Opportunistic Multihop Routing in Wireless Sensor Network

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By

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Certificate

This is to certify that project report entitled "**Secure Opportunistic Multihop Routing in WSNs**", submitted by **Mayank Sharma (132212)** in partial fulfillment for the award of degree of Master of Technology in Computer Science & Engineering to Jaypee University of Information Technology, Waknaghat, Solan has been carried out under my supervision.

This work has not been submitted partially or fully to any other University or Institute for the award of this or any other degree or diploma.

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Acknowledgement

This may seem long but the task of my thesis work both theoretically and practically may not have been completed without the help guidance and mental support of the following persons.

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Abstract

Wireless Sensor Networks (WSNs) are the networks in which many sensor nodes are deployed in the application area to form a network. The sensor nodes collect the information about physical or chemical phenomenon and transfer this information towards the base station for further processing. To accomplish the task of transferring data sensor nodes, we require the routing protocols. Routing protocols for WSN are used to find the best path for the establishment of communication in the networks. Routing in WSN is a challenging task due to the nature and abilities of sensor nodes in WSN like energy, communication architecture and deployment of nodes. Many researchers have proposed routing protocols of various categories like Data Centric Routing, Hierarchical Routing, Location-based Routing and Opportunistic Routing. The use of routing protocols depends on the requirements of applications of WSN and also the capabilities of sensor nodes. In order to achieve a high throughput in unreliable wireless links, Opportunistic Routing (OR) collaborate all the sensor nodes in the path while forwarding the data packets. Opportunistic Routing uses broadcast transmission to send packets through multiple relays. It achieves higher throughput than traditional routing. The main idea behind Opportunistic Routing is to select a subset of the nodes between source and the destination node and the node closest to the destination will first try to retransmit packets. This dissertation studies the properties, power consumption, end to end delay, throughput and protocol design about OR in multihop wireless networks.

CHAPTER 1
INTRODUCTION

1.1 Introduction

Many work carried out in the past to improve the performance in wireless sensor networks in terms of energy consumption, throughput and end to end delay. One proficient approach is to allow the intermediate nodes to assist, thus using the spatial diversification to boost up the capacity of the system. However, the main disadvantage of this approach is that it requires an exchange of information between the nodes, which introduces an overhead and increases the complexity of the receivers [1]. A simpler means of exploiting the spatial diversification is concerned to as opportunistic routing, also called opportunistic forwarding.

In opportunistic routing, the intermediate nodes cooperate with each other on packet forwarding Opportunistic Routing in Wireless Sensor Networks in order to achieve high throughput in the face of lossy links. Opportunistic routing tries to beat the disadvantage of a defective wireless link by taking advantage of the broadcast nature of the wireless sensor network such that one communication can be overheard by more than one node [2]. The numbers of nodes serve as an intermediate node, but only one node will lastly forward the packet. This selection procedure is critical and based on opportunistic rules. Opportunistic routing in WSN can offer enhanced performance in terms of energy consumption and end to end delay.

Routing is critical in wireless sensor networks. The job of routing is the selection procedure of the next node and the path selection procedure toward the target. Traditional routing protocols in WSN generally perform best path routing, which was fixed before the communication started. The extremely dynamic and lossy nature of wireless sensor network causes regular communication crash which leads to retransmission and waste of network resources, or even to system going down. Opportunistic routing takes benefit of the broadcast nature of the medium and change both the relay node selection and the number of the possible paths to the destination in order to improve the performance of the traditional best path routing [3]. Compared to traditional end-to end, multi-hop routing, the core idea in opportunistic routing is that at each hop, a set of next hop relay candidates receiving the packet successfully compete to act as an intermediate. Instead of choosing a single route ahead of time, the path is determined as the packet moves through the network, based on which sensor receives each transmission.

This thesis presents an opportunistic multi-hop routing in Wireless Sensor Network. Our main focus is trade-off between end to end delay and network lifetime. The source of power in the sensors deployed in network is battery and is intended for long-term operation. The key issue in system design is energy saving. On the other hand, system is useless if it end to end delay is more therefore end to end delay must be minimized.

1.2 Challenges

There are three main challenges in relation to an opportunistic routing protocol:

(1) Metric,

(2) Forwarder selection, and

(3) Coordination between the forwarder methods.

First challenge related to opportunistic routing is metric. To correctly select and prioritize the forwarder, opportunistic routing is in need of a metric. Initially, proposed OR algorithms were based on simple metrics; for example, hop count or expected transmission count (ETX). After selecting a proper metric, the wireless nodes use the forwarder selection algorithm.

Second challenge is forwarder selection. To select and order a group of neighboring nodes called the forwarder set, and it is able to help in forwarding the packets to a given destination. To send a data packet using OR, a node usually includes its forwarder selection in the header of the data and broadcasts it. There should then be a mechanism, referred as forwarder coordination that is used by the source node to determine which of them has to forward the packet. The highest priority node must forward the received packet, and the other ones will drop it.

Third challenge routing is coordination between the forwarder methods. Coordination between the forwarder mechanisms usually require signaling among the nodes. If the coordination between the forwarder nodes is done imperfectly, it may result in the sending of duplicate transmissions of packets by different candidates.

1.3 Objectives

- There are three objectives of this thesis. The first objective is to study the various existing wireless sensor network routing protocols, and comparative analysis of these routing protocols. For the completion of first objective have studied study various opportunistic routing protocols for wireless sensor networks.
- The second objective is to propose a new opportunistic multi hop routing protocol for wireless sensor network. In the proposed approach, the overall objective is to verify these assumptions and demonstrate how opportunistic routing can resolve the tradeoff between the end to end delay and network life time in wireless sensor networks. In particular the research goals are:
    - Demonstrate that an opportunistic network utilizing opportunistic message routing with dynamic energy consumption.
    - Propose and evaluate opportunistic design principles that average end to end delay will be low.
    - Propose and evaluate opportunistic design principles that network lifetime will be low.

- The third objective of my thesis is a comparative analysis of the proposed opportunistic routing protocol and the existing opportunistic routing protocols.

1.4 Methodology

This thesis Illustrates, implements and analyzes an opportunistic routing protocol. It promotes different opportunistic approaches to achieve low average end to end delay and high network lifetime. In particular, this work formally defines the problem of tradeoff between the average end to end delay and network lifetime in wireless sensor networks, differentiating it from other security issues in wireless sensor networks. For better understanding the problem, previously proposed approaches are also discussed. The first routing protocol that was EEOR [33] which chooses the node that is nearest to the source and selects it as a forwarder node in the forwarder list. The second routing protocol that was MOOR [36] chooses the node which is nearest to the destination and selects it as a forwarder node in the forwarder list. In wireless sensor networks, there is a trade-off between the end to end delay and network lifetime, when we use the concept of dynamic energy consumption. It is observed that the average end to end delay is high in Energy Efficient Opportunistic Routing (EEOR) protocol as compared to the Multi-hop Optimal position Opportunistic Routing (MOOR) protocol. But in case of dynamic energy consumption, the networks lifetime of an EEOR protocol is better as compared to MOOR. The proposed protocol chooses the node which is neither nearest to the source nor to the destination i.e. chooses any middle node between the source and the destination which is near to both.

1.5 Contributions

In this thesis, we attempt to resolve the tradeoff between the average end to end delay and network lifetime in wireless sensor networks, with the use of an opportunistic routing protocol. The primary objective of the current research work is to address the following issues:

- Analysis of an opportunistic routing protocol. An opportunistic routing scheme, based on existing opportunistic routing protocols, is introduced. In order to evaluate the performance of the proposed scheme in terms of average end to end delay and network life time, the protocol was implemented and simulated with the use of a discrete event simulator system. The metrics that were used are

(a) The time elapsed between the sending of a packet by the source node and receiving that packet by the destination node is termed as end-to-end delay, and

(b) Network's Lifetime is defined as the time when the first node dies out of energy

- Investigation and implementation of different opportunistic routing approaches. Based on the conclusion of the proposed scheme's performance evaluation, extensions of the opportunistic routing are introduced. Each approach is investigated and implemented. All three approaches are examined through simulations. Furthermore, the approaches are also examined in terms of general network performance such as throughput, delivery ratio and energy consumption.

Gist of the above has partly appeared in the following publications:

- Mayank Sharma, Yashwant Singh, Nagesh Kumar, "opportunistic routing in Wireless Sensor Network: A Comparative Analysis" Journal of Basic and Applied Engineering Research (JBAER) Volume 1 Number 6, ISSN: 2350-0255, October 2014.
- Mayank Sharma, Yashwant Singh, "Middle Position Dynamic Energy Opportunistic Routing For Wireless Sensor Networks" International Conference on Advances in Computing, Communications and Informatics (ICACCI)(communicated)

1.6 Report Organization

. In Chapter 2, introduction of Wireless Sensor network is given. In this chapter firstly I discussed about modules of sensor node. After that we discussed the factors that affect the design and implementation of sensors. Typical factors are hardware issues, network issues and the environment issues. Finally, applications of wireless sensor networks and various fields are identified in which WSN is currently used.

Chapter 3, presents some of the routing challenges that influence routing process in WSN. Routing objectives has been explained in details. Finally, illustration of various WSN routing and comparative analysis of WSN routings has been provided.

Basic idea of OR has been provided in chapter 4. In addition to advantage, disadvantages of OR protocol comparative analysis has been provided.

Chapter 5 consists of the proposed middle position based opportunistic routing in wireless sensor network with the help of simulator.

In Chapter 6, consists of simulation results of Energy Efficient Opportunistic Routing (EEOR), Multi-hop Optimal position Opportunistic Routing (MOOR), and propose approach on various parameters, conclusion is presented in chapter 7.

CHAPTER 2
WIRELESS SENSOR NETWORKS AND ROUTING IN WSN

2.1 Introduction

The development of wireless sensor networks comes into existence as a result of advancements in wireless communication technology and development of low cost multifunctional sensor nodes. These tiny nodes are equipped with a battery (energy source), processing unit, a radio module to exchange the data and some memory. The critical factor in these nodes is to save energy and to increase the lifetime of the network. In addition, sensor nodes are provided with actuators for interacting with the physical environment. A sensor node has mainly four modules [4].

2.1.1 Sensing Module

This low power module is a major component of the sensor. It is responsible to gather the information from the outside world and sharing it on the network.

2.1.2 Communication Module

This module consists of transceivers (short range radios) for communication with the other nodes in the network as well as the outside world. The transceivers work in different modes like transmit, receive and sleep. Each mode has different power levels. Power consumption in transmit and receive is higher than the power consumption in sleep mode. If the node does not perform any function, it will go into the sleep mode.

2.1.3 Computation Module

Sensor nodes use the microprocessor for computation purpose which is the combination of microcontroller and micro control unit. Since computation needs high amount of energy for saving the energy in computation module, various power levels are defined for the MCU on which it operates. This low power module is a major component of the sensor. It is responsible for gathering the information from the outside world and sharing it on the network.

2.1.4 Power Module

Sensor nodes are battery operated so it has limited amount of energy. Due to the deficiency of power supply there is a requirement of monitoring the energy level continuously. The life time of node can be increased by turning it on or off depending on the application

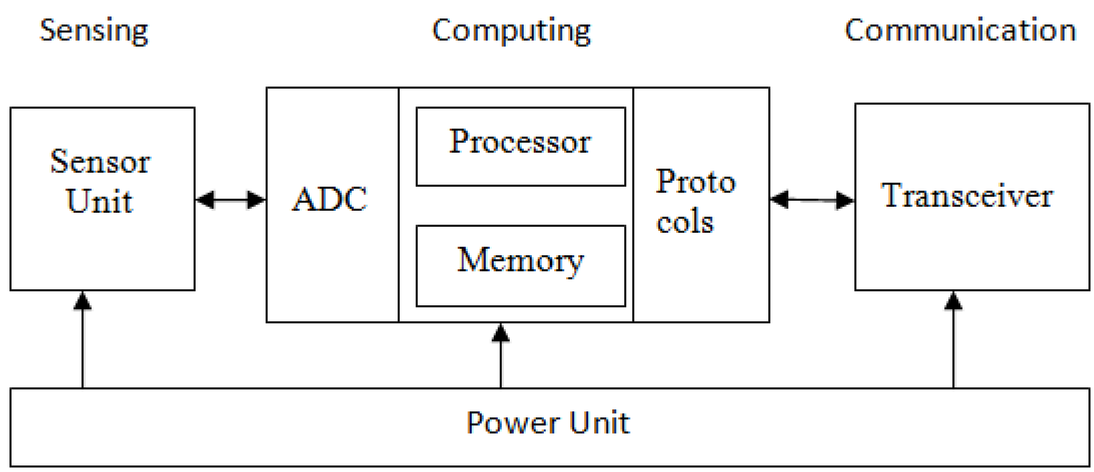


Fig 2.1 Component of a Sensor [4]

Power requirement in wireless sensor networks is high in comparison to traditional wireless and wired networks. Fig 2.1 shows the various component of WSN.

Wireless sensor networks provide a great improvement over a traditional network system. It provides the solutions of various problems in the following context [4].

- Sensors are deployed away from the actual physical process and provide complex techniques to monitor the physical phenomenon.
- Several sensors observed the physical phenomenon and send the sensing result to a centralized fusion center where the information is processed and appropriate measures are taken in response to the input data.

In contrast wireless sensor networks are composed of randomly deployed sensor nodes that are located close to the physical phenomenon. These nodes are required to operate quickly to fulfill an application. These sensor nodes also have the processing capabilities, i.e. raw data can be processed by the sensor nodes, thus processing at centralized unit can be avoided in case of simple applications.

Sensor network consist of different types of sensor nodes such as thermal, visual, infrared, seismic, acoustic, etc. The use of these sensors is to monitor the different type of ambient conditions like Velocity, Humidity, Temperature, Pressure, Noise level, etc. [5]. A typical example of wireless sensor network is described in the fig 2.2. In this the network architecture of the sensor nodes is presented.

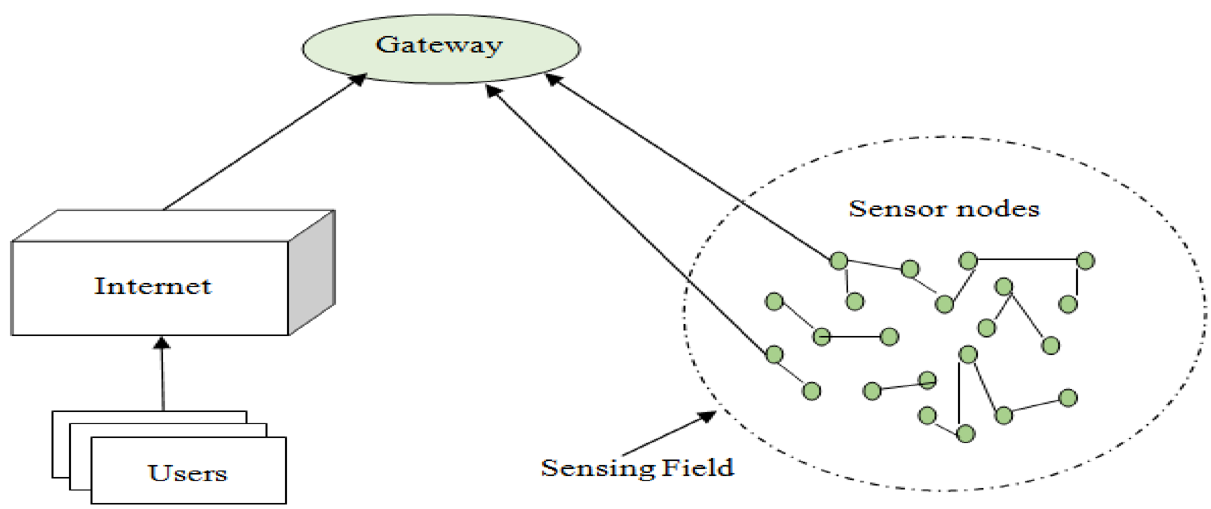


Fig 2.2 Network Architecture of WSN [5]

2.2 Issues affecting Sensor Networks Design

The following factors affect the design and implementation of sensors. Typical factors are hardware issues, network issues and the environment issues.

2.2.1 Hardware Issues

The major component of a sensor node is sensing module, processing module, transceiver, storage module and a power source. In addition a mobilizer service is also implemented. While processing these sensors convert the analog signals into digital output. All these processing must be fitted into small sized node so the size of the node is an important issue. Besides, it some other constraint are also considered [5]

- Minimization of power consumption,
- Volumetric densities of the node must be high,
- Nodes must be low cost and dispensable,
- Operations must occur autonomously,
- With respect to environmental nodes must be adaptive.

The life time of sensor node is depending on the power supply unit of sensors. According to the estimation of Embedded Sensor Board (ESB) node developer, the lifetime of sensor node will be 17 years if 25 bytes will transfer after every 20 Sec [6]. Type of Transceiver unit also affects the sensor networks design. Different nodes have their different transmission ranges and reliability and that value vary according to time. Therefore, it is necessary to check the accuracy of transceivers by comparing the reading with those of a standard. The last hardware issue is related to storage capacity as the sensor nodes have limited storage capacity. Additional memory can be implemented, but it consumes more energy. So, the WSNs protocols are designed to use the limited memory.

2.2.2 Operational Issues

The major requirement of a sensor network is the low power operation. Sensor nodes generally contain the limited power source. These nodes are generally placed in the harsh environment where human intervention is generally not possible so replacement of batteries is not practically possible. Due to limited power option the trade-off between quality of service and the energy conservation is always a major concern in Wireless Sensor Networks [6]. However, dysfunction of some nodes due to power drainage requires rerouting which leads to more energy consumption of other nodes and decreases the lifetime of WSN and managing the quality of service, energy preserving strategies are required. Quality of service depends on the application scenario, for example, in localization example the trade-off is between the energy saving and the accuracy while in routing the major quality of service is network lifetime. Any application implemented in wireless sensor networks must consider the energy constraint of the node.

Sensor nodes are generally equipped with the three 1.5 V batteries so the total power supply is 4.5 V [4]. If the power depletes at high rate then network connectivity no longer exists which reduces the lifetime of the network and desired task is no longer performed. Any algorithm design on wireless sensor networks must be power aware due to these circumstances. The power consumption of the sensor nodes can be considered as the power consumption of the individual modules i.e. sensing communication and processing [5]. Energy consumption in sensing is dependent on application. The major energy consumption part is communication. However, energy consumption can be reduced by aggregating the collected data in the network.

The cost of sensor node is relatively low, but deployed in the large number of quantities. In order to make the deployment feasible, the cost of sensor should not exceed the cost of deploying the nodes.

2.2.3 Network Issues

In network issues, typically deal with network topologies, scalability and fault tolerance. Sensor networks consist of a large number of deployed nodes. So, a topology is needed to manage the large numbers of tiny nodes. The deployment can be random or can be placed in a controlled way by placing manually by humans or robots and expense in planning and installation is considered while deployment. However the way of deploying the nodes in the target area is application dependent. Sensor nodes are statically deployed, though there are various reasons by which change in the topology must be incorporated like power depletion of node, attacks on the network or the node failures. However the power level in each node decreases at a different rate which requires the rearrangements in the network topology. Depending on the kind of phenomenon, number of nodes can be increased in the network. So, the network must be scalable. The network density in a particular area A is calculated by [7]

$$D = \pi r^2 n / A \qquad (2.1)$$

Where n=number of nodes deployed in that region and r= transmission range

The other important phenomenon in network issue is fault tolerance. Various physical or environmental factors must not affect the working of nodes. However, failure of single node should not affect the performance of the networks

2.2.4 Environmental Issues

Sensors are deployed in different geographical areas. So, harsh conditions may be faced like wild animals and other moving objects, harsh environments such as glaciers, hurricanes or oceans, interiors of machinery, biological or chemical contaminated fields. All these things pose challenges in designing the sensor network.

2.3 Application of WSNs

WSNs are an important technology for development of various automated and smart environment system which includes transportation system, smart building, etc. It enables the communication between the real world and smart environment. Besides, WSNs provide greater advantages in different areas like battlefield surveillance, medical and environmental monitoring. Type of sensors used depends on the application like one type of sensor measures various physical parameters like temperature, pressure, humidity etc. So, they are used in general environment monitoring application. The second type of sensor can measure the motion properties like acceleration, velocity, coordinates etc. [5]. So, they are used in determining the position of an entity (target tracking application). In this part we will describe the few specific applications of wireless sensor network.

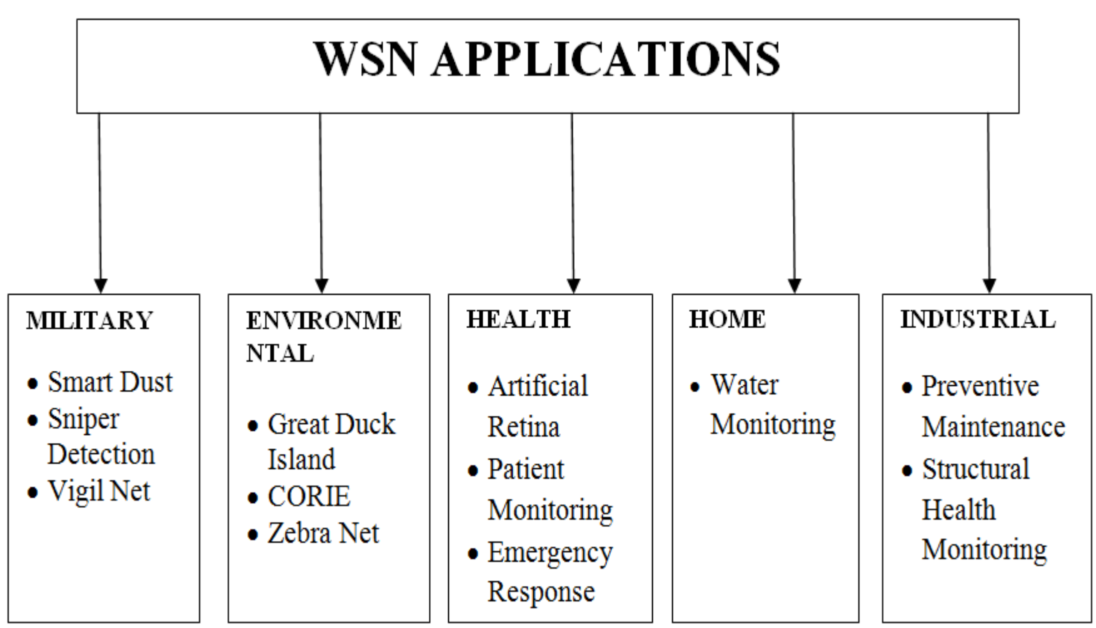


Fig 2.3 Main categories of WSN application and examples

2.3.1 Military Applications

WSNs are an important part of military surveillance system. Its performance is better than the traditional military surveillance system in a way that in WSNs several sensors work collectively. So, the failure of a single node does not affect the surveillance system as much as a traditional system [5]. It is generally used in location detection of ammunition, battlefield surveillance, hostile target detection, nuclear radiation detection, etc. A WSN technology for ground surveillance is proposed in [8]. In [8], author used the hybrid sensor networks for real time tracking of monitoring the area and transfers the gathered data to a monitoring station. Real time tracking is challenging task in WSNs which require cooperation among the sensor nodes, robust environment and complex signal processing. In [8], author has proposed the layered approach to fulfill this function. On the first layer small sensors performed the acoustic sensing and these nodes send the data to more powerful node in the system. At the second layer these nodes send the data to the command center where it is analyzed and appropriate action is taken.

2.3.2 Environmental Applications

Now a day, wireless sensor networks are commonly used in various environmental applications such as wildlife monitoring that include tracking the animals or birds, biological monitoring of soil content, forest fire detection, flood and earthquake monitoring [9] and so on.

Today Wildlife protection is one of the major challenging issues. Many Animals are going to extinct. The main reason behind this is because their natural habitat is destructed. Forest fire is one of reason of destroying the wildlife. According to a survey [10], total 67,774 forest fires destroyed 9,326,238 acres in the USA during 2012. However, satellite monitored can be performed for detection of forest fire, but due to lengthy scan period and low resolution this technique is not effective. Due to these reasons WSNs are proposed for monitoring the forest fire. In this application, sensors are deployed in the area which is to be monitored and programmed to detect temperature, humidity, smoke, etc. Sensors collectively send the data to the base station where it is processed. In addition, if sensors detect any abnormal activity like rise in temperature at once or smoke than it send an alert message to the base station about the possibility of fire.

The other environmental application in which WSNs is widely used is flood control. The author of [5] given a method named ALERT for flood control using WSN. In this system various special sensor like rainfall, water level and weather sensors are used. The sensor is continuously sending the data like average rainfall at a particular time or location where the rainfall exceeded the normal. At the centralized base station, all data is processed and by querying the centralized database at base station experts can analyze the situation and recommended the appropriate action.

