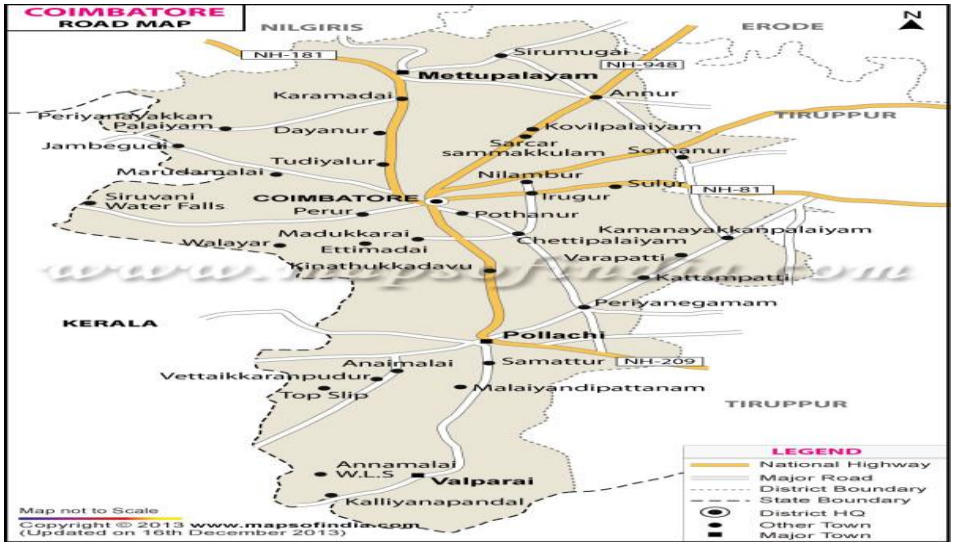

Figure 2. Road map of Coimbatore

3. Related Work

The extensive work has been carried out to clear the traffic for emergency vehicles like fire engines, ambulance and police cars with the help of the intelligent traffic control system [2-4]. An energy centric cluster based routing protocol [1] for WSN is proposed. This protocol can be used for an application where network lifetime to be increased. The Image processing technique is adopted for identifying traffic density in the environment [5]. Various technologies like GPRS, GPS, IR radiation, RFID and strobe emitters are used in the intelligent traffic control system. Farheena and Chandax [6] uses IR and GPS system to identify the emergency vehicle and calculate real time traffic density. Microwaves, radars and ultrasonic waves are also used to detect ambulance in the traffic. Emergency Vehicle Pre-emption (EVP) [7] system using infrared emitters, acoustic system, radio based system. Acoustic sensors are extremely used to detect the emergency vehicles.

Many routing protocols for wireless sensor network are proposed suitable for mission critical applications. These protocols are designed to improve network lifetime, reduce delay, reduce energy consumption. Roseline [9] proposed DRATC, a decentralized routing algorithm for fire monitoring and extinguisher. This algorithm uses decentralized threshold sensitive routing algorithm and Schedule Channel Polling (SCP) for data transmission.

Air pollution is a major threat to the environment. Raja Vara Prasad[10] proposed a cost effective, reliable, and scalable wireless sensor network based air pollution monitoring system. Zigbee network is implemented with the multihop data aggregation algorithm to sense gases like oxygen, carbon dioxide, carbon mono oxide and nitrogen-di-oxide. CIVIC [11] is a context aware routing protocol which has the features of proactive and reactive routing protocol features embedded. This protocol uses power aware and minimum distance mechanism for choosing data forwarding node and to minimize the number of transferring nodes uses directional area neighbor adaptive broadcast policy.

There are different methods and technologies adopted to handle heavy traffic in metropolitan cities. Prakash et. al[12] developed a GPS based shortest path tracking system for smart city ambulance. This system used Dijkstra algorithm to find the shortest time to reach the hospital. An IoT based smart vehicle tracking system[13] is developed that uses MQTT protocol broker mechanism for message delivery to the outside world.

Mittal [14] proposed a green wave system to provide clearance for any emergency vehicles by turning all red lights to green lights. Also, this system helps in tracking stolen vehicle. A video traffic analysis is also made to control traffic in Banglore city.GPS based automatic lane clearance for ambulance system clears the traffic by setting the light to green when an ambulance arrives. The system is fully automated but it requires information like starting point, ending point. The system will not work if the destination is not known.

An RFID traffic control system is proposed [15] which provide an efficient time management scheme, a dynamic time schedule for each passage column. This system lacks in the methodology adopted for communication between the emergency vehicle and traffic signal controller. An energy efficient routing protocol for RFID based smart ambulance tracking is proposed which optimally clears the route for emergency vehicles like ambulance.

4. Mathematical Formulation

Routing protocols designed for time critical applications should be efficient in transmission of data packet without delay and with minimum energy consumption. This becomes an optimization problem. Pareto and Edgeforth proposed Pareto optimality technique for solving multi-objective optimization problem. In general, multi-objective optimization problem can be formulated mathematically as

$$\min(f_1(x), f_2(x), ..., f_m) \tag{1}$$

such that $x \in C$ where $m \geq 2$ is the number of objectives and the set C is the feasible set of decision vectors.

In EEDARP, two constraints namely energy consumption and end to end delay considered where m = 2 and the problem can be modeled as

$$\min(f_1(x), f_2(x)) \tag{2}$$

where $f_1(x)$ is the energy consumption function and $f_2(x)$ is end to end delay function. The pareto curve for two objective function $f_1(x)$ and $f_2(x)$ is shown in Figure 3.

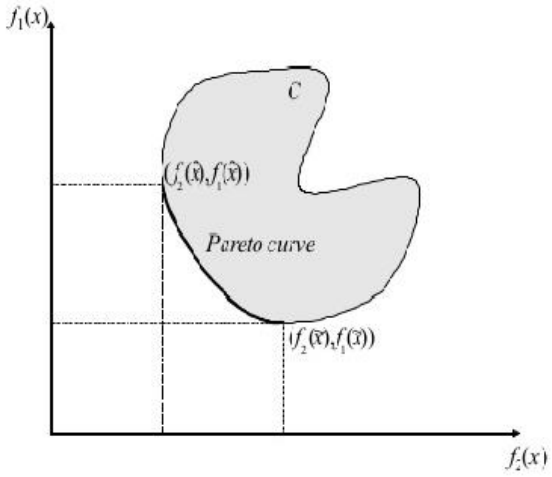

Figure 3 Pareto curve for two objective functions

4.1. Network Architecture

An illustrative real time scenario as shown in Figure 4 is an intersection point with the active traffic signal. Different vehicles are passing by which includes ambulance also. The network model for this scenario consists of n sensors uniformly distributed and deployed in the environment. Following are the assumptions made for the network model.

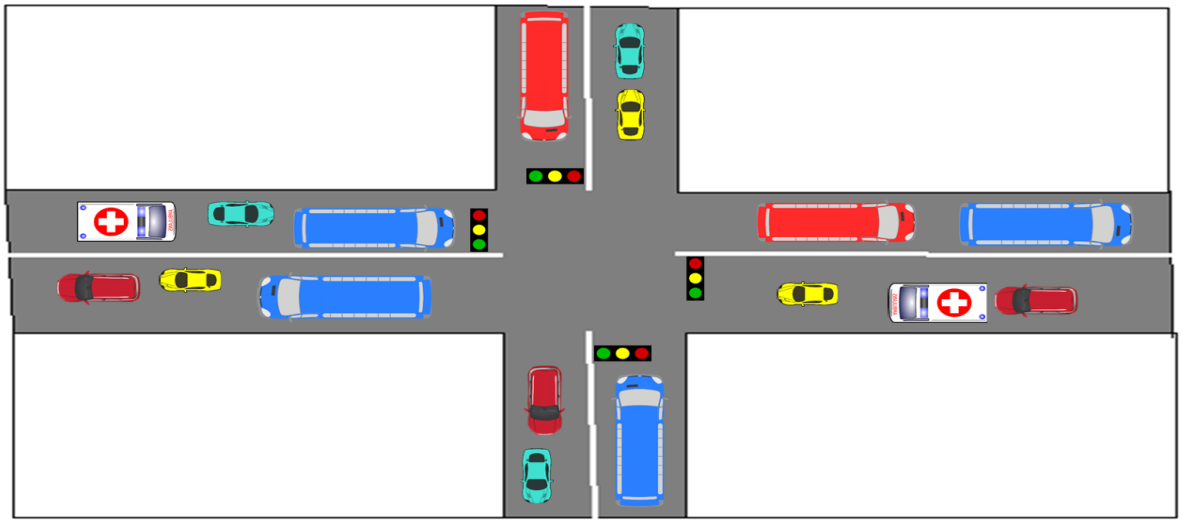

Figure 4 Real time traffic signal intersection point

1) All sensor nodes deployed have equal capability and they have a uniform transmission range r.
2) All sensors once deployed are static and aware of their position and residual energy.
3) Multihop forwarding is supported within the network.
4) Cluster head performs data aggregation and forward it to sink.