2.3.3 Health Applications

WSNs have greater use of heat application like tele-monitoring, patient monitoring telemedicine, etc. [11]. Telemedicine is a revolutionary application in healthcare. Its primary objective is to easy access the healthcare facility and reduces the government's cost in health care. The quality of health care is improved by the telemedicine because of collecting and transmitting the patient data from the medical centers. Another application is tracking and monitoring the patient status remotely. Small sensors are equipped around the patient and they monitor the patient regularly and report and unusual behavior at the medical center. This gathered data help the doctors to identify the patient health related problems while patient gives freedom.

2.4 Challenges and designing issue for routing in WSN

Routing is the most complicated process in WSNs. The design of routing protocols in WSNs is inclined by many testing factors. Efficient communication is dependent on these testing factors. In the following, we précis some of the routing challenges that influence routing process in WSNs [12].

2.4.1 Node deployment

Node deployment is dependent on the application and effect the performance of WSNs. The deployment can be either deterministic or randomized. In deterministic deployment, the sensing elements are manually identified and data is routed through pre-defined routes [12]. However, in random node deployment, the sensor nodes are spotted randomly creating WSNs. If the consequent distribution of sensor node is not uniform, optimal clustering becomes necessary to allow connectivity and enable energy efficient network performance. Inter-sensor communication is normally within short communication ranges due to energy and bandwidth restrictions. Thus, it is most probable that a route will consist of multiple wireless hops.

2.4.2 Energy consumption

The main task of the routing protocols is efficient delivery of data from source to destination. Energy consumption is the major concern in the development of routing protocols for WSNs. Sensor node has limited energy resources and information or data want to be delivered in an energy efficient way without compromising the correctness of the information [12]. The main reason of energy consumption for routing in WSNs is neighborhood discovery and data aggregation.

2.4.3 Scalability

A large number of sensor nodes are scattered in the application area, i.e. thousand or more numbers of node. Routing protocols work with large number of sensor nodes. WSN routing protocols must be an adequate amount of scalable to act in response to events in the network [13, 14]. If an event occurs, then sensor nodes are responsible or handle that event.

2.4.4 Fault Tolerance

A few sensor nodes can crash due to lack of power, physical damage, or environmental interference. The crash of sensor nodes must not influence the overall task of the WSNs. If a large number of nodes crash, MAC and routing protocols must lodge formation of new links and routes for communication in the network. This may need more power for new link formation and route these new links in the sensor network [15]. Therefore, several levels duplication can be needed in a fault tolerant sensor network.

2.4.5 Data Aggregation

Sensor nodes can produce duplicate data from different regions. Data aggregation techniques combine data from various nodes, according to a definite aggregation function, e.g., duplicate repression, minima, maxima and average [14]. Data aggregation is used to meet energy efficiency and data transfer optimization in all routing protocols.

2.4.6 Quality of Service

In many applications, data must be delivered in a definite period of time from the instant it is sensed, otherwise the data will be of no use. Therefore restricted latency for data delivery is another situation for time-constrained applications [15]. Since, the energy gets exhausted, the network has to degrade the performance.

2.5 Routing Objectives

Some sensor network applications only require the successful delivery of messages between a source and a destination. However, there are applications that need even more assurance. These are the real-time requirements of the message delivery, and in parallel, the maximization of networks lifetime. On the basis of that routing objectives are:

2.5.1 Non-real time delivery

The assurance of message delivery is indispensable for all routing protocols. It means that the protocol should always find the route between the communicating nodes, if it really exists. This correctness property can be proven in a formal way, while the average-case performance can be evaluated by measuring the message delivery ratio.

2.5.2 Real-time delivery

Some applications require that a message must be delivered within a specified time, otherwise the message becomes useless or its information content is decreasing after the time bound. Therefore, the main objective of these protocols is to completely control the network delay. The average-case performance of these protocols can be evaluated by measuring the message delivery ratio with time constraints.

2.5.3 Network lifetime

This protocol objective is crucial for those networks, where the application must run on sensor nodes as long as possible. The protocols aiming this concern try to balance the energy consumption equally among nodes considering their residual energy levels. However, the metric used to determine the network lifetime is also application dependent. Most protocols assume that every node is equally important and they use the time until the first node dies as a metric, or the average energy consumption of the nodes as another metric. If nodes are not equally important, then the time until the last or high-priority nodes die can be a reasonable metric.

2.6 Classification of routing protocols

Many researchers proposed routing protocols for WSN. In general, all the routing protocol for WSNs can be divided into data centric protocols, Hierarchical Protocols, location based protocol and opportunistic routing protocols [16, 17]. Classification is shown in fig 2.4.

2.6.1 Data Centric Protocols

Data Centric routing protocols are used to manage the redundancy of data, it happens for the reason that sensor nodes do not have global identification which identifies them uniquely. Therefore, data sent to every node is having significant redundancy. In data centric routing, the destination demand for data by sending the question then the nearby sensor node sends the data selected relating to the query [18]. SPIN is the first data-centric protocol, which considers between nodes in order to eliminate redundant data and maintain energy. Later, directed diffusion has been modernized and has become a breakthrough in data-centric routing.

2.6.1.1 Flooding and Gossiping

There were two classical and simple strategies presented in [19] to transmit data from sensor node to the base station in wireless sensor network. In flooding the source sensor node, broadcast the data packet to its immediate neighbors. After receiving the data packet each sensor node rebroadcasts the data packet to their neighbors. This process will continue until all the nodes in the network receive the packet.

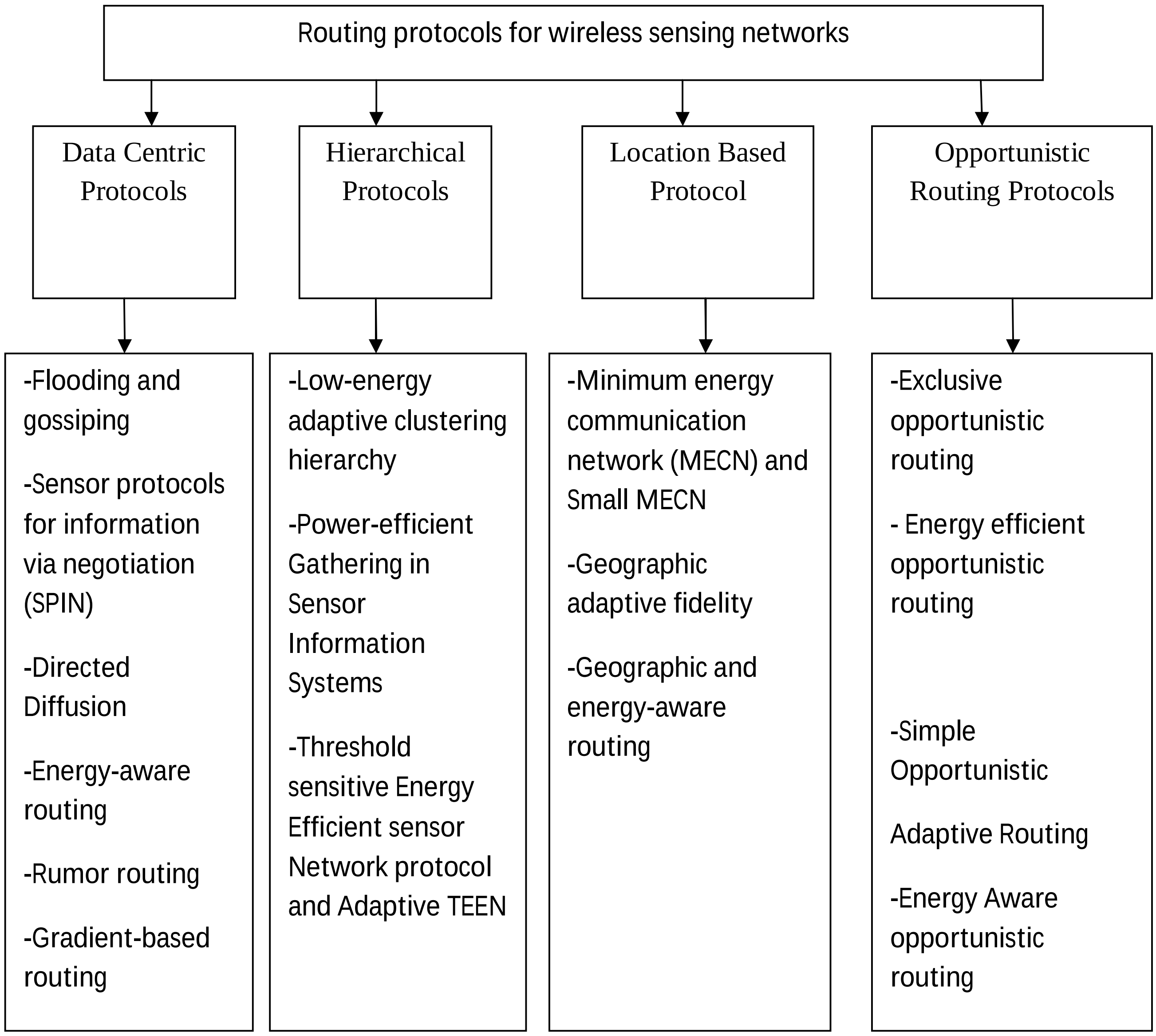


Fig 2.4 Classification of routing protocols

The data packet has to travel maximum number of hops and if there exists a route to the destination, and the communication is lossless, flooding guarantees the data packet to reach the destination. The simplicity of the flooding is its main advantage but there are many disadvantages of using flooding. The main disadvantage is the problem of heavy traffic and measures should be taken so that the packet does not travel through the network indefinitely. For example, to limit the number of times a packet is forwarded one can use the maximum-hop count a packet can travel. It should be small enough so that the data packet does not travel too long and large enough so that it can reach its intended destination. Further, the address of the source in the destination can be combined with a sequence number to uniquely identify the data packets so that the destination can discard the duplicate data packets [19].

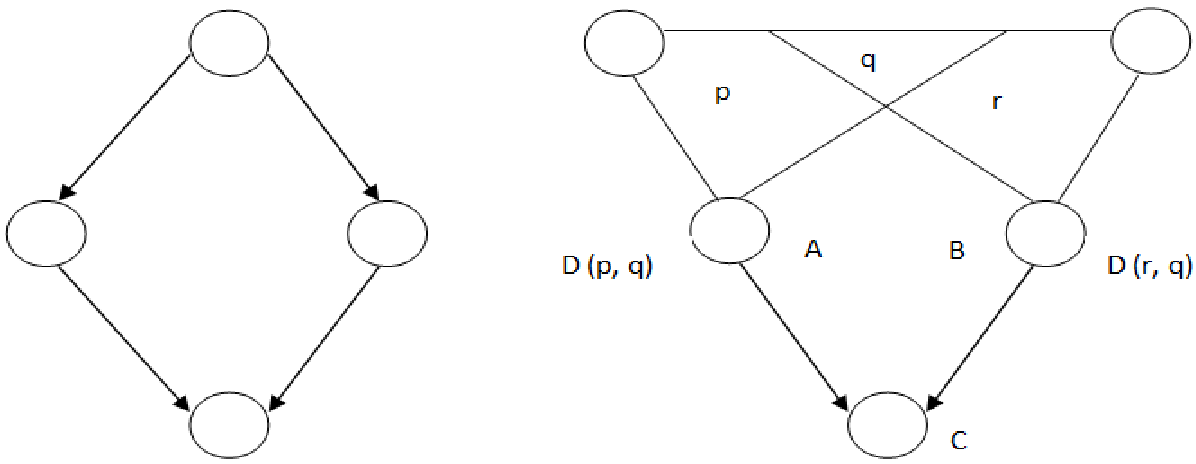


Fig 2.5(a).The implosion problem (left) (b). The overlap problem (right) [20]

There are some additional problems in flooding mechanism explained in [19]: the first problem is *Implosion* which is caused by receiving duplicate data packets on the same node (Figure 5(a)). The other problem *Overlap* (Figure 5(b)) problem arises when two sensor nodes sensing in the same region send identical data packet to the same neighbor. The third one is Resource blindness problem [17] which is caused when the sensor nodes consume large amount of energy without consideration of any energy saving schemes.

The other variation of Flooding is gossiping as presented in [19] remove the problem of implosion. In this the sensor node does not necessarily broadcast the data packet but transmit the packet to a single neighbor which is selected randomly. But also this introduces the problem of delays in transmission of data.

2.6.1.2 Sensor Protocols for Information via Negotiation

SPIN protocol was designed under the category of data-centric routing because its main focus was on data dissemination [20]. SPIN uses meta-data to define/name the original data by using high level descriptor. In SPIN a data advertisement mechanism is followed before the actual data transmission, in which each sensor node sends its meta-data to all of its neighbors. Each node on receiving, check this meta-data for novelty. If the data is new then it is again transmitted to the next level neighbors. The sensor nodes which do not have the new data can request the data from the data generator node and can have the data. The SPIN protocol uses three types of messages [17]: 1) ADV: Advertise the meta-data. 2) REQ: Request data from a sensor node. 3) DATA: carry actual data when requested.

Advantages:

1) SPIN removes the problem of redundant data, overlapping of data and resource blindness. Hence it can achieve a lots of energy efficiency.

2) Topological changes are localized.

Disadvantages:

1) It cannot guarantee the delivery of data.

2) Meta-data calculation introduces extra overhead.

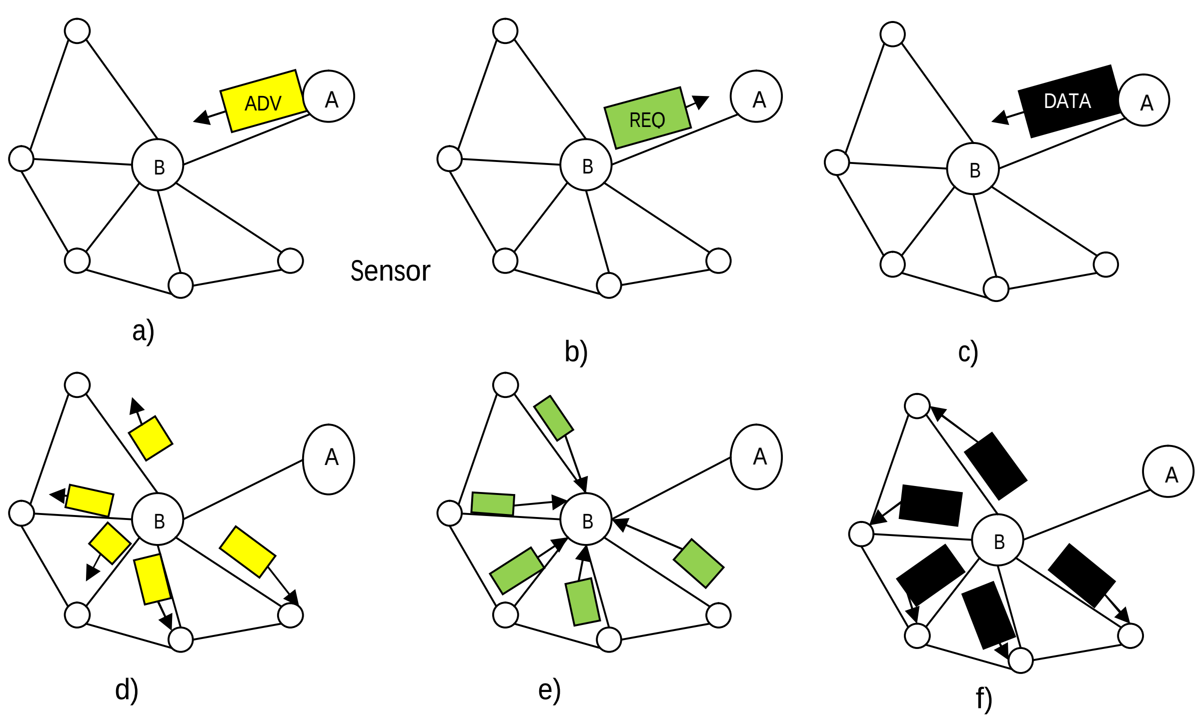


Fig 2.6: The working of SPIN Protocol. a) Node A advertises its data to its neighbor B. b) B Request the data from A. c) Node A sends the data to B. d) Now Node B advertise this new data towards its neighbors. e) Nodes request data from B. f) Node B sends the data.

2.6.2 Hierarchical Routing Protocols

Standardized to a cellular phone network, sensor nodes in a hierarchical routing approach send their information to a key cluster-head and the cluster head then forwards the information to the desired receiver. The primary purpose of hierarchical routing is to efficiently maintain the energy consumption of sensor nodes by taking them in multi-hop communication within a particular cluster and by performing data collection and fusion in order to lessen the number of communicating messages to the destination. Among numerous of hierarchical routing protocols LEACH and PEGASIS are mostly used protocols [18].

2.6.2.1 LEACH

Low-energy adaptive clustering hierarchy [21] algorithm is most popular in many applications of sensor networks. LEACH divides the entire wireless sensor network into clusters according to the signal strength of receiving data and forms cluster heads which will act as routers toward destination [21]. This will be helpful in saving energy, since the communication, processing, fusion are all done only by the cluster head not the other nodes.

LEACH protocol changes cluster heads randomly time-to-time to maintain a balance in energy consumption in the entire sensor network [21]. The decision of choosing cluster head has been made by the sensor nodes by choosing a random number between 0 and 1. One node will become a cluster head if the chosen number is less than the given threshold value which can be calculated by following equation [21].

$$T(n) = \begin{cases} \frac{p}{1-p*(r \bmod 1/p)}, & if\ n \in G \\ 0, & otherwise \end{cases} \tag{3.1}$$

Where p is the percentage of cluster heads, r is current round and G is the set of nodes, which are not the cluster heads in last $1/p$ rounds.

Many researchers have developed routing protocols for WSNs by enhancing LEACH strategy. Various descendants of LEACH are Multi-hop LEACH [22], LEACH-C (Centralized LEACH) [23], LEACH-F (Fixed number of clusters LEACH) [24], LEACH-E (Energy Efficient

LEACH) [24], LEACH-B (Balanced LEACH) [24], LEACH-A (Advanced LEACH) [25], Q-LEACH (Quadrature LEACH) [26], LEACH-SM (LEACH with Spare Management) [27].

Advantages:

1) The clusters are easy to form and are very useful in data aggregation which removes the chances of data duplication at sink node.

Disadvantages:

1) Energy consumption is high which reduces the lifetime of the network.

2.6.2.2 PEGASIS and Hierarchical-PEGASIS

Power Efficient gathering in sensor Information Systems [28] is the next version of LEACH proposed by Lindsey and Raghvendra. In this protocol, the nodes form a chain for communication and transmit data from node to node and select one node among them to transmit data to the base station. Greedy approach is applied to form the chain [28]. Nodes aggregate and eventually forward the data to the base station/sink node.

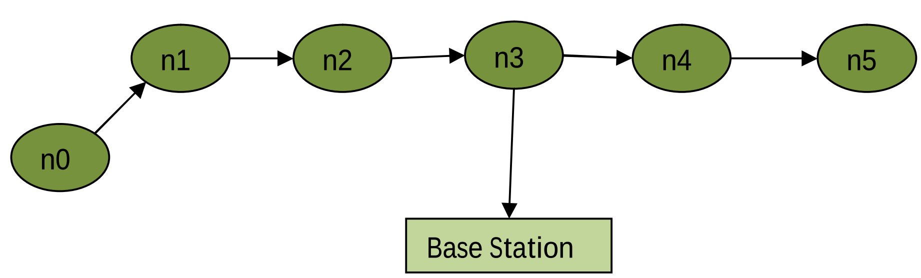


Fig 2.7 PEGASIS Chaining

Instead of using single-hop as in case of LEACH, the PEGASIS protocol uses multi-hop routing technique. PEGASIS works better than LEACH about 100-300% for different network topologies and sizes. It decreases the number of transmissions by using data aggregation and removes the overhead caused by dynamic clustering. But it introduces delays when the chain formed by sensor nodes is very long because it will take long time to decide that which node will forward the data to sink node.

To solve the problems in PEGASIS, Lindsey *et.al*. proposed the extension of PEGASIS [28]. The authors had proposed a solution which is related to data gathering by taking energy x delay metric into consideration. To decrease delay, simultaneous transmissions are allowed in this protocol. But this can cause collisions and interferences in the signals. To avoid these problems Hierarchical PEGASIS [28] uses two approaches, one is signal coding i.e. CDMA and the second is approach is to allow transmission by only those nodes which are separated by regions/spatially.

Advantages:

1) Energy efficient protocol.

2) Works faster in small deployment areas.

Disadvantages:

1) There is no procedure for dynamic topology adjustments.

2) Sometimes there is a problem of selecting one node as a leader for consecutive transmissions which results in depletion of that sensor node.

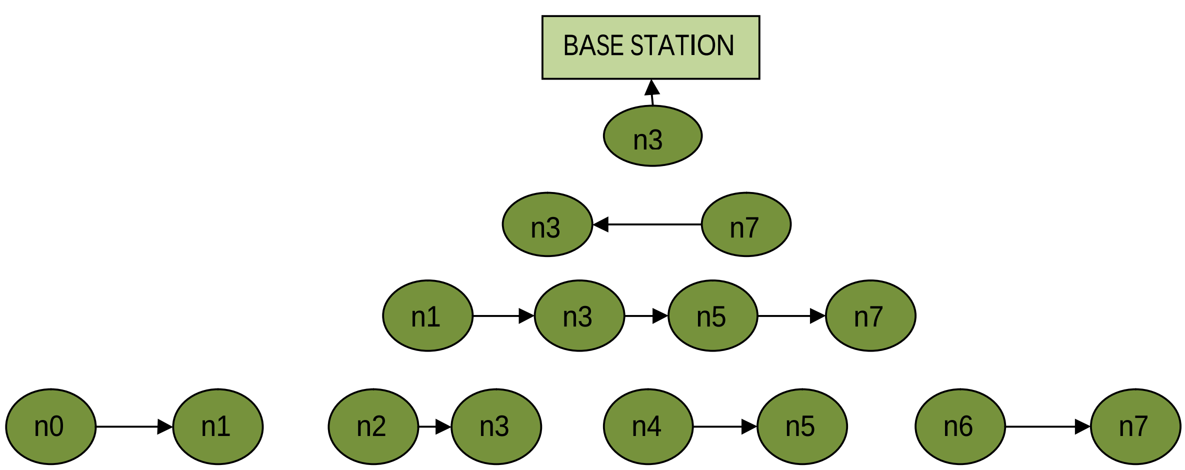


Fig 2.8 The chain based banary scheme of data gathering in Hierarchical PEGASIS

2.6.3 Location Based routing Protocol

The estimation of location-based protocols is using an arena instead of a node identifier as the object of a packet. Any node that positions within the given area will be accepted as a destination node and can obtain and process a message. From the perspective of sensor networks, location-based routing is important to request sensor data from any region. There is no addressing method for sensor networks like IP-addresses and they are spatially deployed in a neighborhood, location information can be used in routing data in an energy-efficient manner. For example, if the region to be sensed is identified then using the location of sensor nodes, the question can be disseminated only to that particular region which will eradicate the number of transmission significantly. The location-based routing protocols obtain into report the mobility of sensor nodes and execute very well when the density of the network increases. Merely, the execution is very pitiful when the network deployment is sparse and there is no data aggregation and further dealing out of the header node. For example, GEAR [18] is one of the location-based protocols.

2.6.3.1 MECN and SMECN

Minimum energy communication network (MECN)[29] is a self-reconfiguring protocol that maintains the energy consumption as minimum as possible by using low power GPS. It generates minimum spanning tree at base station minimum power topology. The tree contains only the routes from source node base station which consume lesser energy.

When forming the topology MECN spot relay regions for each node in the network. Relay region can be defined as the area of surrounding of the sensor node, in which the node can transmit data by using as less energy as it can. After defining the relay region and spanning tree, the enclosure graph is constructed by using lesser number of nodes among which communication requires very less energy. MECN works in two phases mainly:

- Enclosure Graph Construction: It is a sparse graph which consists of all enclosure of each sensor node in the network. The graph contains all possible minimum energy links which are globally optimal.
- Find Shortest Path: In this phase, the protocol finds the shortest path by using the Bellmann-Ford shortest path algorithm with power consumption as a cost factor.

The small minimum energy communication network (SMECN) [29] is an extension of MECN. Unlike MECN, SMECN considers the hurdles in the way of communication between two nodes also. Although the network is still considered as connected, the minimum energy relaying is

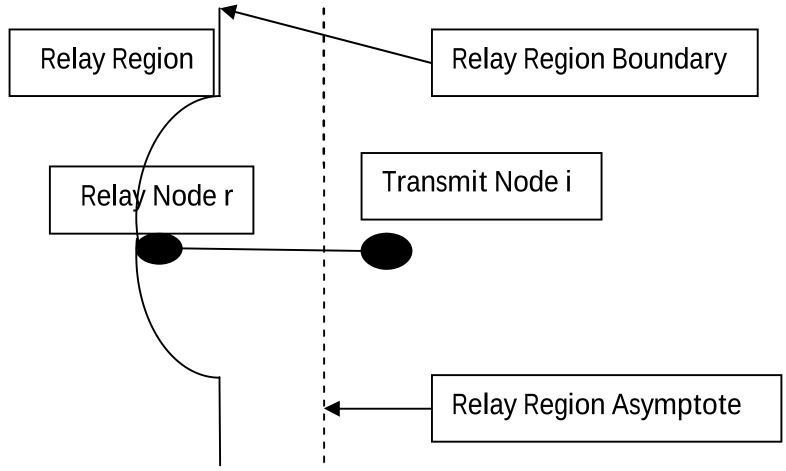


Fig 2.9 MECN Relay region of transmit-relay node pair (i, r)

smaller (in terms of cast edges in graph) than in case of MECN. Hence numbers of transmissions are decreased hop-by-hop. SMECN uses less energy than MECN and also cost of the routes is very less.