The proposed model adopts hierarchical network model as shown in Figure 5 where sensors are randomly distributed will communicate to cluster head, which in turn forward the data packet to sink in the multi hop manner.

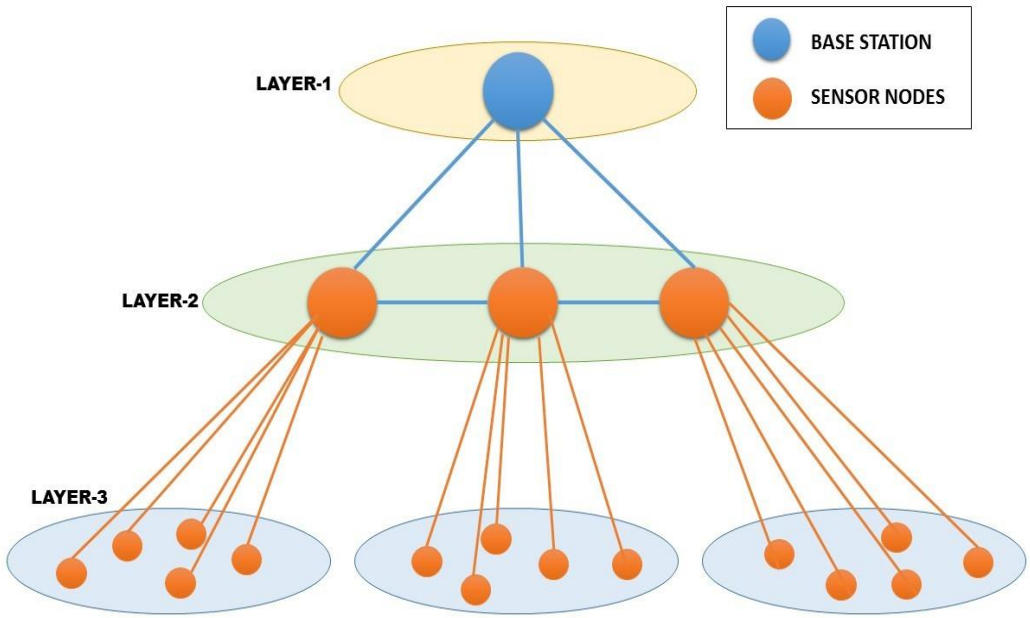

Figure 5 Network Model

Layer 3 consists of sensor nodes grouped as clusters. Each cluster member will communicate to cluster head nodes in layer 2. These cluster heads can forward the packet to the base station in layer 1. The sensor is placed along the roadside to sense the arrival of emergency vehicle. Once detected, sensors forward a data packet with minimum delay to set the green signal.

4.2. Energy Consumption Model

The energy model proposed by Heinzelman is adopted for radio hardware dissipation [16] energy. The energy spent for transmitting p bits of data over a distance d is given below:

$$E_{txd}(p,d)=\begin{cases} p\times E_{ecf} + p\times\varepsilon_s\times d^2, if\ d<d_r \\ p\times E_{ecf} + p\times\varepsilon_n\ d^4, if\ d\geq d_r \end{cases} \quad (3)$$

Where E_{ecf} is the electronic consumption factor, ε_s and ε_n are the amplifiers needed to maintain allowable signal to noise ratio and d_r is the reference distance between transmitter and receiver. Each node should have their residual energy(E_{res}) greater than the threshold energy(E_{thr}) for successful transmission or receiving of a packet.