Advantages:

1) Save a lot of energy used in transmission of data.

Disadvantages:

1) Sub-network with smaller numbers of nodes introduces more overhead in finding the routes.

2.6.3.2 Geographic and energy-aware routing (GEAR)

Geographic and energy aware routing [30] has been proposed by Yu *et.al*. which can build routes on the basis of geographic information of the neighbors. The main idea behind this protocol was to restrict the number of interests in directed diffusion by only sending interests to a specified region, rather than forwarding the interest to each sensor node in the network. Each node in the network retains the estimated cost of transmitting a packet towards the destination. Also the node will retain a learning cost to reach the destination through its neighbors. If there is no neighbor node to any of the sensor node through which it can transmit data towards the destination region, it is considered as a hole. If there are no holes in the network, then the learning cost and the estimated cost are considered to be equal. The algorithm works in two phases [30]:

- Target region forwarding: On receiving any packet, each sensor node will check if there is/are any neighbor(s) which exists, which can be selected as next hop for transmission of data. If there is only one, then the sensor node has to select this neighbor only as a next hop for forwarding the data. But, if there are multiple neighbors then forwarder will select a node as next hop, which is nearest to the target region. If there is no node closer to the forwarder node, then it means that there is a hole. In this case the node will pick neighbor based on the learning cost to forward the data packet.
- Within the Region Forwarding: The packet is diffused in the region by using recursive geographic forwarding or by means of restricted flooding.

Advantages:

1) GEAR reduces energy consumption.

2) Packet delivery is very good as compared to other protocols.

Disadvantages:

1) There is extra overhead of selecting the next neighbor for forwarding the data packets.

2.7 Comparison Table of WSN Routing Protocols

Table 2.1 Comparative study of WSN Routing Protocols

Routing Protocols	Classification	Power Usage	Data Aggregation	Scalability	Query based	Over head	Data delivery model	QoS
SPIN	Flat /Srcinitiated /Data-centric	Ltd.	Yes	Ltd	Yes	Low	Event driven	No
DD	Flat/ Datacentric/ Dstinitiated	Ltd	Yes	Ltd	Yes	Low	Demand driven	No
RR	Flat	Low	Yes	Good	Yes	Low	Demand driven	No
GBR	Flat	Low	Yes	Ltd	Yes	Low	Hybrid	No
CADR	Flat	Ltd		Ltd	Yes	Low	Continuously	No
COUGAR	Flat	Ltd	Yes	Ltd	Yes	High	Query driven	No
ACQUIRE	Flat/ Data centric	Low	Yes	Ltd	Yes	Low	Complex query	No
LEACH	Hierarchical / Dst-initiated /Node-centric	High	Yes	Good	No	High	Cluster-head	No
TEEN & APTEEN	Hierarchical	High	Yes	Good	No	High	Active threshold	No
PEGASIS	Hierarchical	Max	No	Good	No	Low	Chains based	No
VGA	Hierarchical	Low	Yes	Good	No	High		No
SOP	Hierarchical	Low	No	Good	No	High	Continuously	No
GAF	Hierarchical / Location	Ltd	No	Good	No	Mod	Virtual grid	No
SPAN	Hierarchical / Location	Ltd	Yes	Ltd	No	High	Continuously	No
GEAR	Location	Ltd	No	Ltd	No	Mod	Demand driven	No
SAR	Data centric	High	Yes	Ltd	Yes	High	Continuously	Yes
SPEED	Location/Data centric	Low	No	Ltd	Yes	Less	Geographic	Yes

2.8 Conclusion

In this chapter, we discussed various WSN routing protocols. The routing techniques are classified into four categories on the basis of network structure; data centric, hierarchical, location-based and opportunistic routing protocols. Comparative analysis of various WSN routing protocols on the basis of parameters; power usage, data aggregation, scalability, query based, over head, data delivery model, QoS; has been done. We conclude that, in case of hierarchical routing scalability is high as compared to data centric and location based routing protocol. Data centric is query-based while the other two are not. When we talk about the overhead, it is low in data centric routing, moderate for location based and mostly high for hierarchical routing protocol.

CHAPTER 3

OPPORTUNISTICROUTING PROTOCOLS

3.1 Opportunistic Routing

Challenged networks are the ones where network contacts are intermittent or where link performance is highly variable and there is no complete path from source to destination for most of the time. The path can be highly unstable and may change or break quickly [31]. To make communication possible, intermediate nodes may keep the data during the blackout and forward it when the connectivity resumes [31]. Opportunistic Routing uses broadcast transmission to send packets through multiple relays. Opportunistic routing achieves higher throughput than traditional routing. First protocol was designed by Biswas and Morris in 2004 [32].The main idea behind Opportunistic Routing is to select a subset of the nodes between the source and the destination node and the node closest to the destination will first try to retransmit packets.

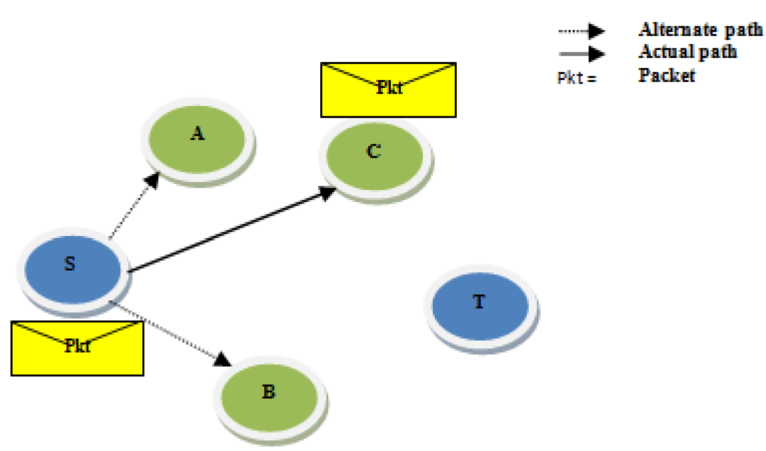


Fig 3.1Opportunistic Routing

The two steps of OR are [11]:

1. Selection of the forwarder sets: Selecting only the potential nodes between the source and destination to increase the routing efficiency.

2. Prioritization among these forwarders: The highest priority forwarder should be the closest one to the destination.

3.1.1. Exclusive opportunistic routing (ExOR)

Ex-OR was proposed by Biswas and Morris in 2005 [32]. This protocol is an integration of routing and MAC protocols. In Ex-OR the routes are established after the transmission of data packet. After transmission of a data packet next hop is selected on the basis of multiple opportunities available for data transmission routes.

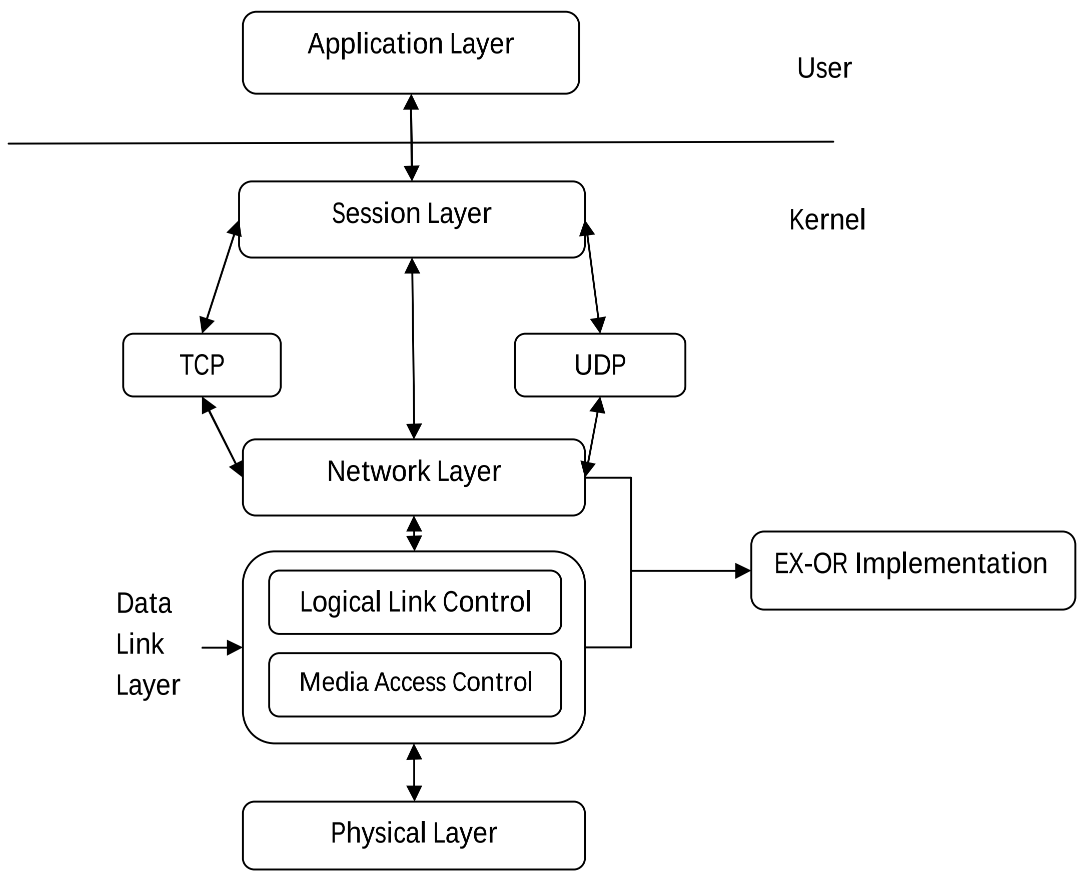


Fig 3.2Layered Architecture – Implementation of EXOR

The data packets are broadcasted by the source node and the next forwarder will be selected only after finding the best set of nodes which are able to forward the data packets further to next hop or destination nodes. The protocol ensures that only the sensor node in the best condition will forward the data packets further. To select the best forwarder node, the Ex-OR forms the batches of data packets and the source node includes a list of forwarder candidates in each packet prioritized on the basis of the closeness to the destination [32]. Receiver node will further do the same process until the whole batch of packets reach the destination node/ sink node and provide acknowledgement to the source node via same path.

Advantages:

1) Provides higher throughput.

2) Acknowledgements prevent unnecessary transmissions.

Disadvantages:

1) Response time might be affected by the larger amounts of buffering in high efficiency networks.

3.1.2. Energy Efficient Opportunistic Routing (EEOR)

EEOR is an algorithm which works on the basis of selecting forwarders' list and prioritizing the nodes in it [33]. Two scenarios have been presented in the paper for adjusting the power of the nodes during transmission. EEOR have been tested on TOSSIM simulator.

In first scenario it is assumed that the sensor nodes cannot adjust the power available with them. In other case the transmission power can be adjusted by the sensor node for each transmission.

When the forwarder list has been formed the expected cost of transmission has been recorded against each forwarder node entry. Initially the cost will be zero for all nodes. Distance vector routing [33] has been used to decide the routes after the expected cost has been calculated. The advantage of this EEOR is that end to end delay is smaller than EXOR routing. It is also better in terms of the packet loss ratio, energy consumption, and the average delivery delay.

Advantages:

1) The data delivery is guaranteed.

2) Problem of duplication of data packets has been resolved by allowing only one node from forwarder list to forward the data.

Disadvantages:

1) Energy cost of communication agreement has been omitted from the cost calculation which is an extra overhead.

2) The expected cost calculations can introduce delays in network communication and the data cannot be delivered in expected time.

3.1.3. Energy Aware Opportunistic Routing (EAOR)

Energy Aware Opportunistic Routing follows a same transmission method as the opportunistic routing. But, the main diversity of this approach is the next relay node selection criterion [34]. The communicating node that will respond first to an RTS packet is different than that of opportunistic routing. In energy aware opportunistic routing, a sensor node checks its energy level. If the energy level is low, then it does not respond to CTS. In this manner, the lifespan of each client is increased. When a node has high power usage, the probability to get a DATA packet is more depressed. But, the sensor node can still involve you in some of the DATA packet transmissions.

If a neighboring node has a high energy level, but it is not that close to the destination in comparison with other neighboring nodes, it will start participating in packet transmissions when some of the neighboring nodes consumed too much energy. Energy aware opportunistic routing tries to send the packets over nodes that are near to the destination and also accept a high energy level. In this manner, it can discover more routing paths compared to the opportunistic routing. These paths do not always consist of a similar number of hops. However, they consist of nodes that have not been used that much and have high energy levels. EOAR does not use beaconing mechanism. For that reason, it avoids the disadvantages of beaconing and this is the advantage of this EOAR protocol.

Advantages:

1) EOAR performs 35% better in energy consumption than traditional routing protocols.

2) Increases network lifetime by 25%.

Disadvantages:

1) The throughput of the network is similar to that of previously proposed opportunistic routing algorithms, and that is less.

2) The energy distribution is not good when the network is of small size.

3.1.4. Simple Opportunistic Adaptive Routing (SAOR)

SOAR is a proactive link state routing protocol. Each sensor node periodically calculates and distributes link quality in terms of ETX. According to this information, a sender chooses the default path and a list of next-hop that are suitable for forwarding the data. It then broadcasts a data packet together with this information. Upon consideration the transmission, the nodes was not present on forwarding list, just discard the packet. Nodes were present at the forwarding list store the packet and set forwarding timers based on their nearness to the destination. Smaller timer is set if the node is closer to the destination and forward the packet earlier. Upon examining this transmission, the other nodes will eliminate the resultant packet from their queues to avoid redundant transmissions. Similar to all the existing opportunistic routing protocols, SOAR broadcast data packets at a fixed PHY data rate. The advantage of SOAR is promising to achieve effectively support multiple simultaneous flows and high efficiency

3.1.5. EFFORT

EFFORT is another opportunistic routing protocol for WSNs. EFFORT based on the OEC (Opportunistic end to end cost) metric, which represents the predictable end to end scarcity energy cost for each data transmission [35]. Effort having three main components is:

- Method for OEC computation,
- Select Candidate and relay priorities, and
- Data forwarding and OEC is updating.

The first component enables each sensor node to calculate its optimal OEC in a dispersed manner. The second component lets every sensor node put its optimal forwarding set of its neighbors and verify the relay sequence. The third component tells how the chosen forwarders help with each other to relay data and update the OEC value consequently. Main advantage of this EFFORT routing is the improvement of transmission reliability and path diversity, to develop a distributed routing scheme for keeping up the network-lifetime of a WSN.

Advantages:

1) EFFORT considers energy cost of end to end data forwarding and also residual energy of the sensor nodes.

2) EFFORT ensures transmission reliability.

3) EFFORT achieves network lifetime enhancement.

Disadvantages:

1) Algorithm design and implementation is very complex.

2) Performance degrades when the sensors in the network are scattered far away from each other.

3.1.6 Multi-hop Optimal Position based (MOOR)

Multi-hop Optimal Position based Opportunistic Routing (MOOR) [36] has been proposed by Devi *et.al*. in 2014. The authors have used the opportunistic routing and apply a broadcasting scheme to design this new protocol called as MOOR. The protocol considers the communication between source and destination pairs as most important.

MOOR decides the routes which are containing minimum number of hops between source and destination. The data packets will be transmitted on the route which is of smaller distance. MOOR has a good end to end delay and it also increases the lifetime of the network [36].

The average end to end delay by using MOOR is lesser than that of EEOR, to which the authors have compared it.

3.2 Comparison table and Analysis

We have compared the following routing protocols according to their design characteristics and the results are described in table 3.1:

Table 3.1 Comparison of various ORP

Name of Protocol	Power Usage	Data Aggregation	Scalability	Data delivery model	QoS
ExOR	Moderate	YES	Poor	Continuous	NO
EEOR	LOW	YES	Moderate	Event Driven	YES
SAOR	LOW	NO	Poor	Continuous	NO
EAOR	LOW	YES	Good	Event Driven	YES
EFFORT	LOW	YES	Good	Active	YES
MOOR	High	No	No	Query Driven	No

3.3 Conclusion

In this chapter, we performed a comprehensive survey of opportunistic routing techniques for WSNs. We also discuss various opportunistic routing protocols, and the design tradeoffs between energy and communication overhead savings in some of the routing paradigm. Also, the advantages and disadvantages of each opportunistic routing technique have been discussed. Although several opportunistic routing techniques look promising, still there are many challenges that need to be solved in the WSN. We highlighted those challenges and pinpointed future research directions in this regard. We have compared the various routing protocols in the basis of some parameters; Power usage, Data aggregation, Scalability, Data delivery model and QoS.

CHAPTER 4

MIDDLE POSITION DYNAMIC ENERGY OPPORTUNISTIC ROUTING

4.1 Introduction

In this chapter, Middle Position Dynamic Energy Opportunistic Routing (MDOR) has been proposed for efficient multi-hop communication between a source and destination pair in WSN. MDOR uses dynamic energy consumption when a packet is transmitted between nodes. In wireless sensor networks, there is a trade-off between the end to end delay and network lifetime, when we use the concept of dynamic energy consumption. It is observed that the average end to end delay is less in Energy Efficient Opportunistic Routing (EEOR) protocol as compared to the Multi-hop Optimal position Opportunistic Routing (MOOR) protocol. But in case of dynamic energy consumption, the networks lifetime of an EEOR protocol is better. The proposed protocol has optimized the end to end delay and network lifetime with the use of dynamic energy consumption

4.2 Related work

To increase the overall throughput of Multi-hop Wireless Networks, authors have proposed ExOR [32]. It describes MAC and an integrated routing. The protocol chooses each hop destination of the route of a packet after the completion of the hop. The protocol gives a choice to decide which of the neighboring nodes should receive the packet. ExOR protocol provides us a better output as compared to the traditional routing protocols with the same network capacity. For minimizing the energy consumption, authors [33] focused on selecting and prioritizing the forwarder list of a node by designing Energy Efficient Opportunistic Routing. Energy consumption, the average delivery delay and the ratio of the packet loss of the networks are the analyzed output parameters. The basic concepts and the components of opportunistic routing are reviewed and discussed by authors [37]. Current trends, issues and challenges in opportunistic routing are explained with examples. The key challenges to be addressed by the researchers in the field of opportunistic routing are discussed in detail.

An Energy Efficient Opportunistic Routing (EEOR) was proposed by authors [33] to improve the energy consumption, the packet loss ratio, and the delivery delay of multi-hop wireless sensor networks. The overhearing feature of the sensor nodes is used by the protocol and proves to be better than the ExOR Protocol. Hybrid Multi-hop routing (HYMN) was proposed by authors [38] .It is hybrid architecture of both clusters based on multi-hop routing and flat based routing architectures of wireless sensor networks. With the help of simulation, it is shown that the HYMN protocol improves the lifetime of the networks as compared to multi-hop routing and flat based routing individually

4.3 Methodology

In multi hop wireless sensor networks, the source sends data to the destination with the help of some intermediate nodes. Speed and reliability of the transmission depends on the position and energy level of the nodes and number of hops between the source and the destination. In opportunistic routing protocol, each node maintains a list of neighbors and a subset of neighbor list called the forwarder list. EEOR [33] chooses the node which is nearest to the source and selects it as a forwarder node in the forwarder list (shown in Fig. 3 A). MOOR [36] chooses the node which is nearest to the destination and selects it as a forwarder node in the forwarder list (shown in Fig. 3 B). The proposed protocol MDOR chooses the node which is neither nearest to the source nor to the destination i.e. chooses any middle node between the source and the destination which is near to both (shown in Fig. 3 C). The process of choosing the forwarder node and forwarding the packet continues until the target node is reached.

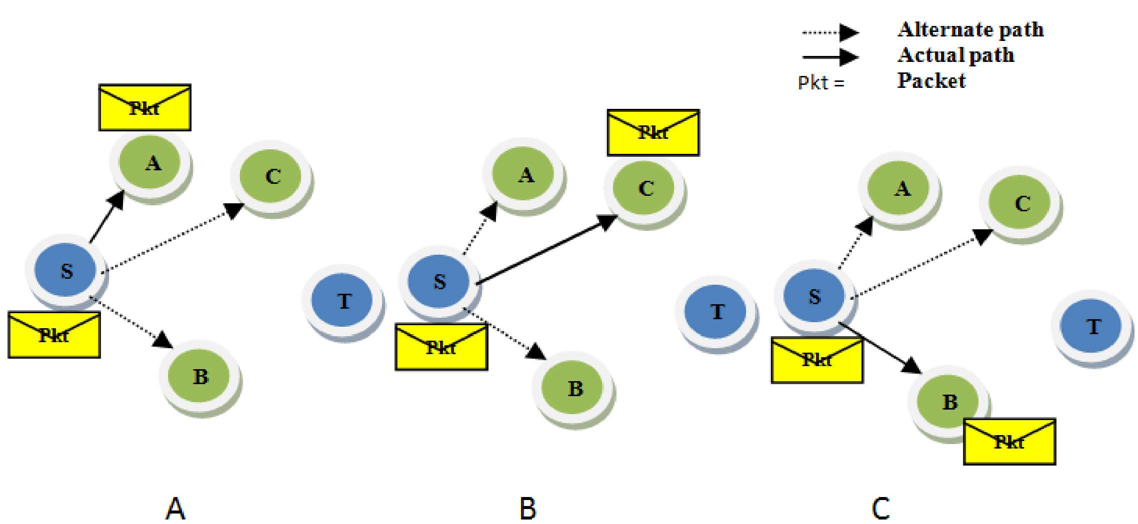


Fig 4.1 (A)EEOR protocol, (B) MOOR protocol and (C) MODR protocol

Each node maintains a list of neighbors and nodes identify their neighbors by broadcasting a *hello* packet in the networks. Each sensor node including the source node broadcasts a *hello* packet, so that all sensor nodes create their own routing table. *hello* packet is broadcasted at regular intervals of time so that sensor nodes update their routing table. Once the routing table is created, source node chooses a forwarder node which is at a minimum distance from the target node to ensure that the packet reaches the destination. When the packet reaches the sink node, it sends an acknowledgement to the source node. Proposed approach MDOR opportunistically chooses the path for sending acknowledgment packet to optimize the energy consumption in the networks.

4.3.1 Algorithm for MDOR Protocol

Input: source node *S*, target node *T*, dist(S, T).

Output: Transmit the packet from node S to node *T* using opportunistic routing

1. Take S
2. Generate neighbor list N for S
3. Sort neighbor list according to distance
4. if T is neighbor of S
5. Send packets to T
6. else
7. F_L is the subset of N (F_L is the forwarder list)
8. Select the middle node (F) from the forwarder list i.e. (neither near to S nor near to T).
9. Send packets to F.
10. if F is destination then receives packets
11. else repeat step 2 to step 9 until T is reached

Fig 4.2 Algorithm for proposed MDOR protocol

4.3.2 System Model

4.3.2.1 Network Model

Here, the network model uses 50 sensor nodes which are randomly deployed in the target area of 500 m by 500 m. Transmission range of each node is 100 m. Each node is static and generates a data packet at the rate of 1000 bytes per sec. Out of 50 nodes, we have selected 5 pairs of source and destination for the analysis of the networks according to the chosen parameters.

4.3.2.2 Energy Model

Sensor nodes need energy for sensing, processing, receiving and transmitting packets. In wireless sensor networks, each sensor node is provided with some initial energy. The first order radio model for energy dissipation is used [39], as is shown in Fig. 2.

When a sensor node transmits a k bit packet over distance d, it will consume E_{TX} amount of energy:

$$E_{TX}(k,d) = \begin{cases} k.E_{elec} + k.\varepsilon_{fs}.d^2, \ if\ d < d_0 \\ k.E_{elec} + k.\varepsilon_{amp}.d^4, \ if\ d \geq d_0 \end{cases} \quad (5.1)$$

When a sensor node receives a k bit packet, it will consume E_{RX} amount of energy:

$$E_{RX}(k) = l.E_{elec} \quad (5.2)$$

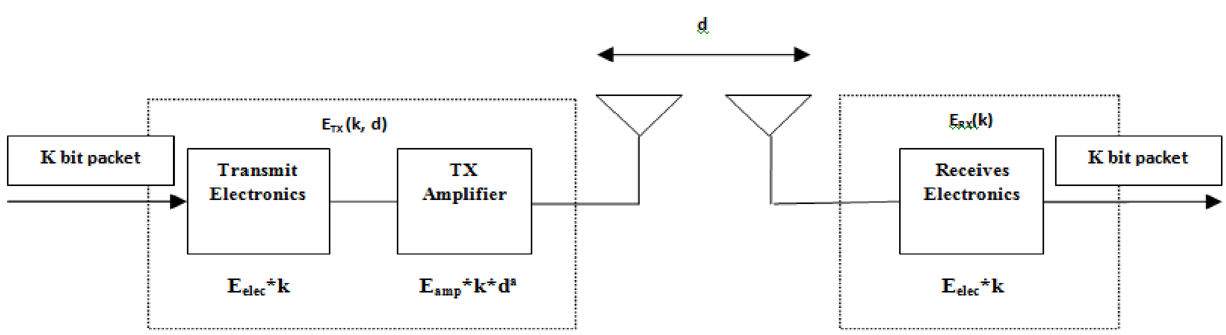


Fig 4.3 Energy dissipation model for wireless communication [39]

When a sensor node forwards a k bit packet, it consumes EFX amount of energy. This means that first it receives a k bit packet and consume ERX amount of energy and then transmit k bit packets and consumes ERX amount of energy. So, we add the ERX and ETX to get EFX for forwarding a k bit packet:

$$\begin{aligned} E_{FX}(k,d) &= E_{TX}(k,d) + E_{RX}(k) \\ &= \begin{cases} 2k.E_{elec} + k.\varepsilon_{fs}.d^2, \ if\ d < d_0 \\ 2k.E_{elec} + k.\varepsilon_{amp}.d^4, \ if\ d \geq d_0 \end{cases} \end{aligned} \quad (5.3)$$

The definition of the radio parameters is listed in Table 4.1.

Table 4.1 Details of various Wireless Parameters

Parameter	Definition	Value/Unit
E_{elec}	Energy dissipation to run the radio	50 nJ/bit
ε_{fs}	Free space model of transmitter amplifier	10 pJ/bit/m^2
ε_{amp}	Multi-path model of transmitter amplifier	0.0013 pJ/bit/m^4
L	Data length	2,000 bits
d_0	Distance threshold	$\sqrt{\varepsilon_{fs} / \varepsilon_{amp}}\, m$

Energy consume by the sensor nodes in the networks activities is E.

Let P_{TX} = number of packets transmitted.

P_{RX} = number of packets received by the sensor node.

P_{FX} = number of packets forwarded by the sensor node.

N = number of events in the networks.

I = ideal time spent by the sensor node.

$$E \leq NE_S + P_{TX}E_{TX} + P_{RX}E_{RX} + P_{FX}E_{FX} + IE_I \tag{5.4}$$

List of components of energy consumed by a sensor node in the network is listed in Table 5.2.

Table 4.2 Energy Model of a Sensor Node

Symbol	Description
E	Initial Energy
E_S	Energy consumed in sensing an event
E_{TX}	Energy consumed in transmitting a packet
E_{RX}	Energy consumed in receiving a packet
E_{FX}	Energy consumed in forwarding a packet
E_I	Energy consumed in idle mode
E_{RS}	Residual energy

4.4 Installation and Simulation

4.4.1 The Network Simulator (NS2)

Simulation can be defined as "Imitating or estimating how events might occur in the aid of technology, or combinations. The value lies in the pacing you under realistic conditions that change as a result of behavior of others involved, so you cannot anticipate the sequence of events or the final outcome.

4.4.2 NS2 Overview

NS [40] is an event driven network simulator developed at University of California at Berkeley, USA, as a REAL network simulator projects in 1989 and was developed at with cooperation of several organizations. Now, it is a VINT project supported by DARPA.NS is not a finished tool that can manage all kinds of network model. It is actually still a non-going effort of research and development. The users are responsible to verify that their network model simulation does not contain any bugs and the community should share their discovery with all. There is a manual called NS manual for user guidance. NS is a discrete event network simulator where the timing of events is maintained by a scheduler and able to simulate various types of network according to the programming scripts written by the user. Besides that, it also implements variety of applications, protocols such as TCP and UDP, network elements such as signal strength, traffic models such as FTP and CBR, router queue management mechanisms such as Drop Tail and many more.

There are two languages used in NS2 C++ and OTcl (an object oriented extension of Tcl). The compiled C++ programming hierarchy makes the simulation efficient and execution times faster. The OTcl script which written by the users the network models with their own specific topology, protocols and all requirements need. The form of output produce by the simulator also can be set using OTcl. The OTcl script is written which creating an event scheduler objects and network component object with network setup helping modules. The simulation results produce after running the scripts can be use either for simulation analysis or as an input to graphical software called Network Animation (NAM).

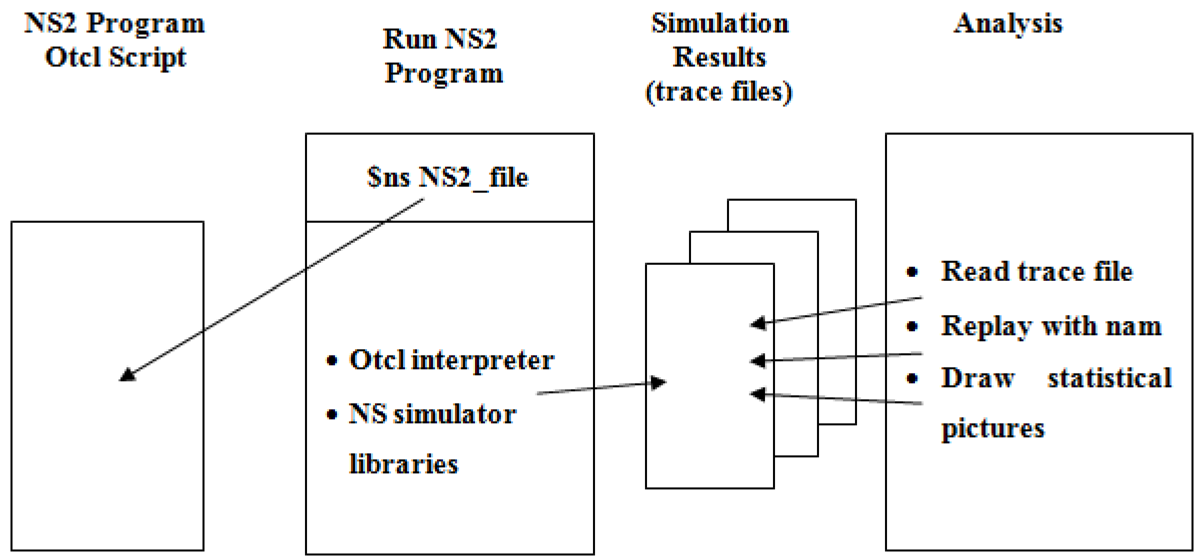


Fig 4.4 Running NS2 Program

NS2 is an event driven network simulator, which can be implemented in Linux-based platform. This report will explain on how to install NS2 in Fedora Core platform. TheNS2 files (recommended to download a piece of file which includes all the needed files called ns-allinone-2.xx from http://www.isi.edu/nsnam/ns/ must be downloaded into any media storage, most preferred is inside the computer itself where the NS2 is going to be installed. Since, we are using NS 2.29. It is not recommend logging in as a root because installation at root may interfere with any important Linux files.

4.4.3 Tool Command Language (Tcl)

Short for Tool Command Language, Tcl [41] is a powerful interpreted programming language developed by John Ouster out at the University of California, Berkeley. Tcl is a very powerful and dynamic programming language. It has a wide range of usage, including web and desktop applications, networking, administration, testing etc. Tcl is a truly cross platform, easily deployed and highly extensible. The most significant advantage of Tcl language is that it is fully compatible with the C programming language and Tcl libraries can be interoperated directly into C programs.

4.4.4 The Network Animation (NAM)

The network animator began in 1990 as a simple tool for animating packet trace data. This trace data is typically derived as output from a network simulator like ns or from real network measurements, e.g., using tcp dump. Steven McCanne wrote the original version as a member of the Network Research Group at the Lawrence Berkeley National Laboratory, and has occasionally improved the design, as he's needed it in his research. Marylou Orayani improved it further and used it for her Master's research over summer 1995 and into spring 1996. The nam development effort was an ongoing collaboration with the VINT project. Currently, it is being developed at ISI by the SAMAN and Conser projects.

4.4.5 Trace File

The trace file is an ASCII code files and the trace is organized in 12 fields as in Figure5.2 below.

Event	Time	From node	To node	Pkt size	Flags	Fid	Src addrs	Dst addrs	Seq num	Pkt id

Fig 4.5 Fields of Trace File

The first field is the event type and given by one of four available symbols r, +, - and which correspond respectively to receive, enqueued, dequeued and dropped. The second field is telling the time which the event occurs. The third and fourth fields are the input and output node of the link at which the events takes place. The fifth is the packet type such as continuous bit rate (cbr) or transmission control protocol (tcp).The sixth is the size of the packet and the next field is some kind of flags. The eighth field is the flow identity of IPv6, which can specify stream color of the NAM display and can be use for further analyze purposes. The ninth and tenth fields are the source and destination address in the form of “node. port”. The eleventh is the network layer protocol’s packet sequence number. NS keeps track of UDP packet sequence number for the analysis purposes. The twelfth, which is the last field, is the unique identity of the packet. Results of simulation are stored into trace file (*.tr). Trace Graph was used to analyze the trace file.

4.4.6 Trace graph

It is a data presentation system for Network Simulator NS2. The simulator doesn’t have any options implemented to analyze simulations results so it’s hard to use it. Trace graph [42] system provides many options for analysis, including 250 graphs and statistical reports. It is implemented in MATLAB 6.0 and can be compiled to run without MATLAB. Compiled versions for Linux and Windows systems are available for download at http://www.geocities.com/tracegraph/.

Trace graph supports the following NS2 trace file formats; wired, satellite, wireless(old and new trace), wired-cum-wireless. Trace file loading stage is divided into 4 stages; automatic trace file format recognition, trace file parsing to extract necessary simulation data which is saved to a temporary file, trace files can contain much more data than is needed by the system, so unnecessary information is omitted to speed up trace file loading, temporary file loading, constants calculations (packets types, packets sizes, flows IDs, trace levels, number of nodes, simulation time) in order to speed up data processing. Wireless and wired-cum-wireless trace files are parsed and saved in Trace graph format.

4.5 Parameters of Opportunistic Routing Protocols

Simulation of different routing protocols (EEOR, MOOR and MDOR) has been carried out to evaluate the performance. Various parameters that are considered for simulation are listed in table 4.3.

Table 4.3 Network Parameter Definition

Networks Parameters	EEOR	MOOR	MDOR
Radio model	Propagation/TwoRayGround	Propagation/TwoRayGround	Propagation/TwoRayGround
Channel type	Channel/WirelessChannel	Channel/WirelessChannel	Channel/WirelessChannel
Mac protocol	Mac/802_11	Mac/802_11	Mac/802_11
netif	Phy/WirelessPhy	Phy/WirelessPhy	Phy/WirelessPhy
ifqlen	30	30	30
ifq	Queue/DropTail/PriQueue	Queue/DropTail/PriQueue	Queue/DropTail/PriQueue
Routing protocol	EEOR	MOOR	MDOR
Number of Nodes	50	50	50
Networks Area	500 m X 500 m	500 m X 500 m	500 m X 500 m
Packet Generation Rate	1 Packet per Second	1 Packet per Second	1 Packet per Second
Transmission Range	250 m	250 m	250 m
Data Packet Size	1000 bytes	1000 bytes	1000 bytes
Simulation Time	50/150 Seconds	50/150 Seconds	50/150 Seconds
Initial Energy of Nodes	50 Joules (J)	50 Joules (J)	50 Joules (J)
Transmission Energy	Dynamic(depend on distance)	Dynamic(depend on distance)	Dynamic(depend on distance)

4.6 Conclusion

A routing protocol MDOR is presented in this chapter, which uses the concept of dynamic energy consumption. Due to dynamic energy consumption, when a node is closer to the source it takes less energy to transmit a packet and when node is far from the source it takes more energy to transmit a packet. In wireless sensor networks there is a tradeoff between the End-to-End delay and Network's Lifetime when we use the concept of dynamic energy consumption. Also, we discussed about the network simulator (NS2). We also talk about the various parameters of opportunistic routing protocols.

CHAPTER 5
RESULTS, PERFORMANCE EVALUATION &ANALYSIS

This chapter shows the results of the simulation. The study of the protocol is done on the basis of the outcome of *.tr file and the *.nam file. The ns2-allinone contains NAM is a build-in program. NAM helps us to see the flow of communication between the sensor nodes. It also shows the packets are falling or receiving to the sink correctly. Once the TCL file is written, NAM is start inside that file. With the help of 2 dimension and 3dimension figures we have attempted to examine the simulation results with different simulation time. The output scripts for tracegraph *.tr and for the NAM is stored as *.nam is used. The simulation has been essentially categorized in three parts that are given below:

- Simulation of Energy Efficient Opportunistic routing protocol (EEOR),
- Simulation of Multi-Hop Optimal Position Based Opportunistic Routing (MOOR) and
- Simulation of Middle Position Dynamic Energy Opportunistic Routing (MDOR)

The comparison between these three EEOR, MOOR and MDOR are performed over the common factors like energy consumption and average end-to-end delay in the system over different simulation time.

5.1 Simulation of Energy Efficient Opportunistic routing protocol (EEOR).

Simulation of EEOR Protocol is performed over 50 nodes having energy 100 J. Nodes in the network are in random position. In this scenario, there is a start node that will transmit the data and all the nearest nodes will do the same after getting it. Node 7 is the start node and node 33 is the destination node. In fig 5.1show the networks scenario with 50 nodes. Each node maintains a list of neighbors and nodes identify their neighbors by broadcasting a hello packet in the networks. Each sensor node including the source node broadcasts a hello packet, so that all sensor nodes create their own routing table. hello packet is broadcasted at regular intervals of time so that sensor nodes update their routing table. In fig 5.2show that each sensor node broadcasting a hello packet in the networks.

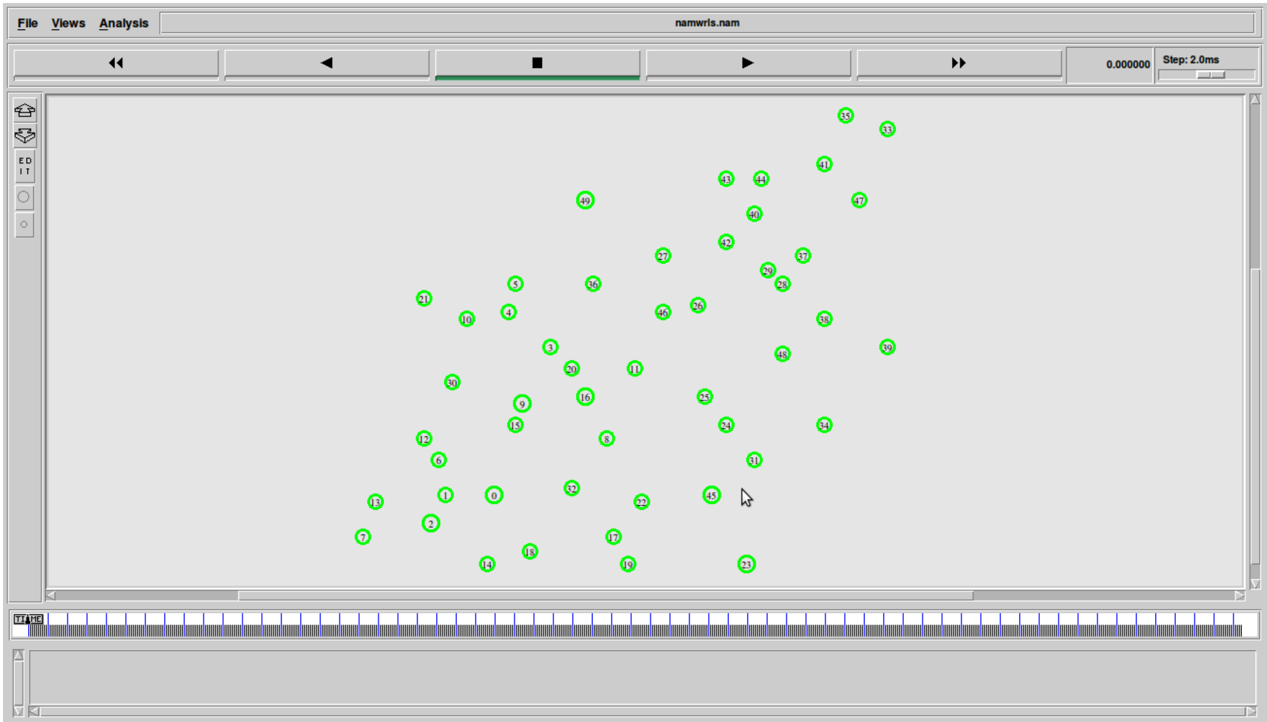


Fig 5.1 EEOR Protocol: Networks scenario with 50 nodes

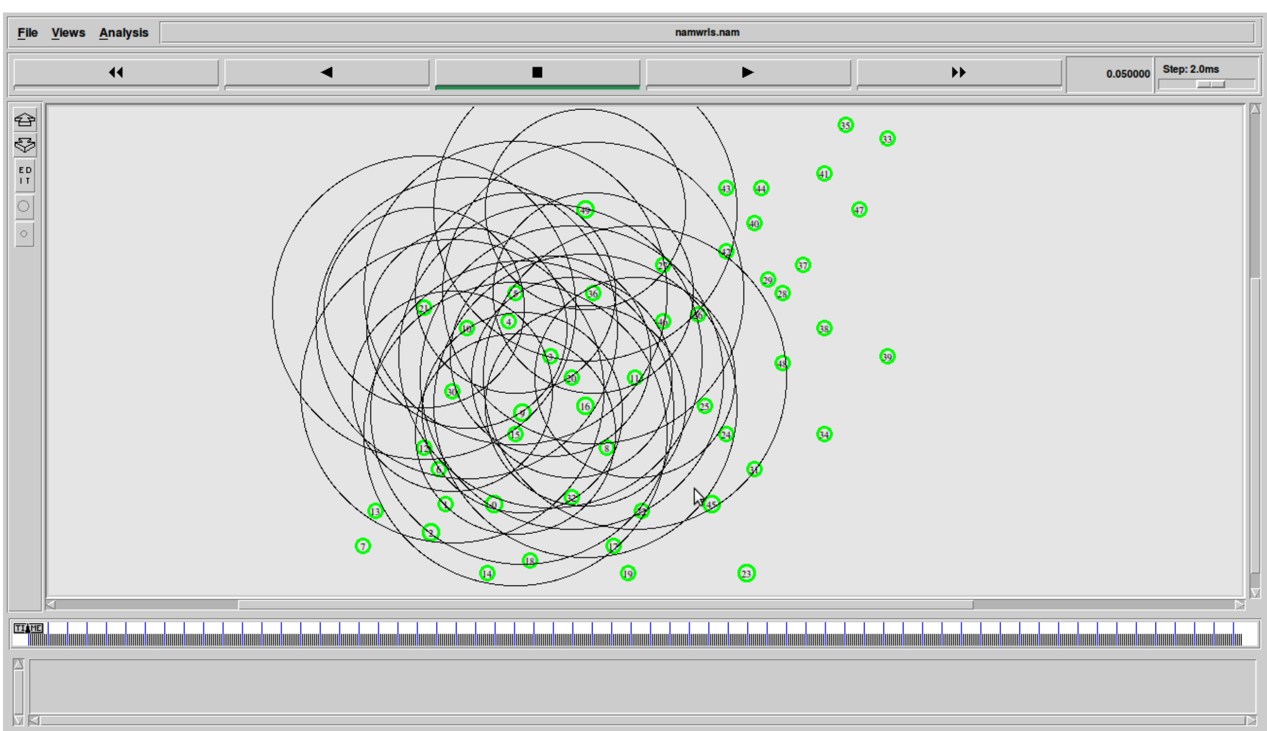


Fig 5.2 EEOR Protocol: Broadcasting hello packet between the Nodes

Once the routing table is created, source node chooses a forwarder node which is at a minimum distance from the target node to ensure that the packet reaches the destination. When the packet reaches the sink node, it sends an acknowledgement to the source node. In figure 5.3 shows that, packet send from source to destination.

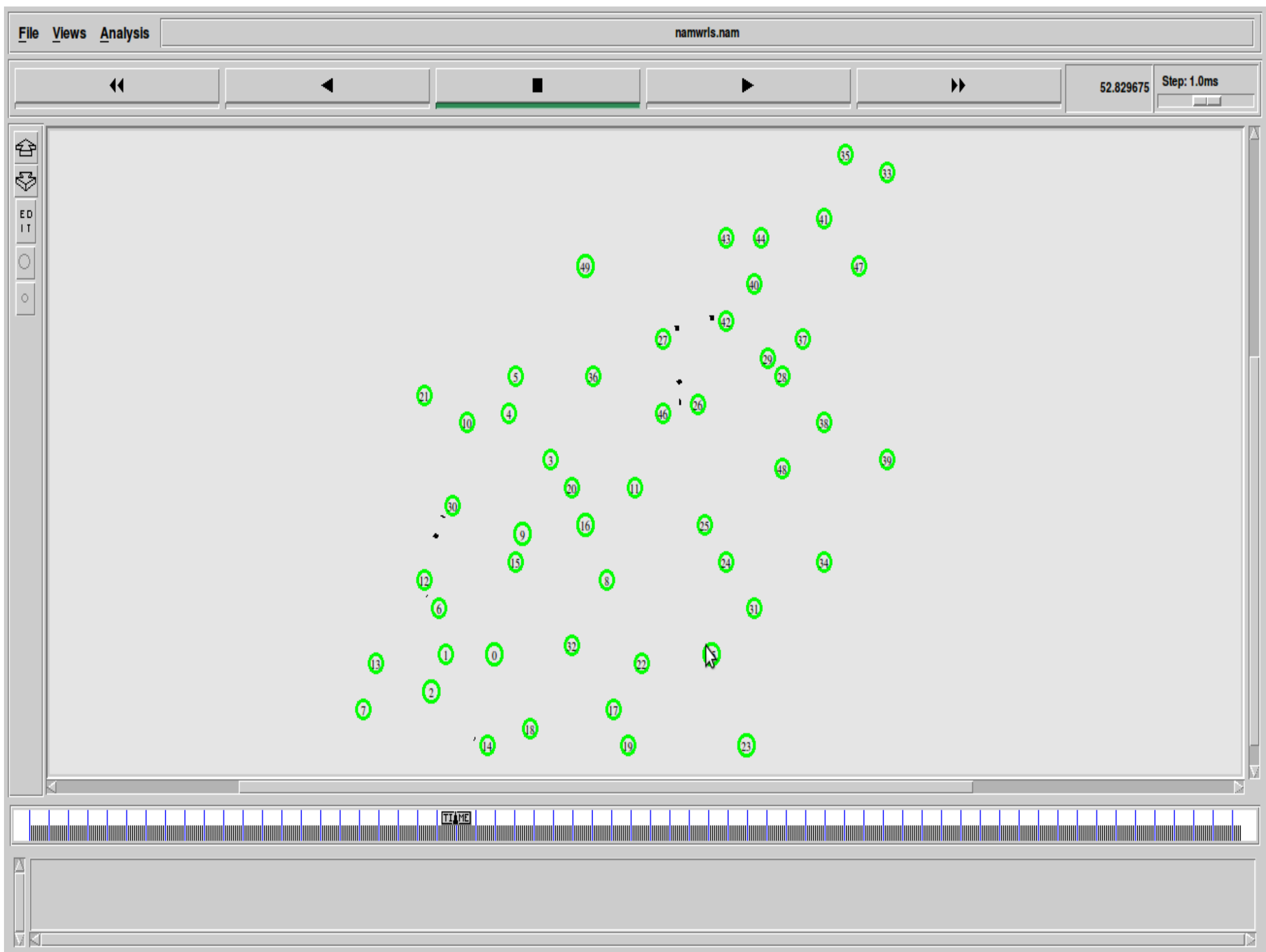


Fig 5.3EEOR Protocol: Sending packet from source to destination

The trace graph figs have been involved with the simulation time of 150 minutes. In fig 5.4, the whole simulation picture has been displayed along with the end-to-end delay. The fig 5.5 describes the throughput of Simulation Time versus Sending Packets. The throughput of receiving Packets versus Simulation Time has been displayed in fig 5.6. The Throughput of forwarding Packets versus Simulation Time has been displayed in fig 5.7.