4.3 End to end Delay

The end to end delay during packet transmission is due to different aspects of communication such as radio operation, medium access mechanism, congestion control and transmission delay. The delay during a packet transmission over a link (D_l) should

be less the maximum delay allowed during packet transmission. The end to end to delay(D_{tot}) is computed as

$$D_{tot} = \left(Delay_{MAC} + Delay_{Q} + Delay_{txd}\right) \quad (4)$$

Where $Delay_{MAC}$, $Delay_{Q}$, and $Delay_{txd}$ are the delay occurred in medium access, delay in queue and delay during transmission of packet respectively. The queues in the sensor nodes are of type M/M/1. The waiting time for this queue (W) is given by

$$W = \frac{1}{(\mu - \lambda)} \quad (5)$$

Where μ is the service rate and λ is the service rate.

The overall objective function for optimizing the routing protocol is to

Minimize E_{tot} (6)

Minimize D_{tot} (7)

Subject to

$E_{res} \geq E_{thr}$ (8)

$D_{l} \leq D_{\max}$ (9)

5. Energy Efficient Delay Aware Routing Protocol for Ambulance tracking system

The In the proposed model to detect the ambulance, the system consists of the RFID system that is connected at the certain distance from the traffic lights. The signal from this RFID reader is sent through wireless sensor node that is fixed to the existing street lights. Each ambulance is given a registered RFID tag which is fixed in it. RFID reader placed at 800m away from the junction reads the RFID tag attached to an ambulance as shown in Figure 6. At times multiple ambulances can reach the junction from different directions. In such scenario, distance of the ambulance from the junction is computed and the green signal is released for the lane with ambulance which is near to the junction. If two or more ambulances are in same distance, random selection of one ambulance is cleared followed by other signals.

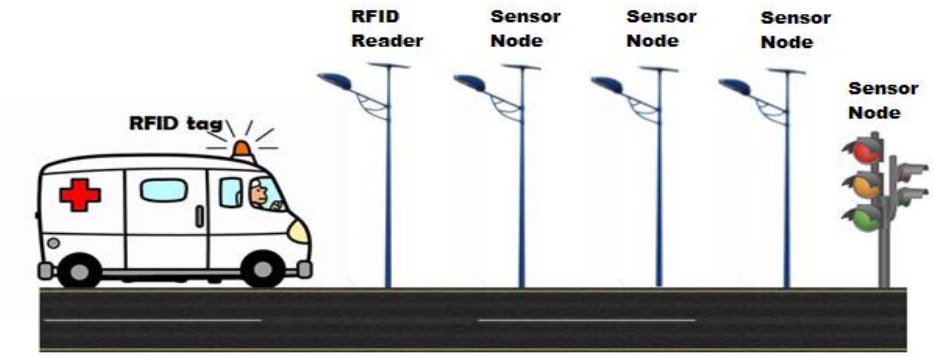

Figure 6. Working model of Ambulance tracking system

The RFID reader detects the tag when a tagged ambulance passes through it. The signal from the reader is sent to the gateway attached to the traffic light through wireless sensor node on the street light. The gateway on receiving the signal checks for the status of the traffic light. In case of green light the gateway just adds up the time and keep opened the signal. Whereas in the case of red light encountered the gateway immediately communicate with the microcontroller of the traffic lights and make it a green light and open the signal. The design and implementation of this technique are directly targeted for traffic management so that an emergency vehicle on the road gets clear way to reach their destination in less time and without any human interruption.

The various steps in the ambulance tracking system are as follows.

Step 1: RFID Tag Detection

The ambulances are given a unique RFID tag. When these tags are detected by the RFID reader that is placed before few meters from the traffic light signal, sends a signal through sensor node to interrupt the microcontroller of the signal to open the signal.

Step 2: Signal Forwarding

The RFID reader on receiving a signal it forwards it to the nearest sensor node. Forwarding of the signal happens until it reaches the sensor node that is attached to the traffic light microcontroller. The microcontroller is interrupted once it receives the signal.

Step3: Traffic Light Signal Interruption

When the microcontroller of the traffic light signal get a signal from the sensor node immediately open the signal as green closing other signals and providing a way for the ambulance to move without any delay.

6. Experimental Setup

The various hardware components used for experimental set up includes RFID tag, RFID reader, XBee S1 series for transmitting and receiving data.