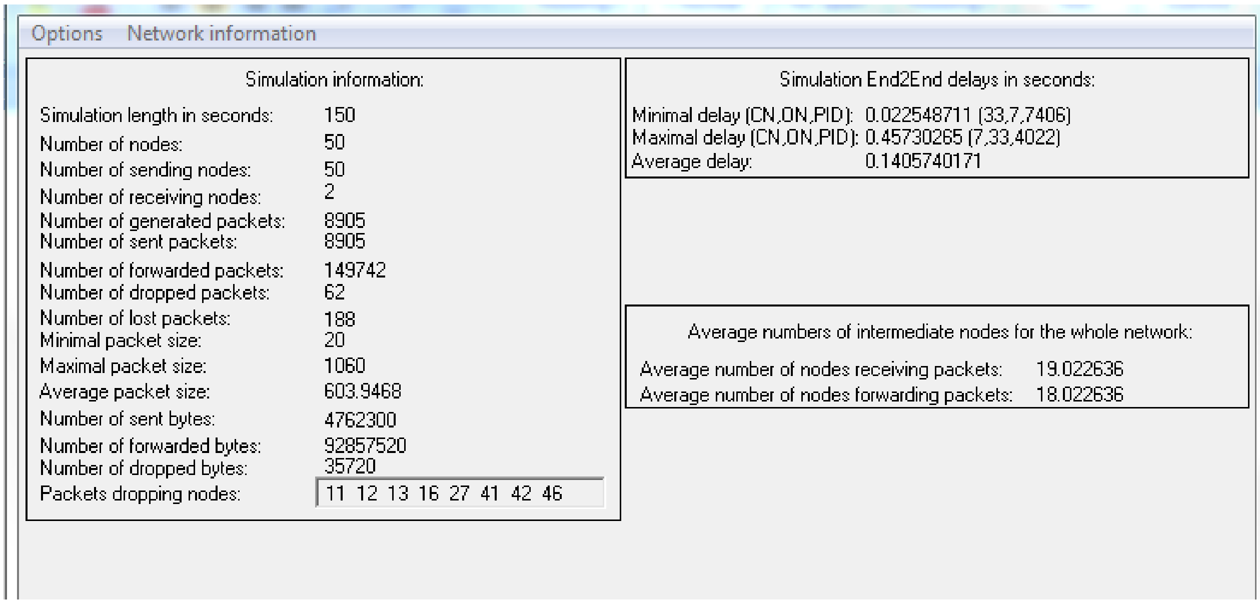


Fig 5.4 EEOR Protocol: Simulation details and End to End delay

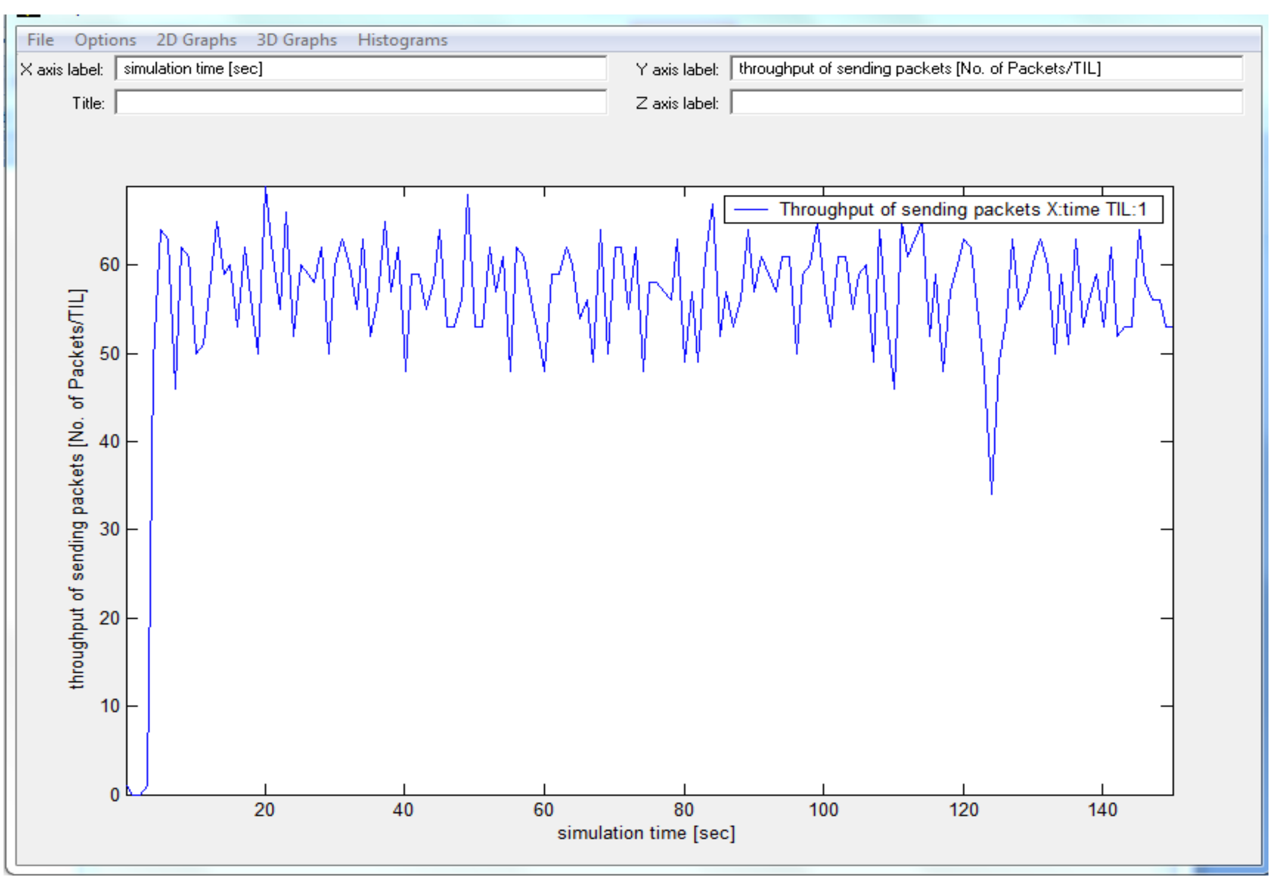


Fig 5.5 EEOR Protocol: Throughput of Sending Packets vs. Simulation Time

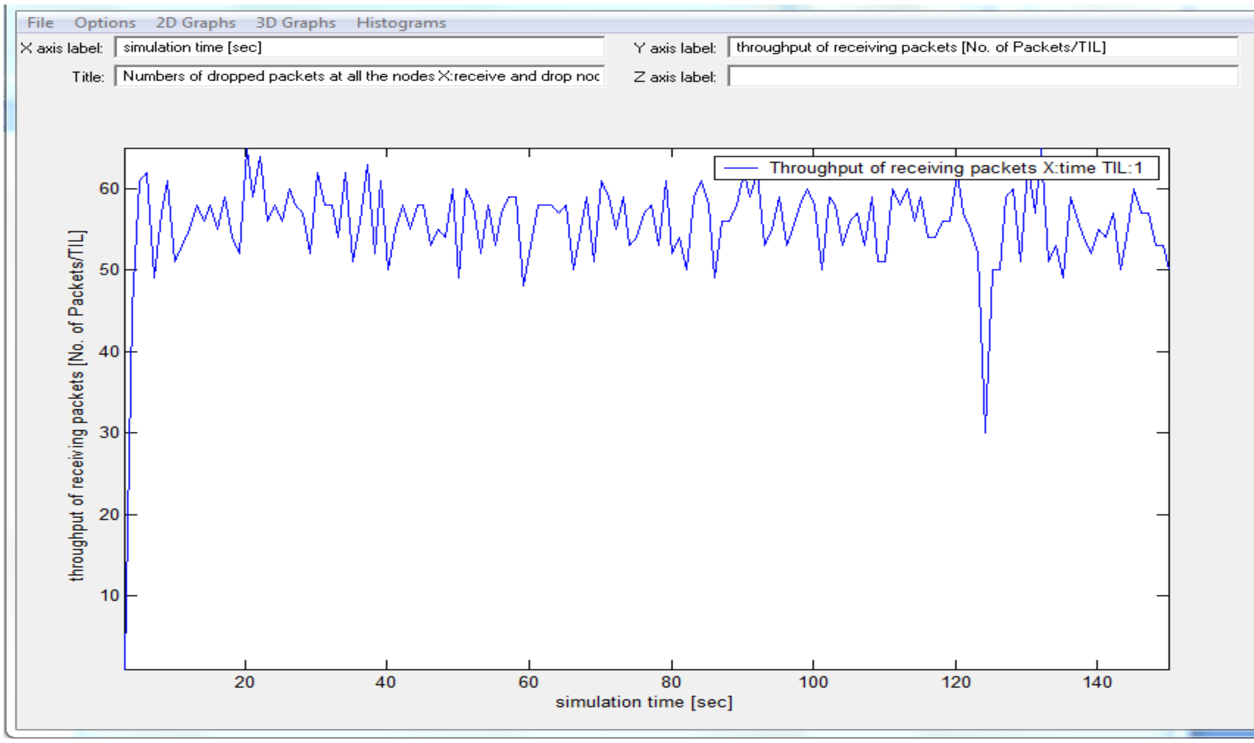


Fig 5.6EEOR Protocol: Throughput of receiving Packets vs. Simulation Time

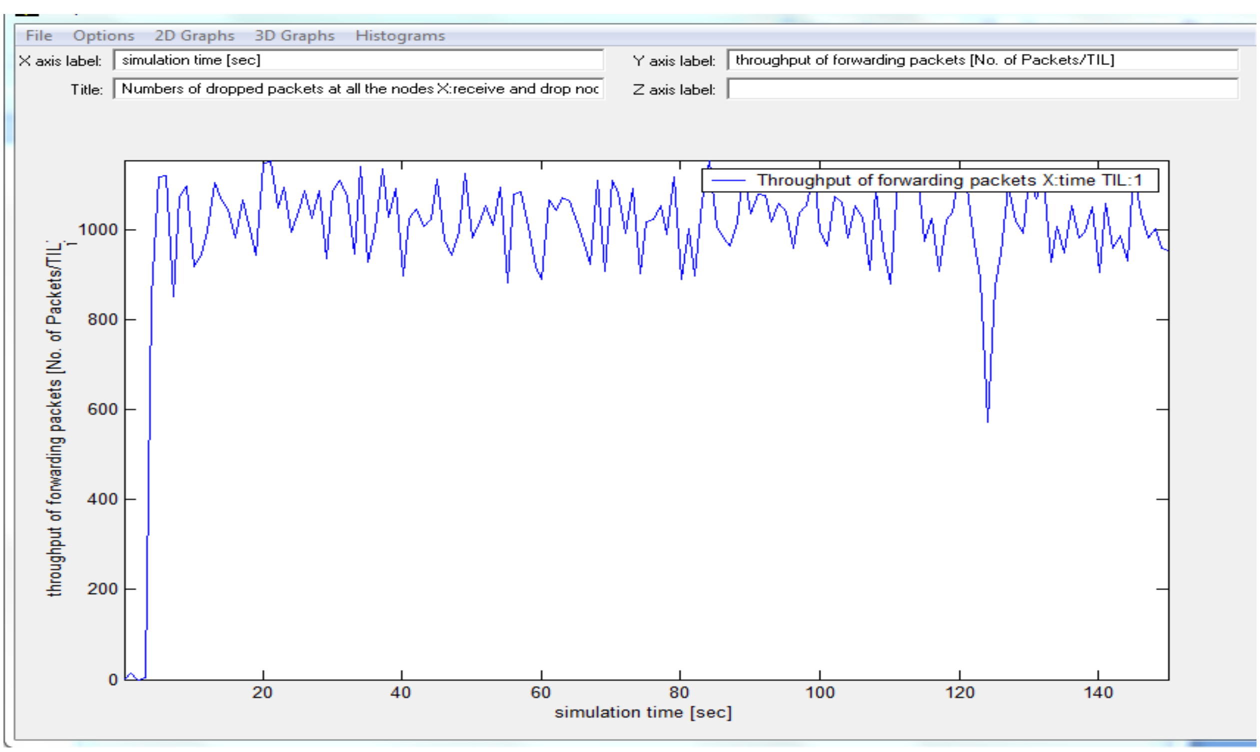


Fig 5.7EEOR Protocol: Throughput of forwarding Packets vs. Simulation Time

End to end delay is increasing continuously because node which is nearest to the source and selects it as a forwarder node in the forwarder list. So to reach to the sink a relatively long path is being followed by the packet which implies the extra end-to-end delay. In fig 5.8 end-to-end delay with its frequency distribution is being shown. The average delay of this EEOR protocol is 0.140sec. The maximum delay in this scenario is 0.457sec and minimum delay is 0.022sec. The cumulative frequency distribution has been shown in fig 5.9, which implies that the cumulative delay is rising continually to 0.31sec. In fig 5.10 shows the number of dropped packets at all nodes.

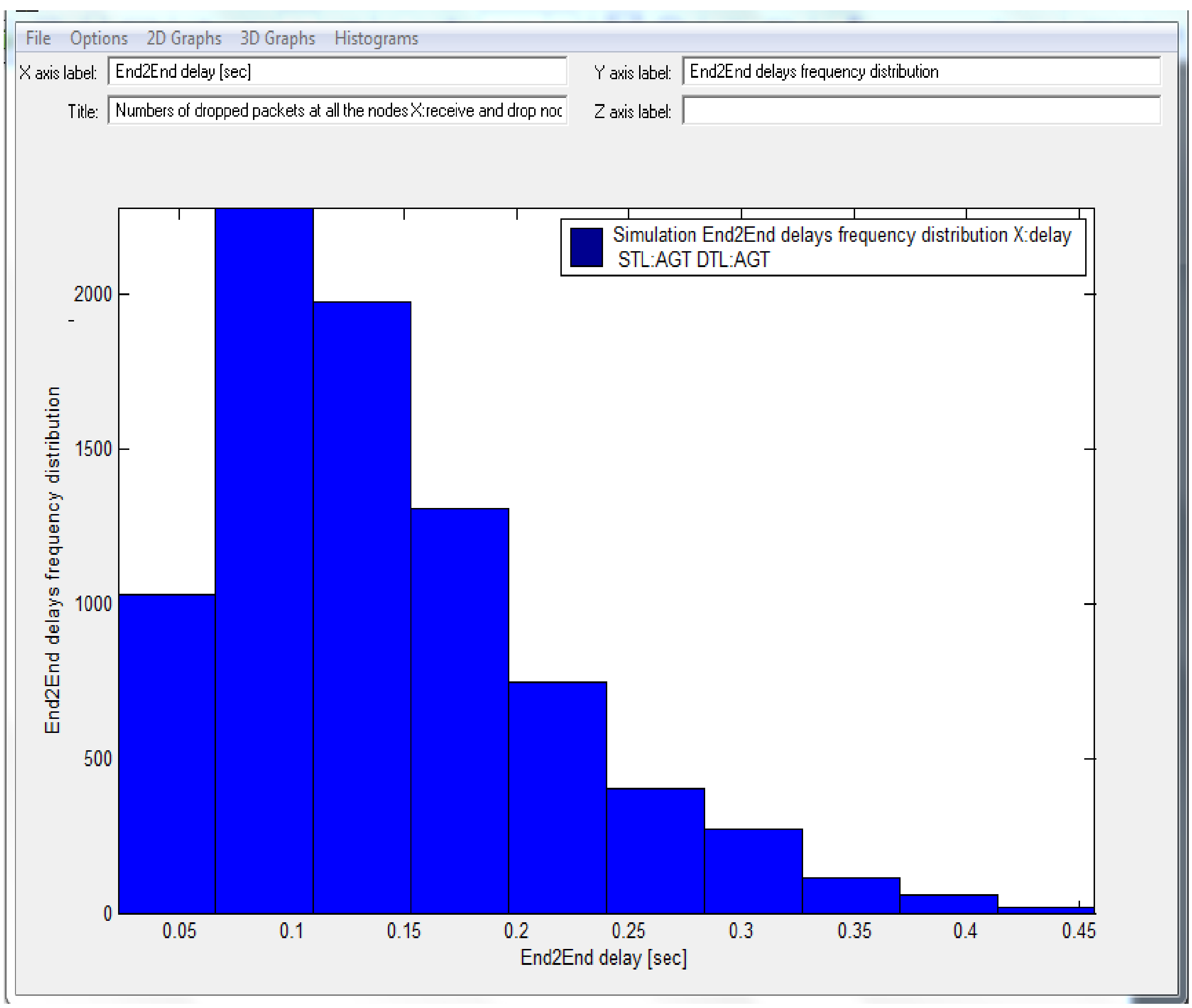


Fig 5.8 EEOR Protocol: End-to-end Delay Frequency Distribution

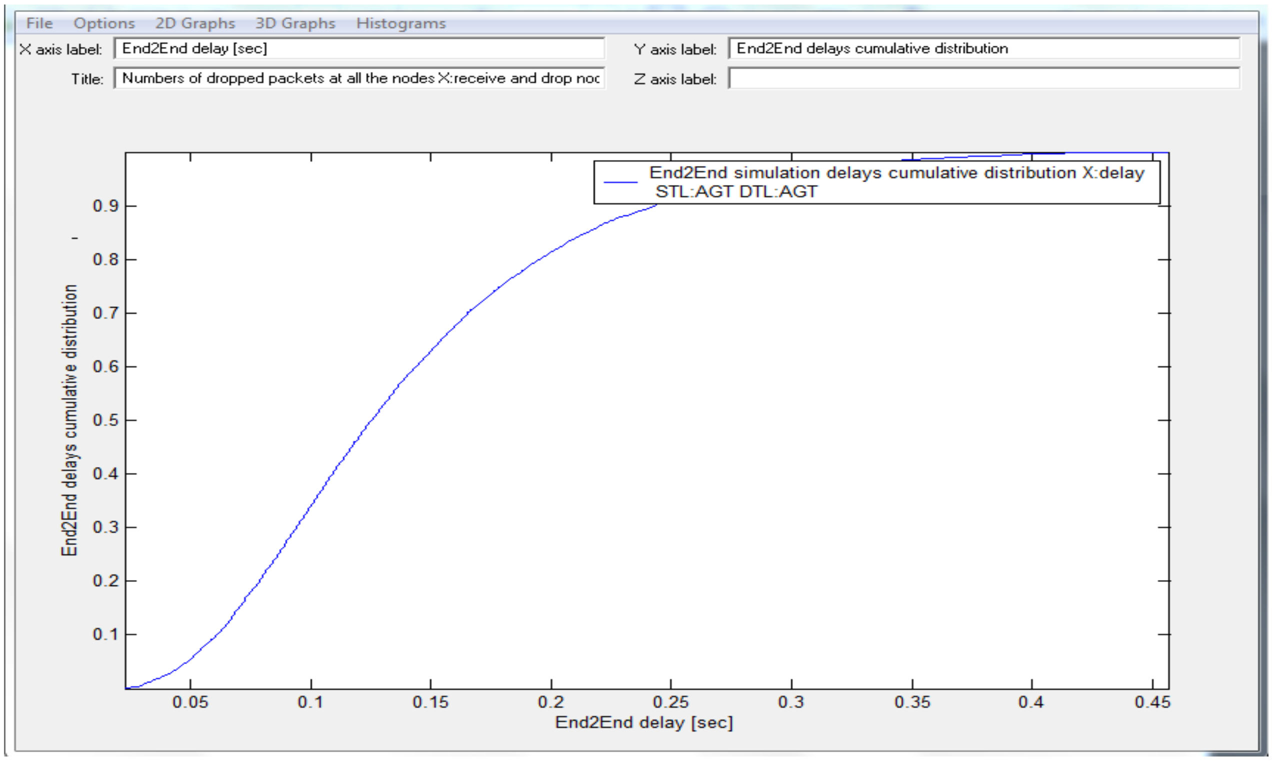


Fig 5.9 EEOR Protocol: End-to-end Delay Cumulative Distribution

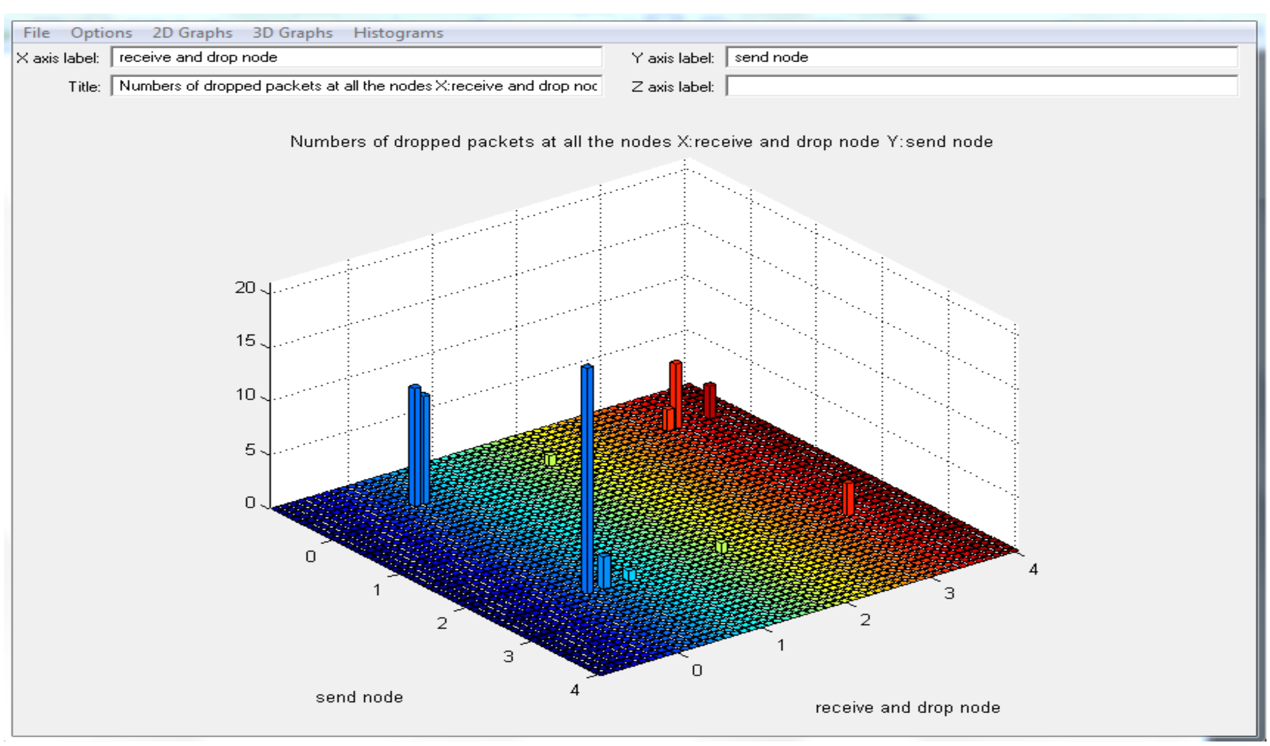


Fig 5.10 EEOR Protocol: Dropped Packets

5.2 Simulation of Multi-Hop Optimal Position Based Opportunistic Routing (MOOR).

Simulation of MOOR Protocol is performed over 50 nodes having energy 100 J. Nodes in the network are in random position. In this scenario, there is a start node that will transmit the data and all the nearest nodes will do the same after getting it. Node 7 is the start node and node 33 is the destination node. In fig 5.11show the networks scenario with 50 nodes. Each node maintains a list of neighbors and nodes identify their neighbors by broadcasting a hello packet in the networks. Each sensor node including the source node broadcasts a hello packet, so that all sensor nodes create their own routing table. hello packet is broadcasted at regular intervals of time so that sensor nodes update their routing table. In fig 5.12 show that each sensor node broadcasting a hello packet in the networks

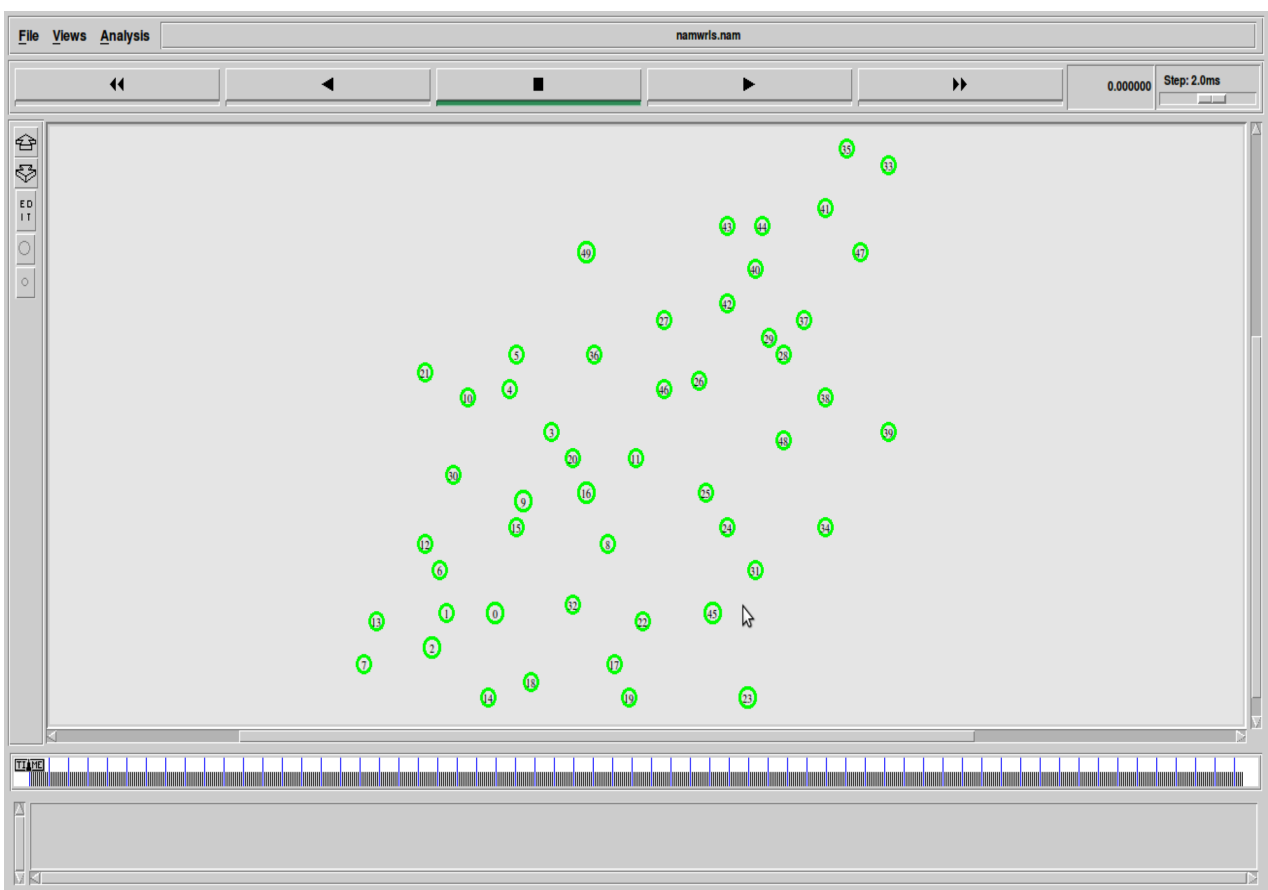


Fig 5.11 MOOR Protocol: Networks scenario with 50 nodes

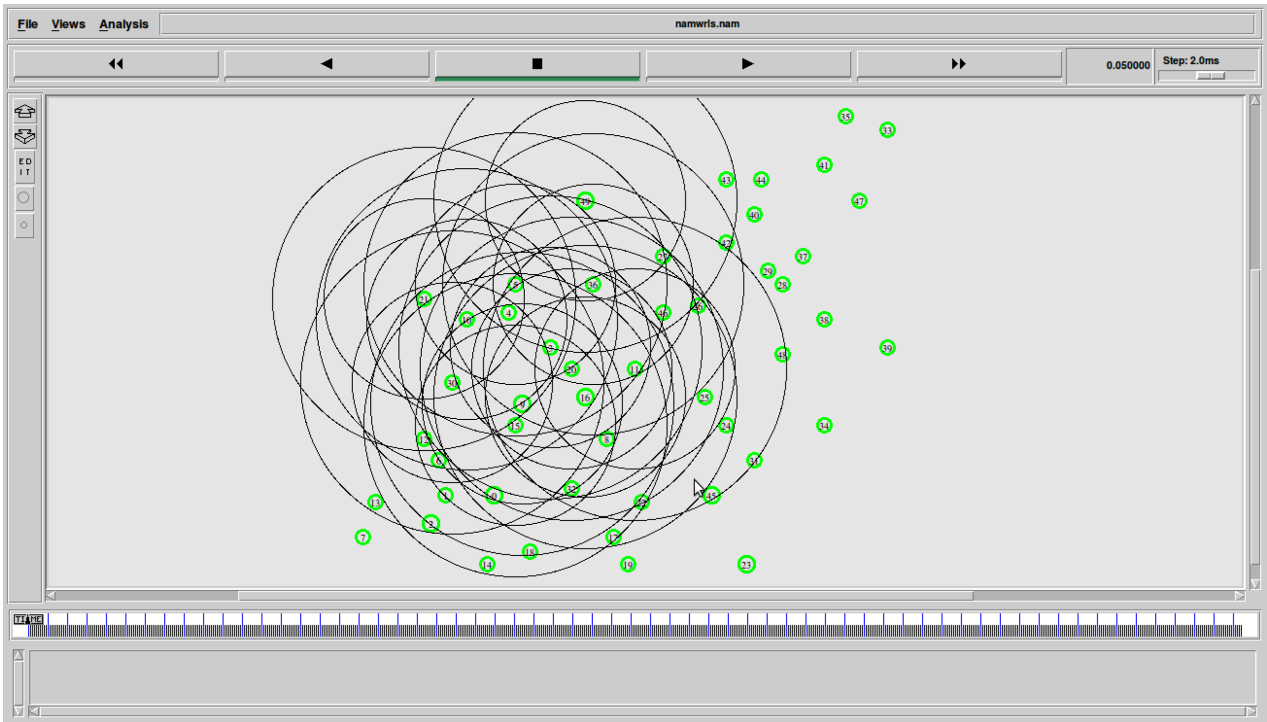


Fig 5.12 MOOR Protocol: Broadcasting hello packet between the Nodes

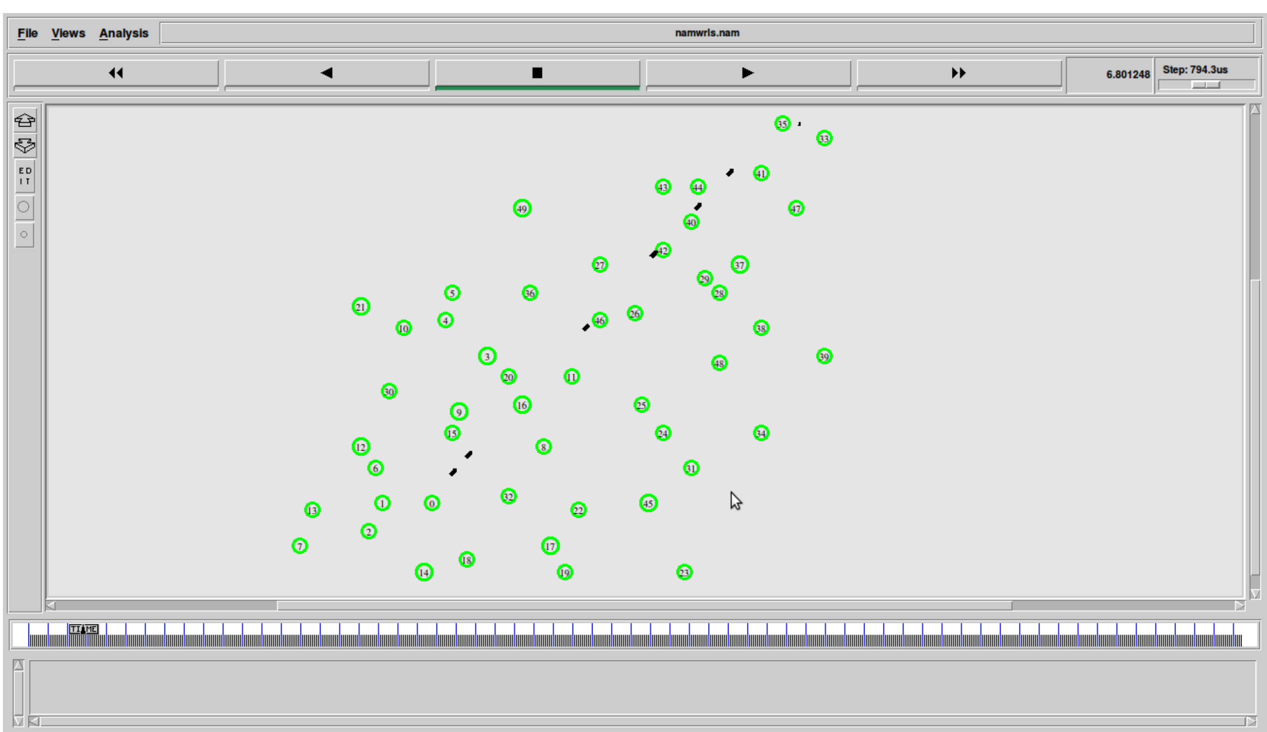


Fig 5.13 MOOR Protocol: Sending packet from source to destination

Once the routing table is created, source node chooses a forwarder node which is at a minimum distance from the target node to ensure that the packet reaches the destination. When the packet reaches the sink node, it sends an acknowledgement to the source node. In figure 5.13 shows that, packet send from source to destination. The trace graph figs have been involved with the simulation time of 150 minutes. In fig 5.14, the whole simulation picture has been displayed along with the end-to-end delay. The fig 5.15 describes the throughput of Simulation Time versus Sending Packets. The throughput of receiving Packets versus Simulation Time has been displayed in fig 5.16. The Throughput of forwarding Packets versus Simulation Time has been displayed in fig 5.17.

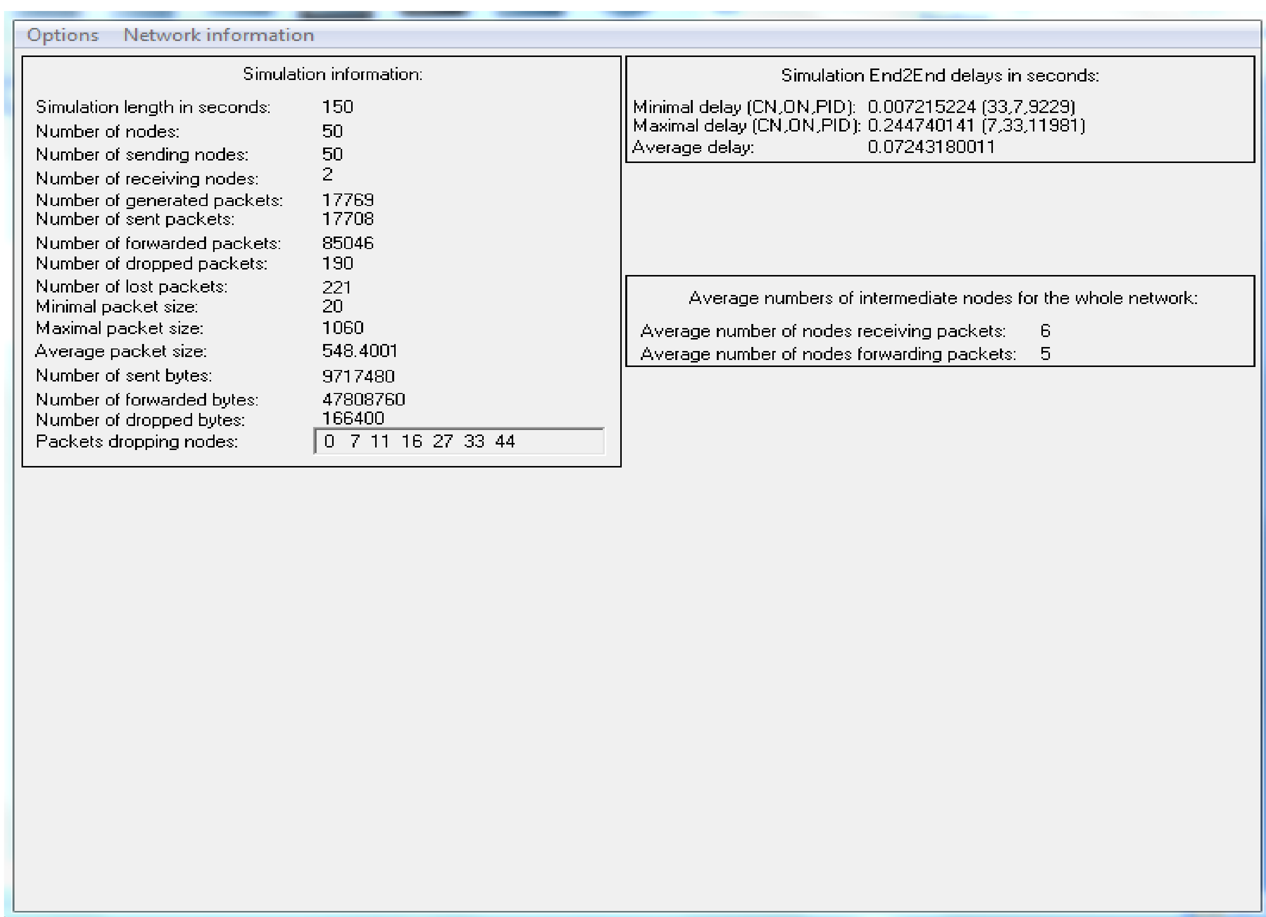


Fig 5.14 MOOR Protocol: Simulation details and End to End delay

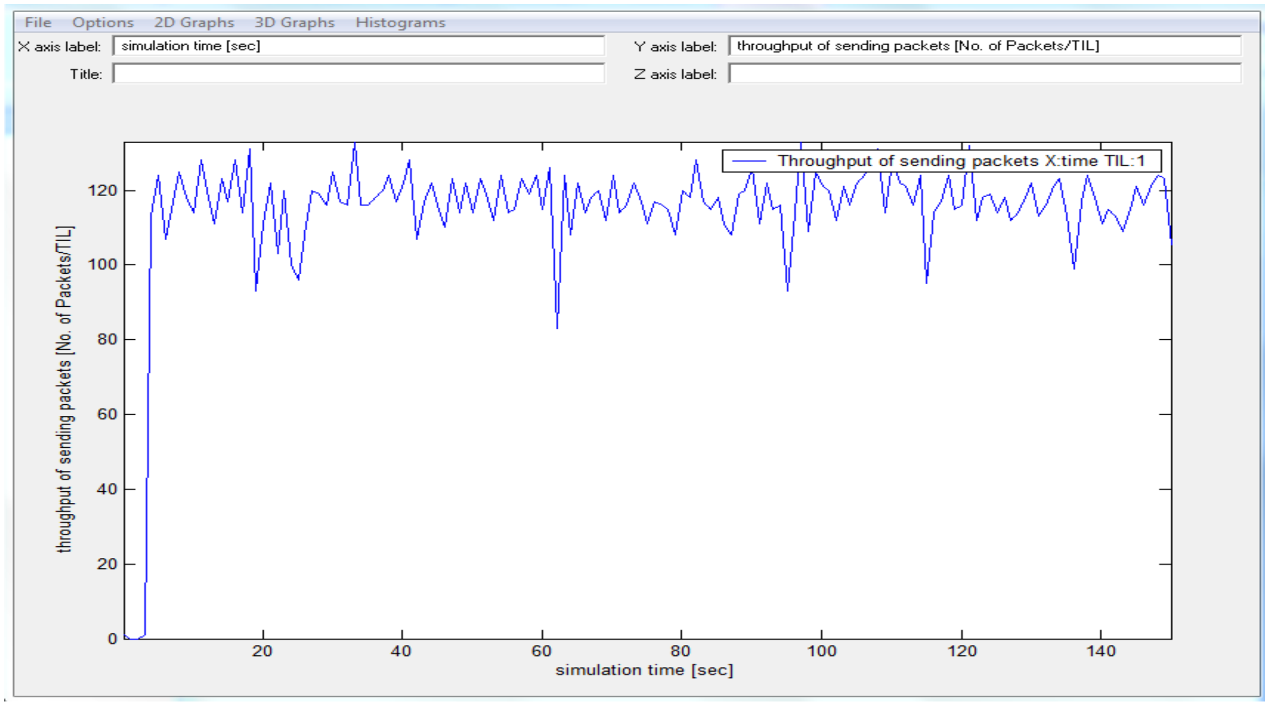


Fig 5.15 MOOR Protocol: Throughput of Sending Packets vs. Simulation Time

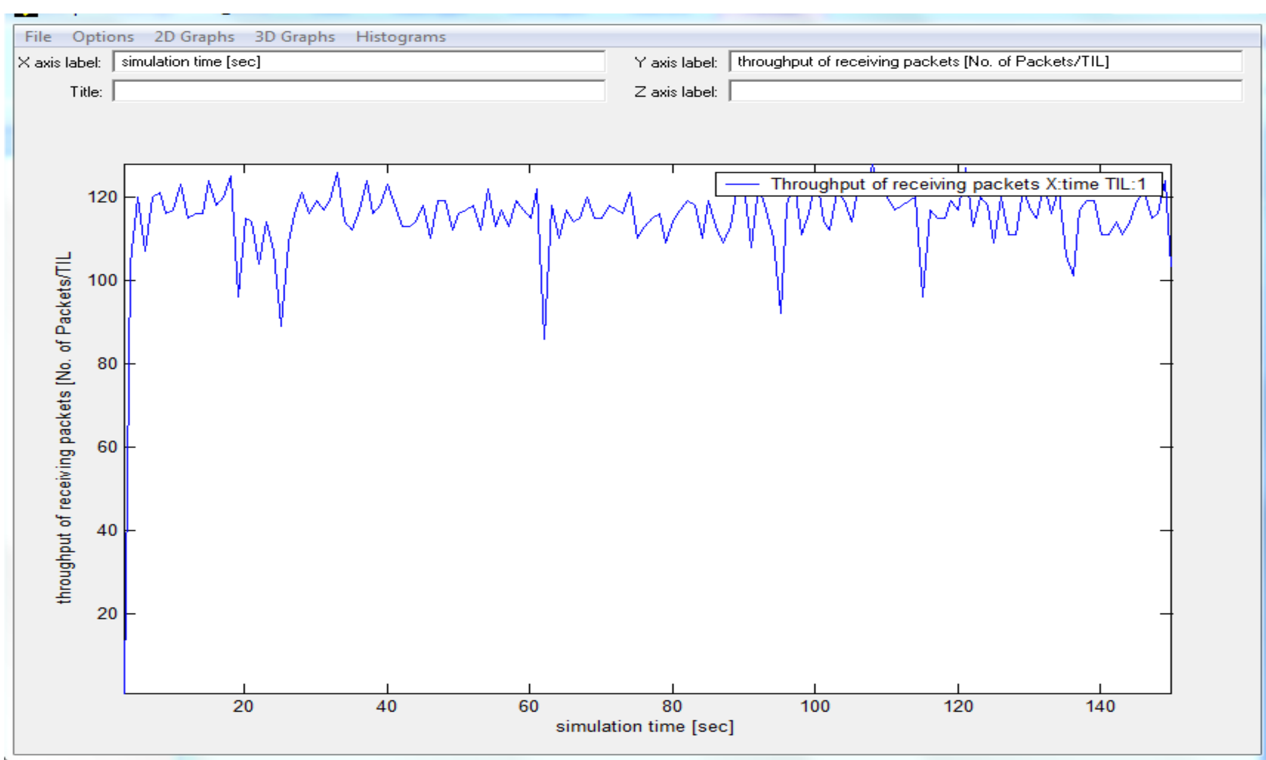


Fig 5.16 MOOR Protocol: Throughput of receiving Packets vs. Simulation Time

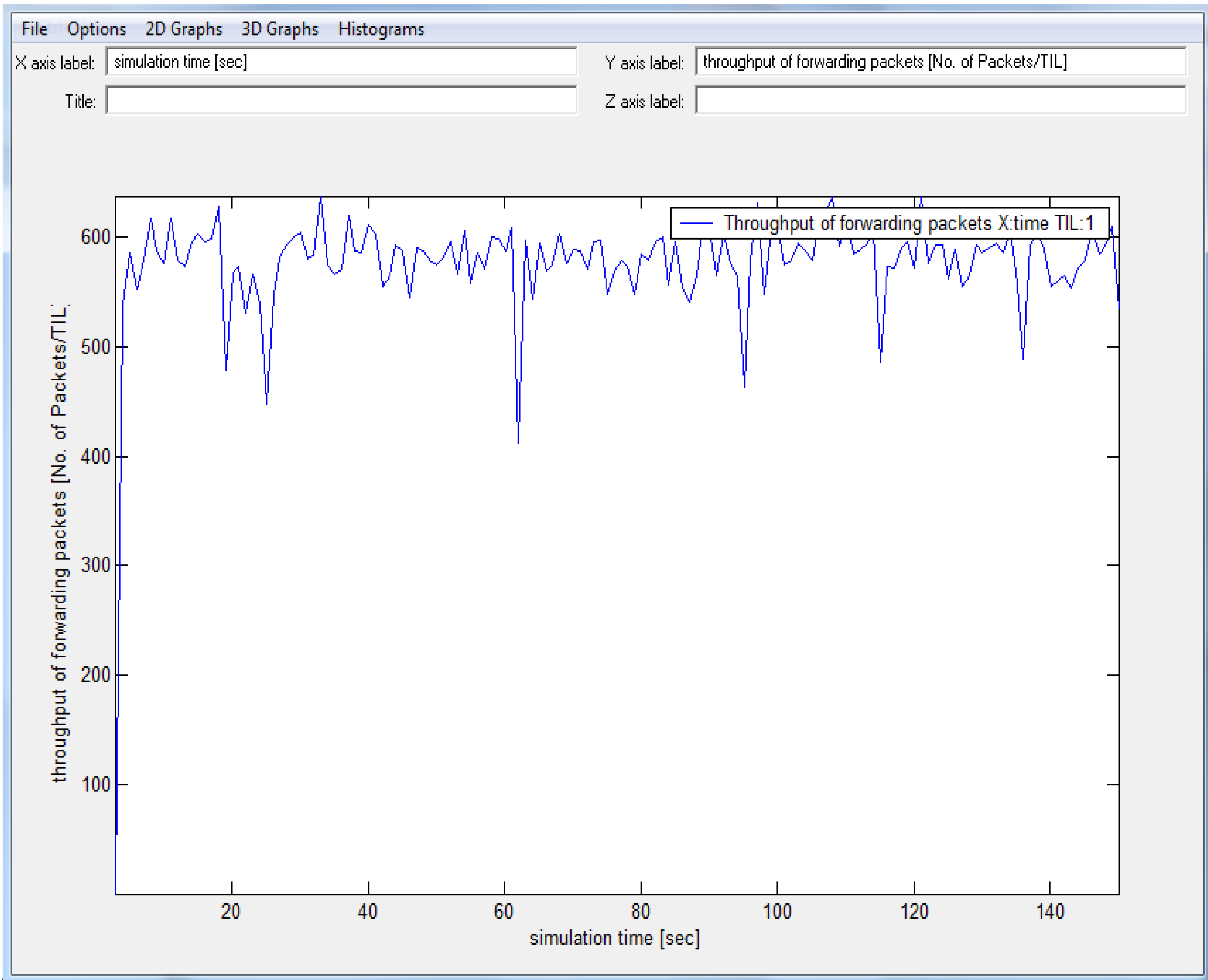


Fig 5.17 MOOR Protocol: Throughput of forwarding Packets vs. Simulation Time

End to end delay is decreasing with respect to EEOR protocol because chooses the node which is nearest to the destination and selects it as a forwarder node in the forwarder list. So to reach to the sink a relatively small path is being followed by the packets which imply the less end to end delay. In fig 5.18 end-to-end delay with its frequency distribution is being shown. The average delay of this EEOR protocol is 0.072sec. The maximum delay in this scenario is 0.244s and minimum delay is 0.007sec. The cumulative frequency distribution has been shown in fig 5.19, which implies that the cumulative delay is increasing continually to 0.15sec. In fig 5.20 shows the number of dropped packets at all nodes.