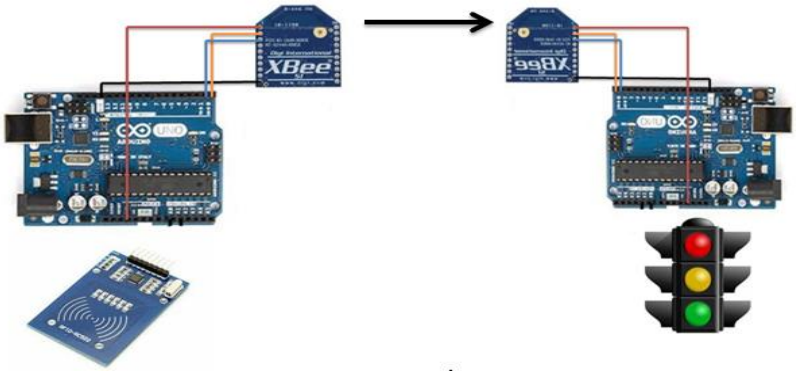

Figure 7 Hardware components involved in the ambulance tracking system

The Figure 7 pictorially represents the working of the smart ambulance tracking system. RFID tags when detected by the reader sends a signal to microcontroller

Adriuno. The microcontroller intimates the sender XBee and hence it forwards the signal to the receiver XBee. On receiving the signal the receiver XBee interrupt the traffic light logic that is fed in the receiver microcontroller and runs the interrupt code to open the signal and close all other signals. The prototype model developed for the two way traffic signal path is shown in Figure 8.

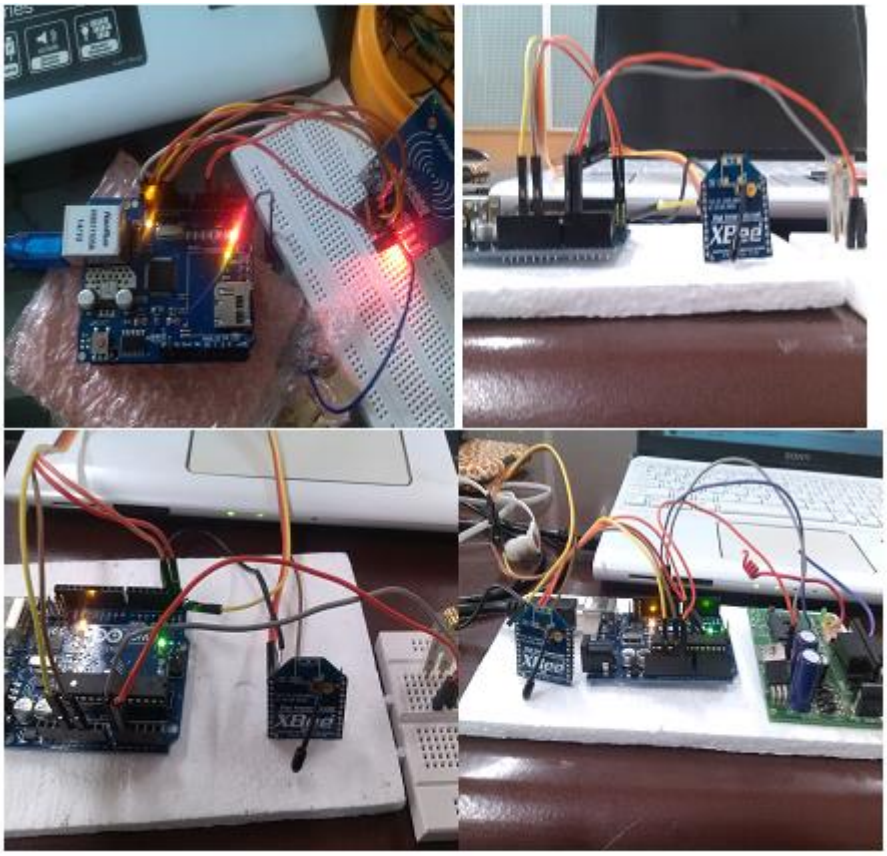

Figure 8 Experimental Setup for smart Ambulance Tracking System

7. Simulation Results and Analysis

The protocol is simulated using the network simulator (NS2.34)[17] to analyze the energy consumption and delay during packet transmission. The simulations are conducted by varying simulation time in the topographical space of 1000 x 800. The simulation results are carried out varying network density. As the simulation starts, each node senses the information transmit the packet to clusterhead. The transmission range of each node is assumed to be 100m. The initial energy of all the nodes is set to be 1000J.