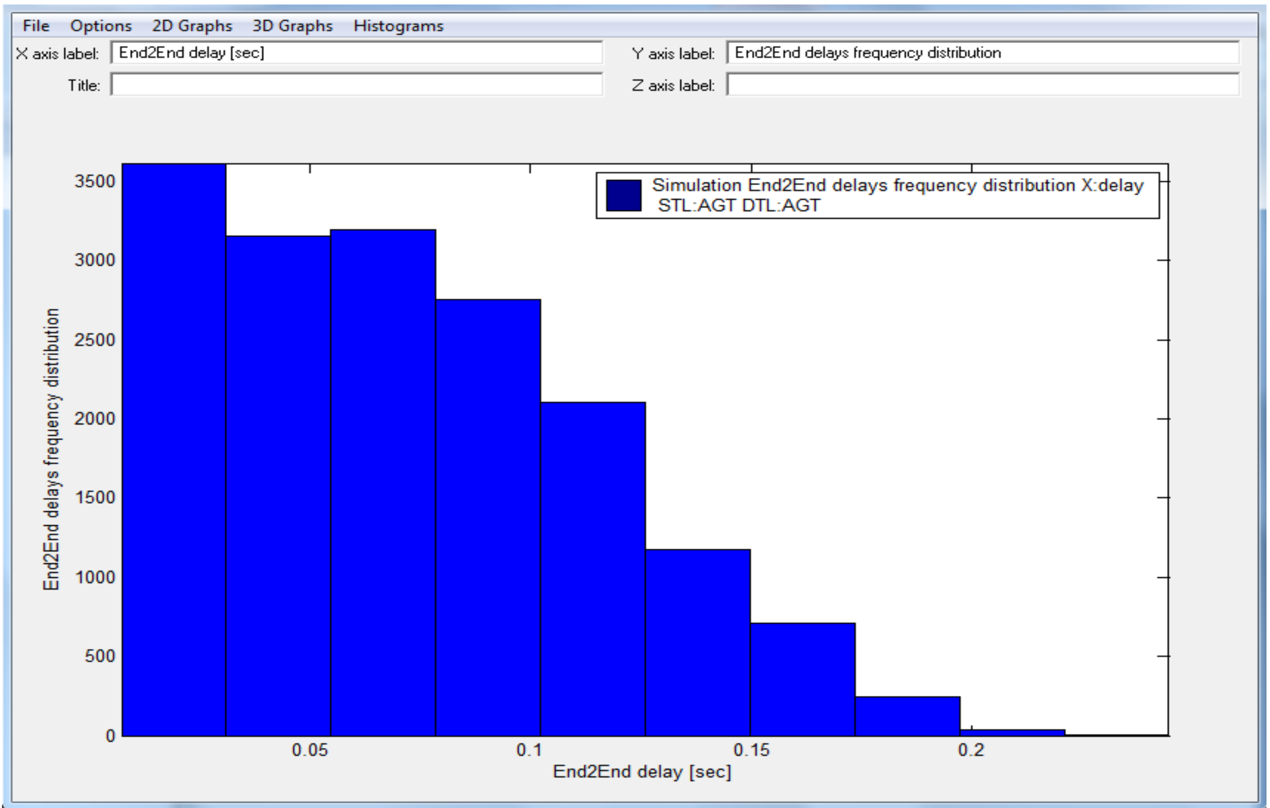


Fig 5.18 MOOR Protocol: End-to-end Delay Frequency Distribution

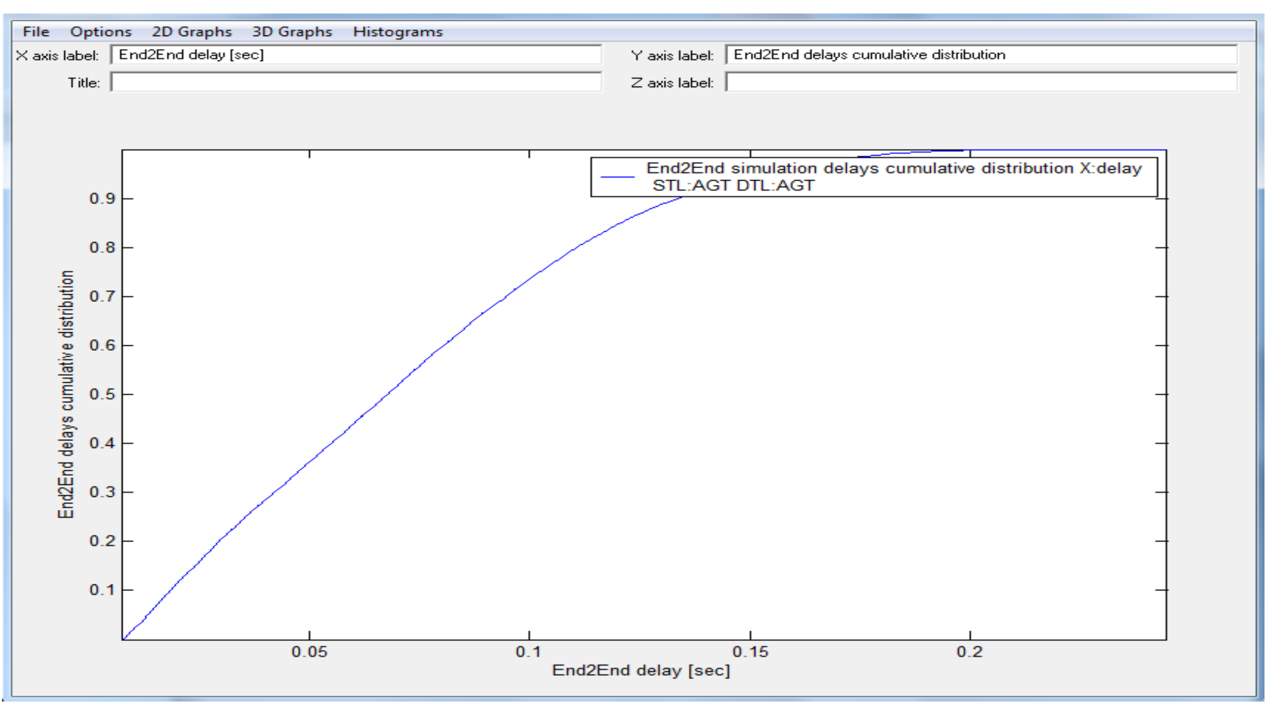


Fig 5.19 MOOR Protocol: End-to-end Delay Cumulative Distribution

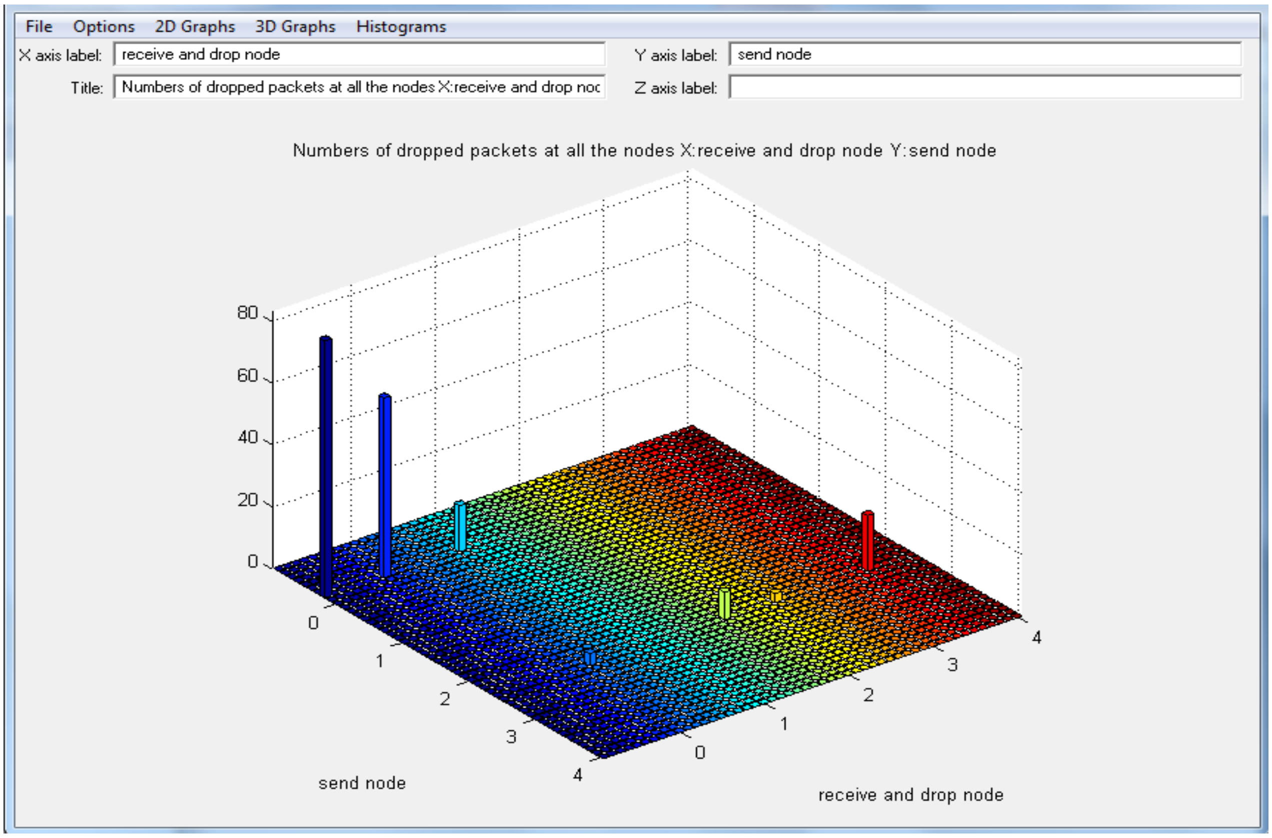


Fig 5.20 MOOR Protocol: Dropped Packets

5.3 Simulation of Middle Position Dynamic Energy Opportunistic Routing (MDOR)

Simulation of MDOR Protocol is performed over 50 nodes having energy 100 100 J. Nodes in the network are in random position. In this scenario, there is a start node that will transmit the data and all the nearest nodes will do the same after getting it. Node 7 is the start node and node 33 is the destination node. In fig 5.21 shows the networks scenario with 50 nodes. Each node maintains a list of neighbors and nodes identify their neighbors by broadcasting a hello packet in the networks. Each sensor node including the source node broadcasts a hello packet, so that all sensor nodes create their own routing table. *hello* packet is broadcasted at regular intervals of time so that sensor nodes update their routing table. In fig 5.22 show that each sensor node broadcasting a hello packet in the networks

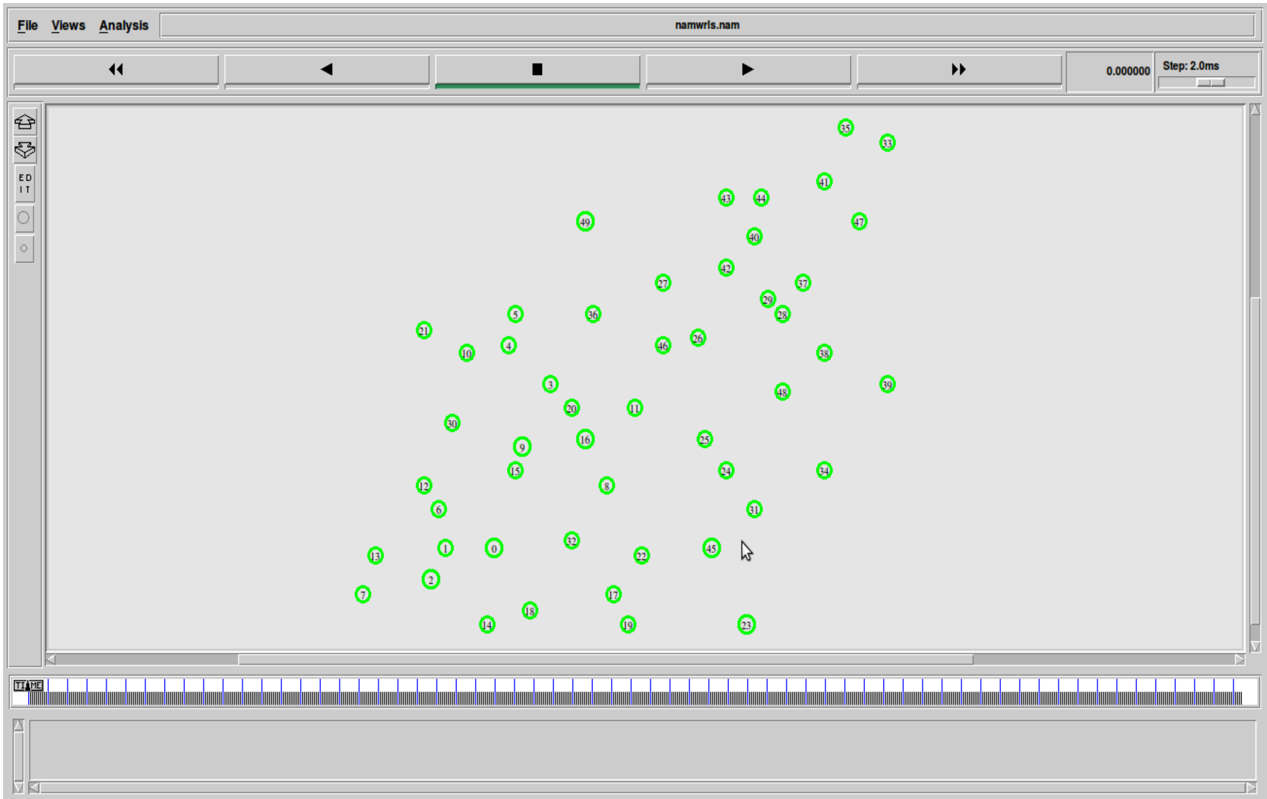


Fig 5.21 MDOR Protocol: Networks scenario with 50 nodes

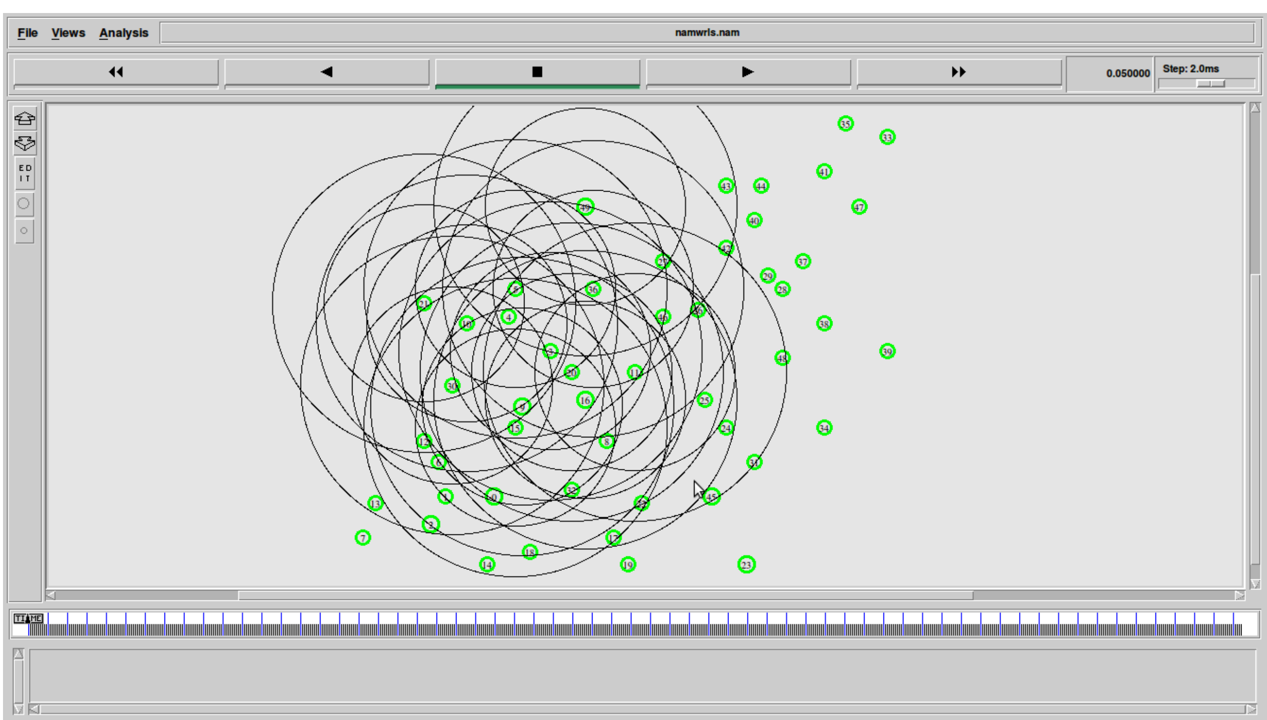


Fig 5.22 MDOR Protocol: Broadcasting hello packet between the Nodes

Once the routing table is created, source node chooses a forwarder node which is at a minimum distance from the target node to ensure that the packet reaches the destination. When the packet reaches the sink node, it sends an acknowledgement to the source node. In figure 5.23 shows that, packet send from source to destination.

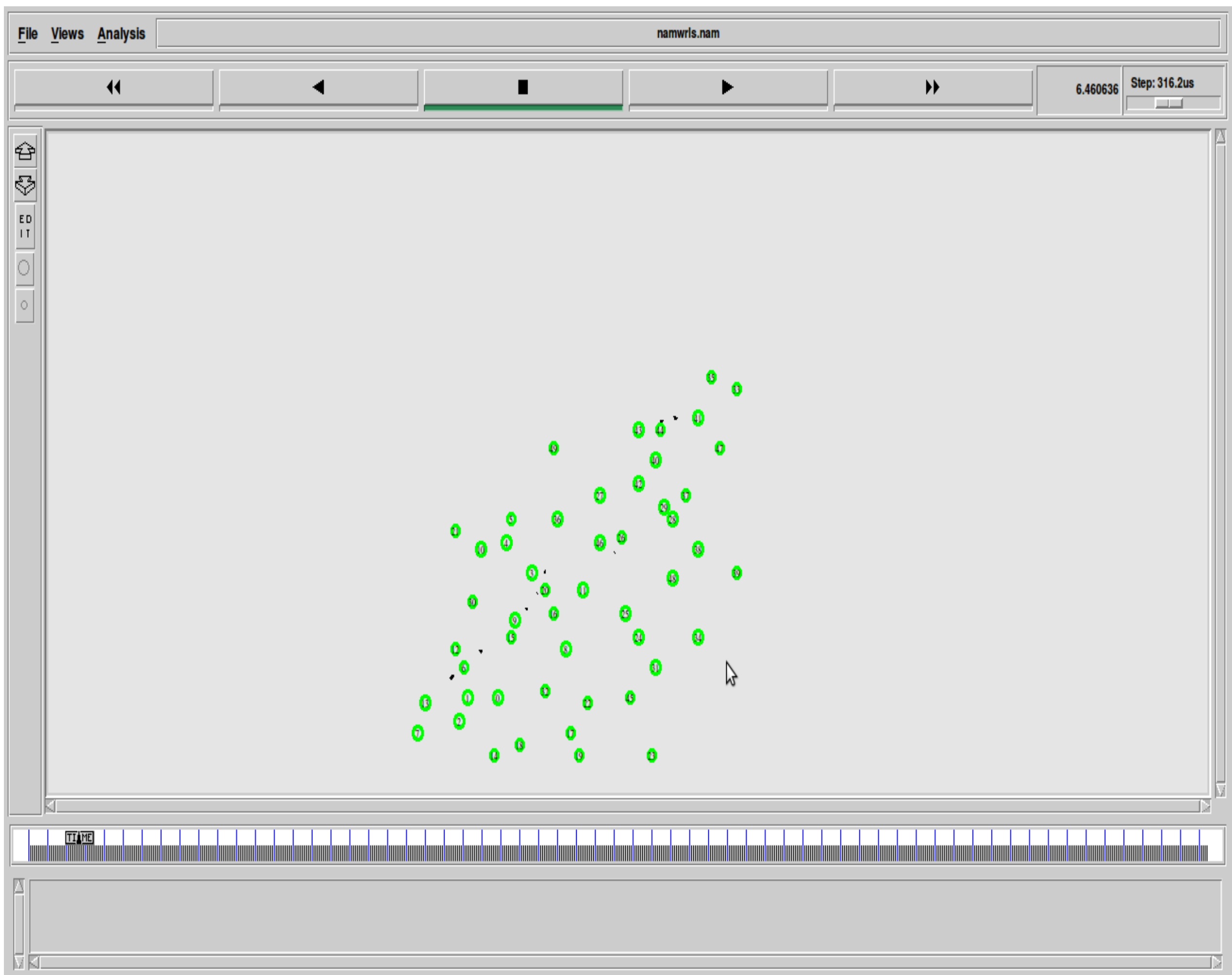
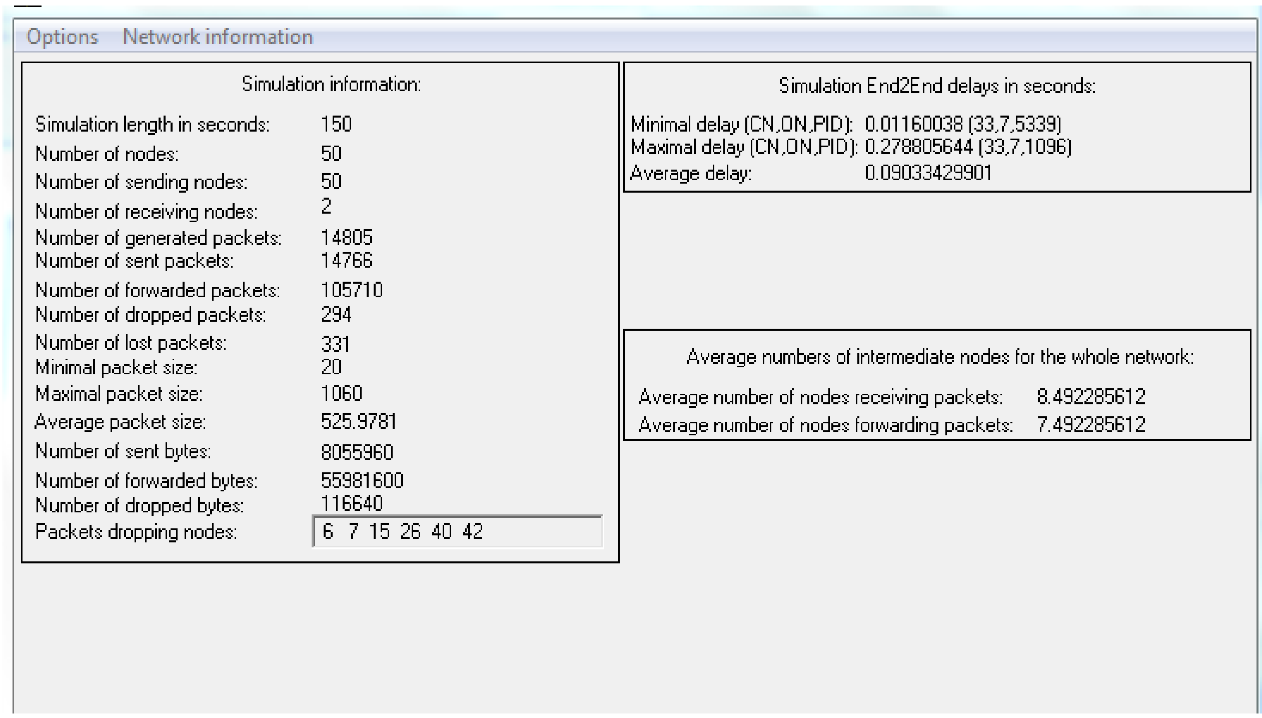


Fig 5.23 MDOR Protocol: Sending packet from source to destination

The trace graph figs have been involved with the simulation time of 150 minutes. In fig 5.24, the whole simulation picture has been displayed along with the end-to-end delay. The fig 5.5 describes the throughput of Simulation Time versus Sending Packets. The throughput of receiving Packets versus Simulation Time has been displayed in fig 5.26. The Throughput of forwarding Packets versus Simulation Time has been displayed in fig 5.27.



5.24 MDOR Protocol: Simulation details and End to End delay

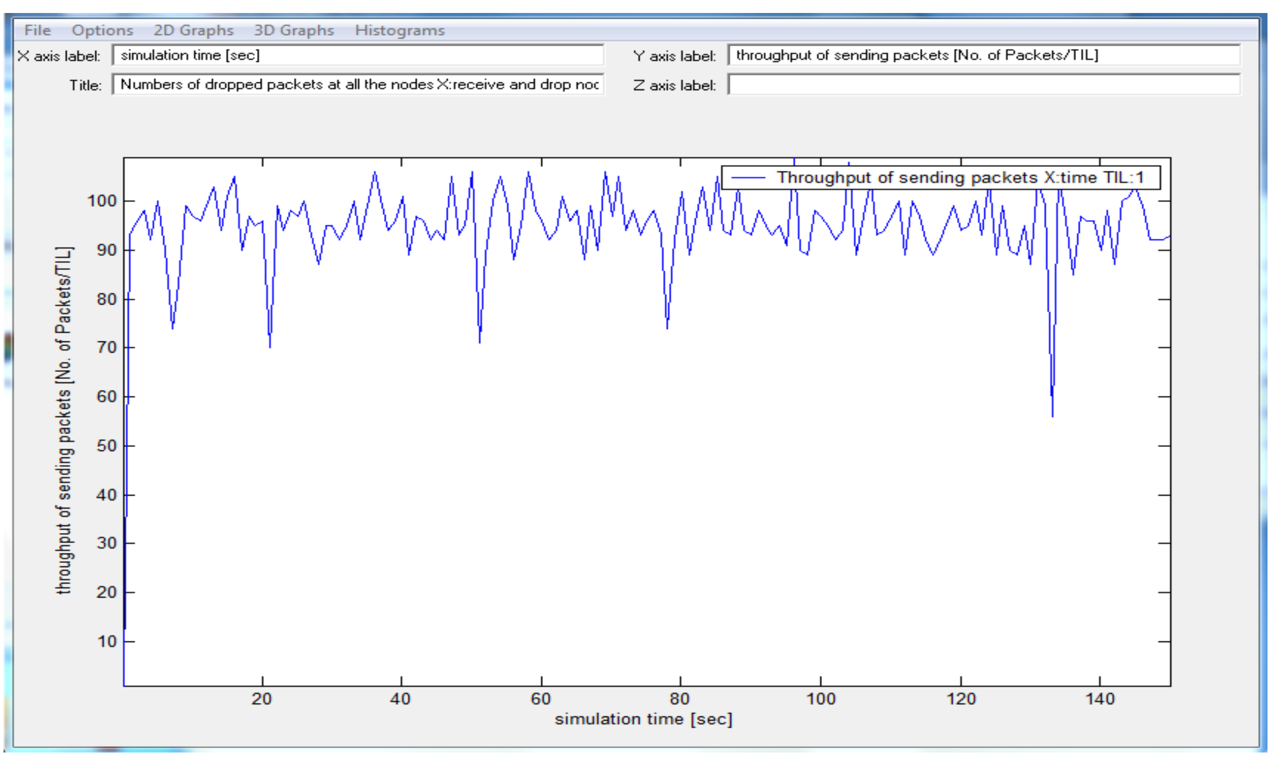


Fig 5.25 MDOR Protocol: Throughput of Sending Packets vs. Simulation Time

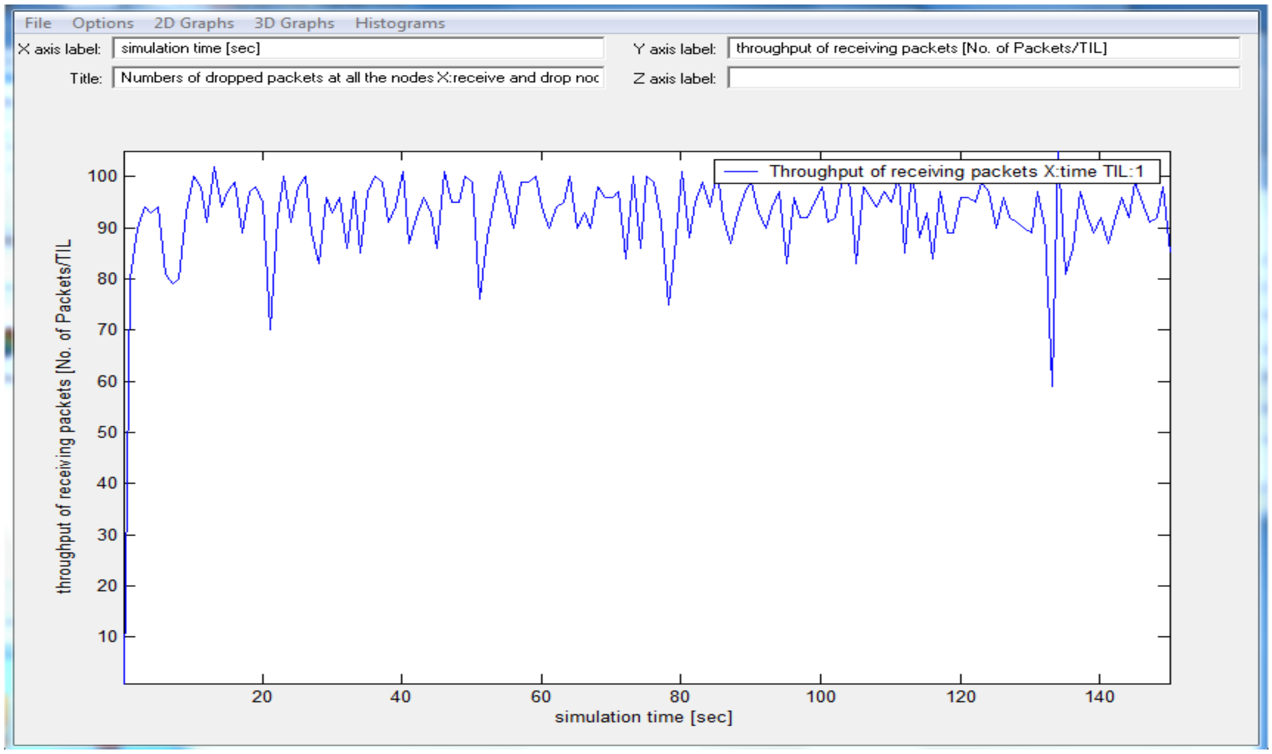


Fig 5.26 MDOR Protocol: Throughput of Receiving Packets vs. Simulation Time

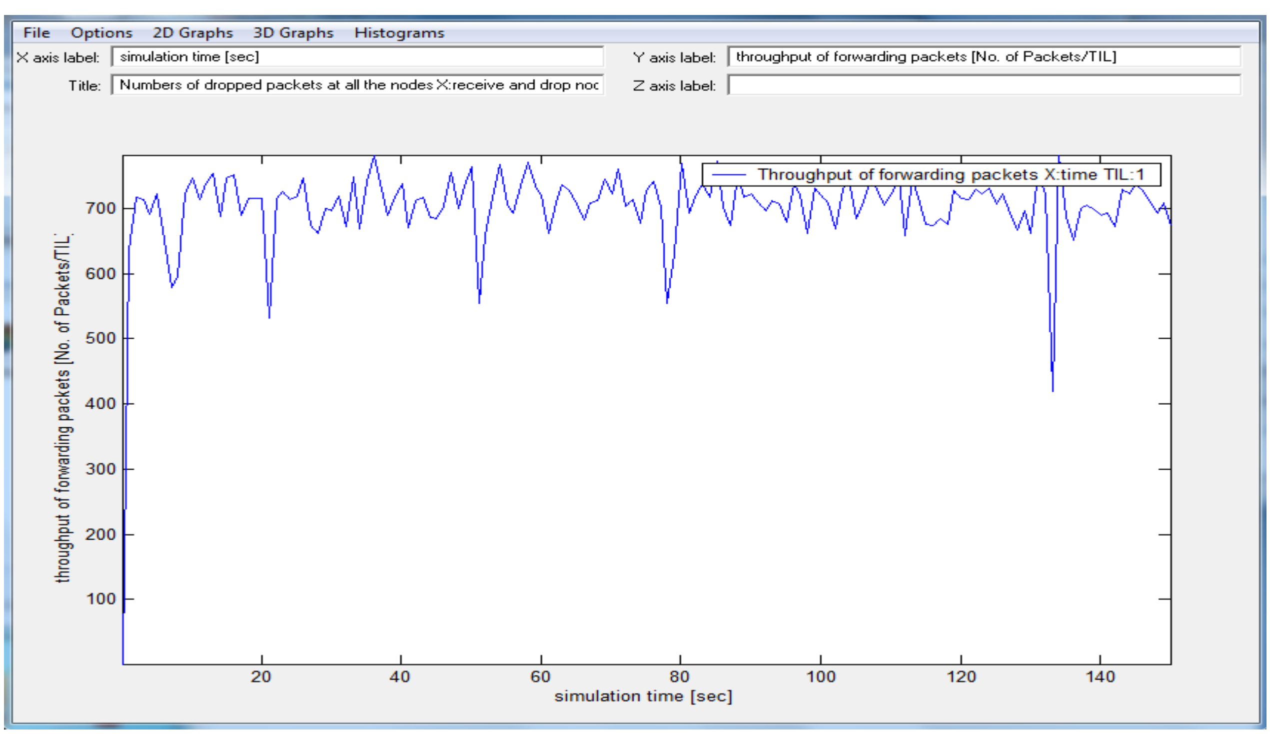


Fig 5.25 MDOR Protocol: Throughput of Forwarding Packets vs. Simulation Time

End to end delay is increasing continuously because node which is nearest to the source and selects it as a forwarder node in the forwarder list. So to reach to the sink a relatively average path is being followed by the packets which imply the moderate end to end delay. In fig 5.28 end-to-end delay with its frequency distribution is being shown. The average delay of this EEOR protocol is 0.090sec.The maximum delay in this scenario is 0.278sec and minimum delay is 0.011sec. The cumulative frequency distribution has been shown in fig 5.29, which implies that the cumulative delay is increasing continually to 0.18sec. . In fig 5.10 shows the number of dropped packets at all nodes.

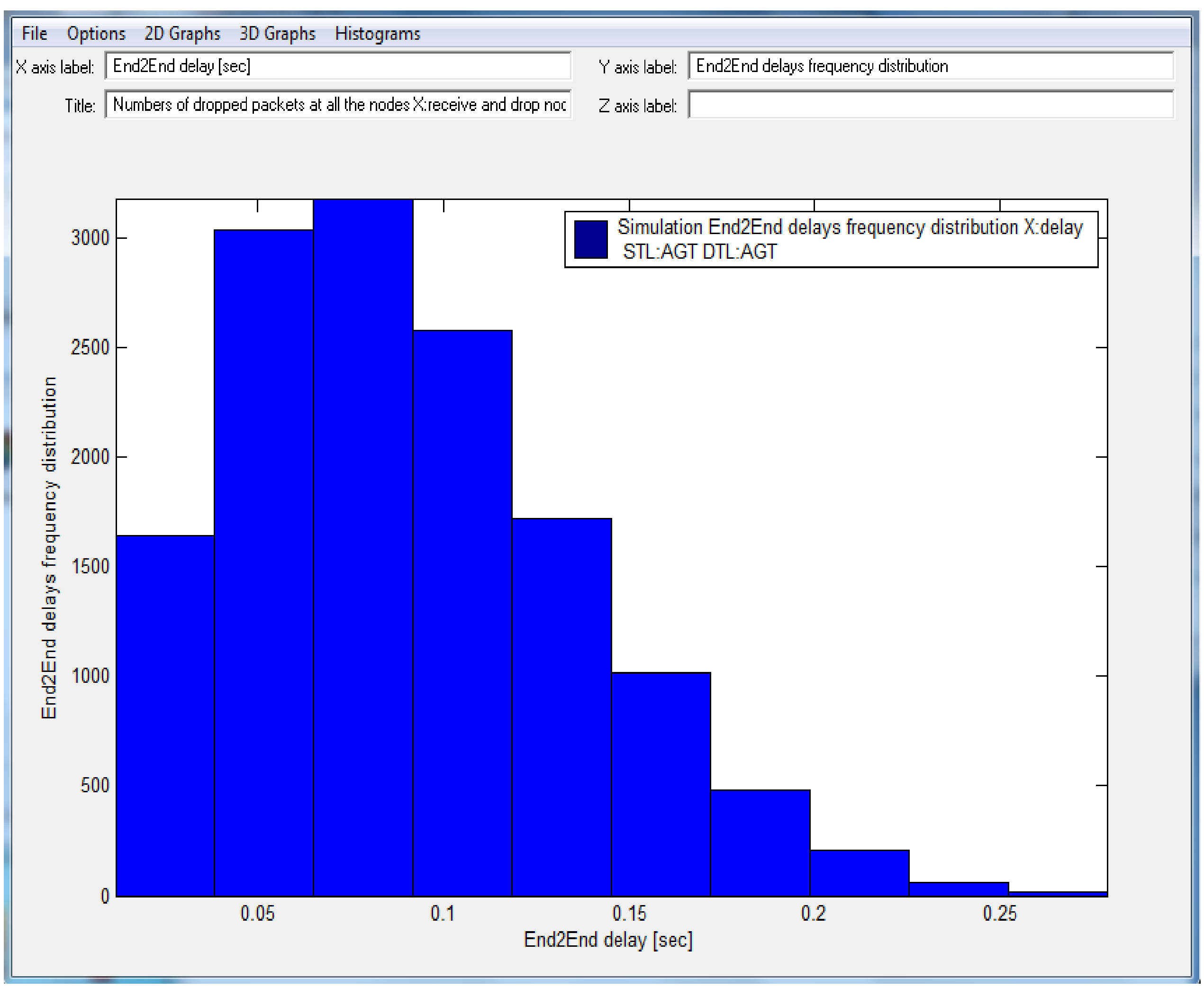


Fig 5.28 MDOR Protocol: End-to-end Delay Frequency Distribution

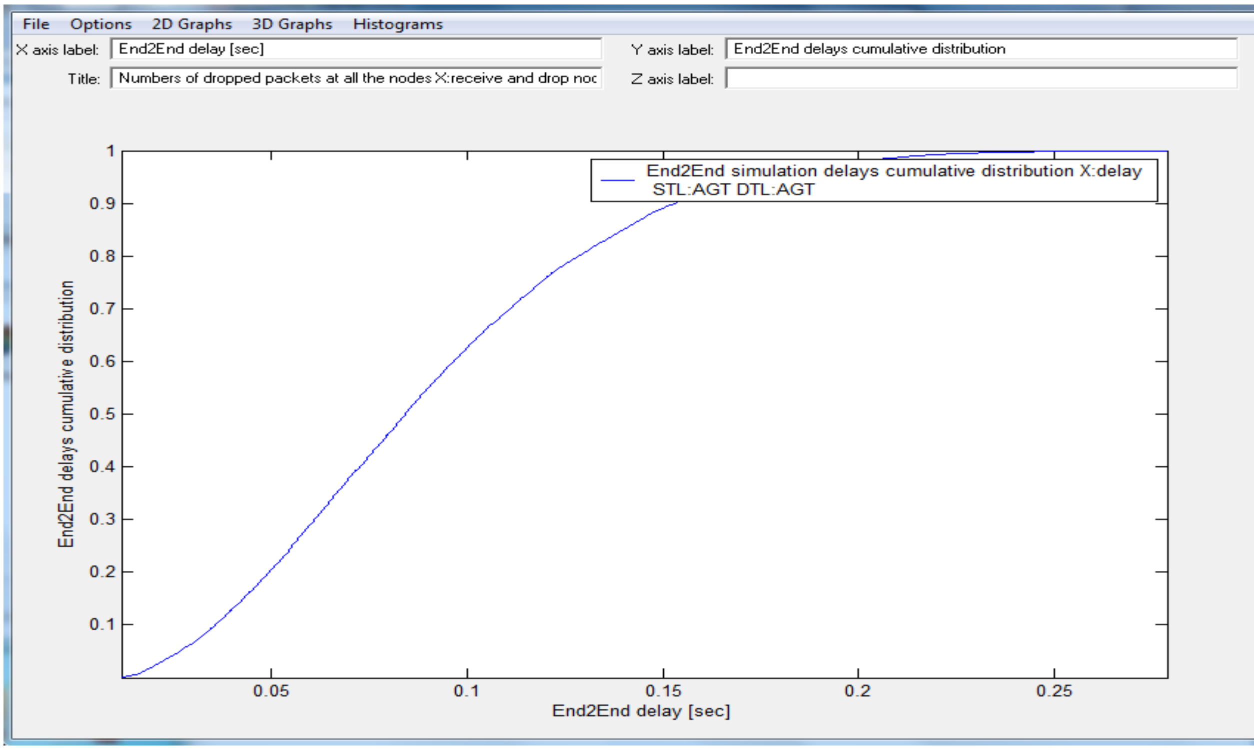


Fig 5.29 MDOR Protocol: End-to-end Delay Cumulative Distribution

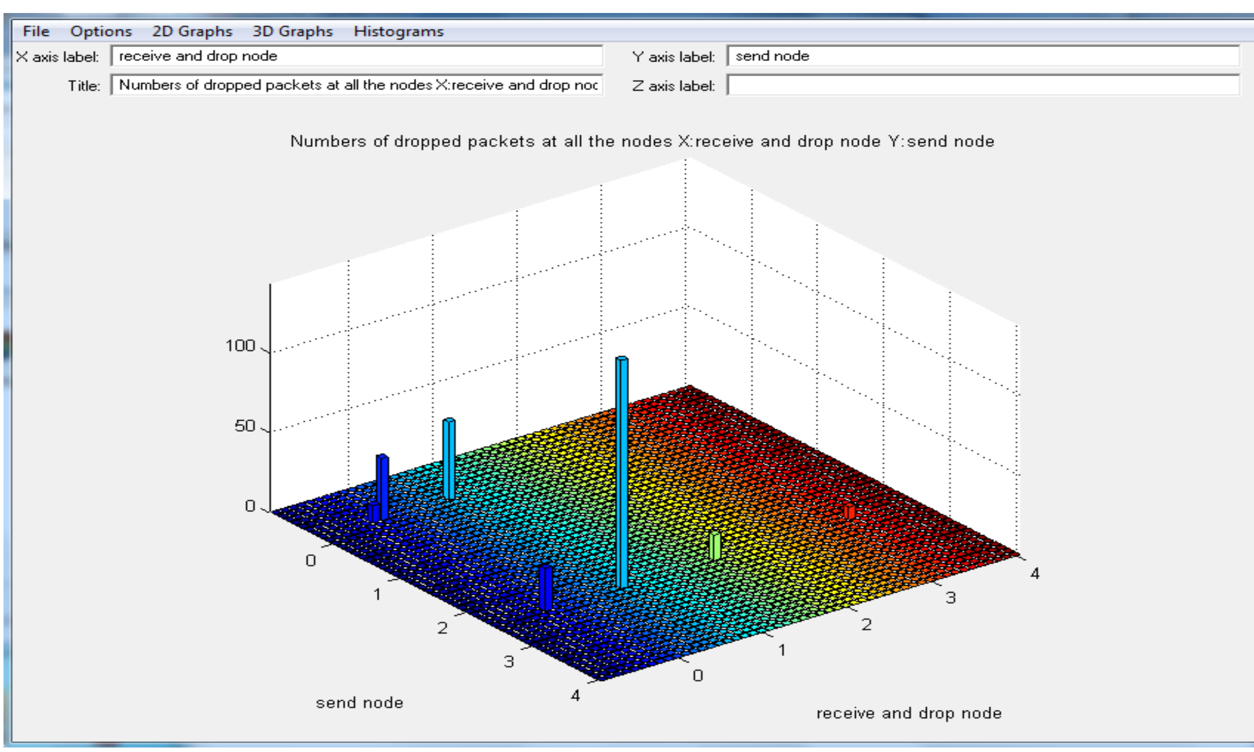


Fig 5.30 MDOR Protocol: Dropped Packets

5.4 Comparison between EEOR, MOOR and MDOR

The performance of the networks is analyzed on the basis of Networks Lifetime and Average End-to-End Delay. 50 sensor nodes are randomly deployed in the target area of 500 m by 500 m using uniform distribution as shown in Fig.5. Out of these nodes, 6 different source and sink pairs are randomly selected for one-hop, two-hop, and more than two-hop communications

Constant Bit Rate (CBR) is used for packet generation. Packets are generated at the rate of one packet per second. Length of the buffer is set to 30 packets at each sensor node in the network. Initial energy of each sensor node is 100 J. Energy consumed by a sensor node in transmission and forwarding packet to another node depends on the distance of the two nodes. 1000 packets of 1000 bytes each are transferred between source and destination pairs. The performance of wireless sensor networks for MDOR is analyzed using some parameters (Networks Lifetime and Average End-to-End delay) for different source and destination pairs.

5.4.1 Networks Lifetime

Sensor nodes have a limited amount of energy and once the node is deployed, it is difficult to replace the battery. The lifetime of a sensor node will be calculated as the time from its deployment to the time when the node has a residual energy up to 90%. In this period node is said to be alive. After this period, the node becomes dead. Here, the Network's Lifetime is defined as the time when the first node dies out of energy. This is because when a node dies, a networks partition or an isolated area may occur quickly afterwards. Fig. 5.31 shows the graph of Network's Lifetime (EEOR, MDOR and MOOR protocols) plotted against networks size (50 nodes). The graph shows that the Network's Lifetime of EOOR protocol is greater as compared to MDOR protocol and MOOR protocol, irrespective of the number of nodes in the networks. But the Network's Lifetime of MDOR is greater as compared to MOOR protocol. Hence, the Network's Lifetime of the proposed MDOR protocol lies between the EEOR and MOOR protocols.

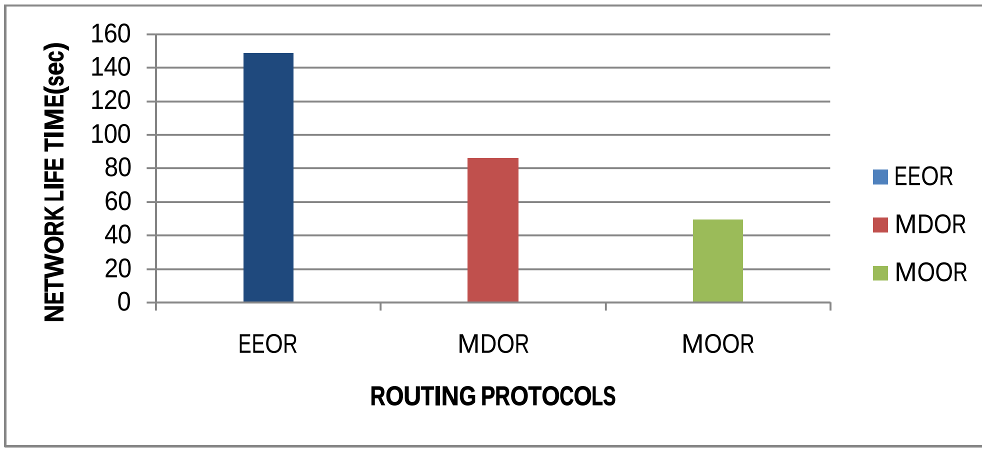


Fig 5.31 Networks Lifetime vs. routing protocols

6.4.2 Average End-to-End Delay

The time elapsed between the sending of a packet by the source node and receiving that packet by the destination node is termed as *End-to-End delay*. Average End-to-End delay is defined as the average of all the packets transmitted between each pair of source and destination. The graph is plotted between the average End-to-End delay and different pairs of source and destination in Fig. 5.32 It is observed that the proposed protocol i.e. MDOR does not show any improvement for one hop count. When number of hops increases, End-to-End delay increases respectively. End-to-End delay is smaller in case of MOOR protocol as compared to MDOR and EEOR protocol irrespective of the source and destination pair. But MDOR protocol has a smaller End-to-End delay as compared to EEOR protocol. End-to-End delay is reduced up to 0.05 s for '7-35' source and sink pair for more than two hops paths as compared to the EEOR protocol.

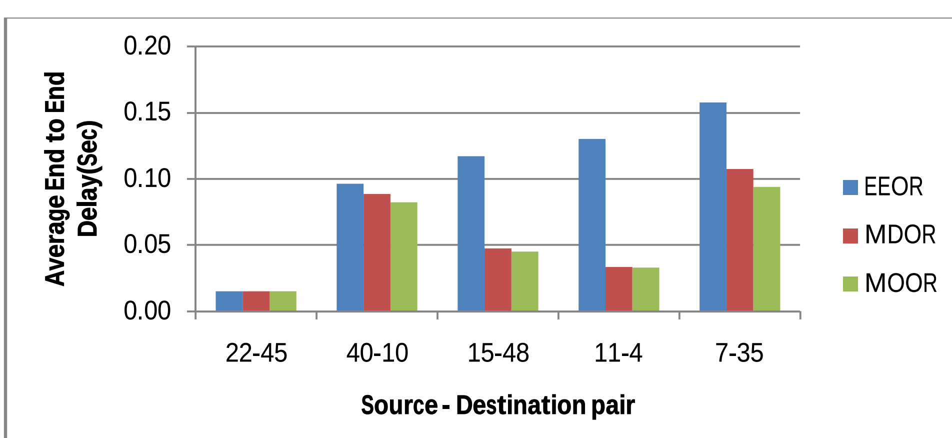


Fig 5.32 Average End-to-End Delay for Different Source-Destination Pairs

6.5 Conclusion

In MOOR protocol, End-to-End delay is smaller in comparison to the EEOR protocol. On other hand, Network's Lifetime of EEOR protocol is greater as compared to the MOOR protocol. The simulated result for the proposed MDOR protocol shows that for both the parameters i.e. End-to-End delay and Networks Lifetime, the graph lies between the MOOR and EEOR protocol. The End-to-End delay of proposed protocol is better than EEOR and comparable to MOOR. The Networks lifetime of proposed protocol is better than MOOR and comparable to EEOR. Therefore, proposed protocol optimizes the End-to-End delay and Network's Lifetime

CHAPTER 6
CONCLUSION

Previously, we discussed various WSN routing protocols. The routing techniques are classified into four categories on the basis of network structure; data centric, hierarchical, location-based and opportunistic routing protocols. Comparative analysis of various WSN routing protocols on the basis of parameters; power usage, data aggregation, scalability, query based, over head, data delivery model, QoS; has been done. We conclude that, in case of hierarchical routing scalability is high as compared to data centric and location based routing protocol. Data centric is query-based while the other two are not. When we talk about the overhead, it is low in data centric routing, moderate for location based and mostly high for hierarchical routing protocol.

In the presented work, we have discussed a comparison between the EEOR, MOOR, and MDOR protocols for wireless sensor network with different simulation times. The network's performance is analyzed according to the parameters using networks simulator (NS2).The performance of the network is analyzed on the basis of network lifetime and average end to end delay. 50 sensor nodes are randomly deployed in the target area of 500 m by 500 m using uniform distribution

A routing protocol, MDOR is presented in this thesis which uses the concept of dynamic energy consumption. Due to dynamic energy consumption, when a node is closer to the source it takes less energy to transmit a packet and when node is far from the source it takes more energy to transmit a packet. In wireless sensor networks, there is a tradeoff between the network lifetime and average end to end delay when we use the concept of dynamic energy consumption. In MOOR protocol, end to end delay is smaller in comparison to the EEOR protocol. On other hand, Network's Lifetime of EEOR protocol is greater as compared to the MOOR protocol. The simulated result for the proposed MDOR protocol shows that for both the parameters i.e. network lifetime and average end to end delay, the graph lies between the MOOR and EEOR protocol. The end to end delay of proposed protocol is better than EEOR and comparable to MOOR. The network lifetime of proposed protocol is better than MOOR and comparable to EEOR. Therefore, proposed protocol optimizes the network lifetime and average end to end delay.

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