The end to end delay is calculated by varying the simulation time and network density. The end to end delay increases when the number of nodes increases as given in Figure 9. When simulation time is increased the delay gets reduced because the clusters became stable and there is a less retransmission of packet.

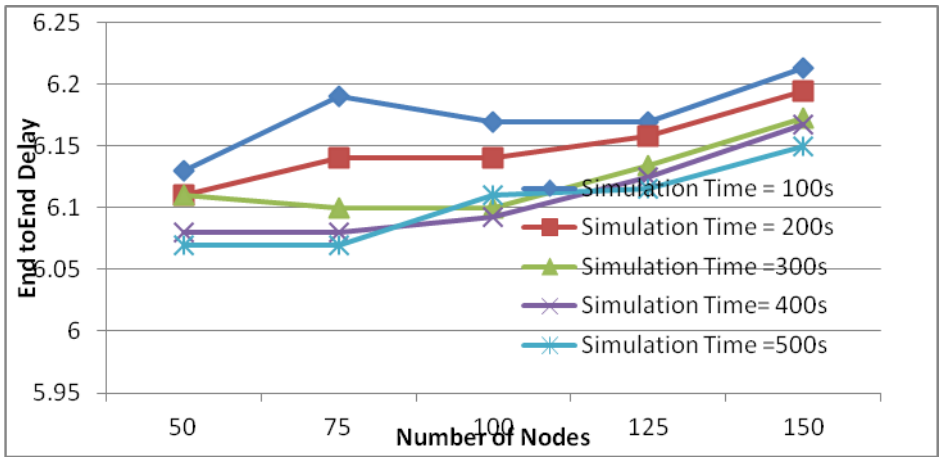

Figure 9 End to end delay varying simulation time

The energy consumption is measured by varying simulation time. Two cases of network density 50 nodes and 100 nodes are compared. The results in Figure 10 show that the energy consumptions increases as simulation time increases and also when number of nodes is also increased.

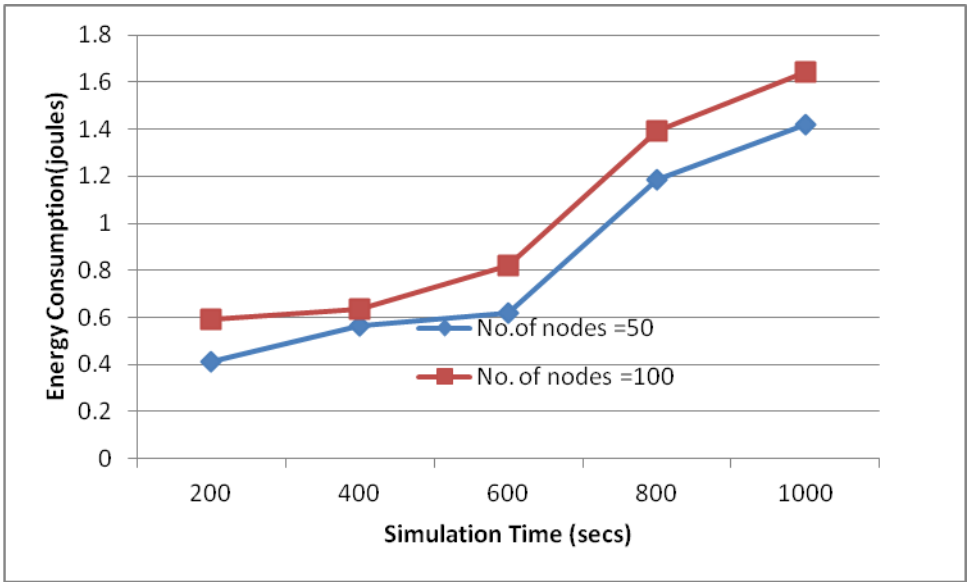

Figure 10 Energy consumption varying simulation time

7. Conclusion

The energy efficient delay aware routing protocol helps to transmit the packet without much delay for the smart Ambulance tracking system. This reduces the human intervention during traffic clearance and help to rescue human life. The prototype model is implemented and tested successfully. Further enhancements can be made to prototype model to cover long distance system. The protocol is also simulated and the results show that packets are transmitted with minimum delay and energy consumption.

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