Energy Efficient Routing Protocol for MANETs

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Certificate

I hereby certify that the work which is presented in the dissertation entitled, "**Energy Efficient Routing Protocol for MANETs**" , in partial fulfillment of the requirements for the award of degree of the **Master of Technology** in **Computer Science and Applications**, submitted in School of mathematics and Computer Applications of Thapar University, Patiala, is an authentic record of my own work carried out under the supervision of Dr. Rajesh Kumar and refers others researcher's work which are duly listed in the reference section.

The matter presented in the dissertation has not been submitted for award of any other degree of this or any other university.

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This is to certify that above statement made by the candidate is correct and true to the best of my knowledge.

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Abstract

Deployed in 1990's, Mobile Adhoc networks have been widely researched for many years. Mobile Ad-hoc Networks are a collection of two or more devices equipped with wireless communications and networking capability. These devices can communicate with other nodes that are within their radio range or one that is outside their radio range. For the later, the nodes should select an intermediate node to be the router to forward the packets from the source to the destination. In MANETs every node can act as the gateway. In this dissertation, focus is laid on energy efficiency. There are many routing protocols in MANETs like DSDV, DSR and AODV etc. and each one has its own approach for dissemination of data packets in MANETs. But these routing protocols are less energy efficient. The aim of this dissertation is to design a routing protocol which would be better than the existing ones in terms of energy utilization and delivery ratio. In this dissertation an energy efficient routing protocol has been proposed which uses Dijakstra's algorithm as a fundamental algorithm to route the nodes to their intended destination and a comparison is laid between the proposed protocol, AODV, DSDV and DSR, and the performance measures are evaluated.

Keywords:

Energy, MANETs, Protocol, Efficiency, Routing, Packets, Delivery ratio.

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Chapter 1
Introduction

This chapter introduces Mobile Adhoc Networks (MANETS), its applications at commercial sector, at local level or at military battlefield. A brief introduction about various challenges and research issues in MANETs and network management in MANETs is given followed by research motivation and organization of the thesis

1.1 Mobile Adhoc Networks (MANETs)

Deployed in 1990's, Mobile Adhoc networks have been widely researched for many years [4]. Among all the contemporary wireless networks, Mobile Ad hoc Networks (MANETs) is one of the most important and unique applications [6, 17]. Mobile Ad-hoc Networks are a collection of two or more devices equipped with wireless communications and networking capability. These devices can communicate with other nodes that are within their radio range or one that is outside their radio range. For the later, the nodes should deploy an intermediate node to be the router to route the packet from the source toward the destination. The Wire-less Ad-hoc Networks do not have gateway, every node can act as the gateway. Although since 1990s', lots of research has been done on this particular field, it has often been questioned as to whether the architecture of Mobile Adhoc Networks is a fundamental flawed architecture. The main reason for the argument is that Cellular Networks are almost never used in practice, almost every wireless network nodes communicate to base station and access points instead of co-operating to forward packets hop-by-hop.

1.1.1 Definitions of Mobile Adhoc Networks

Mobile Adhoc Network (MANET) is a collection of independent mobile nodes that can communicate to each other via radio waves. The mobile nodes that are in radio range of each other can directly communicate, whereas others need the aid of intermediate nodes to route their packets. These networks are fully distributed, and can work at any place without the help of any infrastructure. Following figure shows view of MANETs.

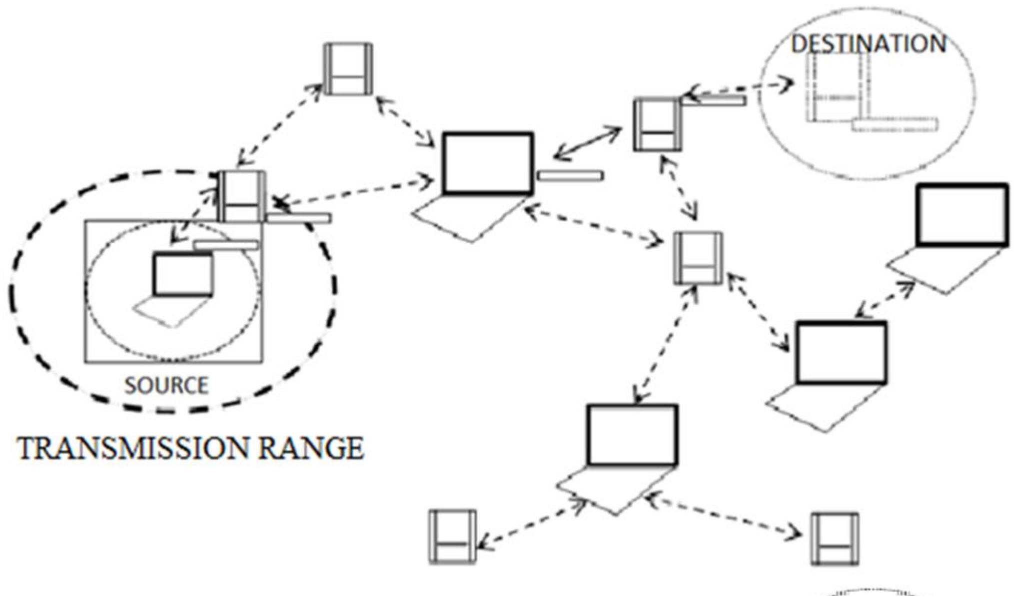


Figure 1.1: View of Mobile Adhoc Networks

Following are the characteristics of MANETs [3]

- Communication via wireless means.
- Nodes can perform the roles of both hosts and routers.
- No centralized controller and infrastructure.
- Intrinsic mutual trust.
- Dynamic network topology.
- Exile
- Robust

1.2 Evolution of MANETs

The life cycle of mobile ad hoc networks can be characterised into first, second and third generation. Present ad hoc network are considered the third generation [2][3]. The first generation of ad hoc network can be traced back to 1970's. In 1970's, these were called Packet Radio Network (PRNET) [4]. The Defence Advanced Research Project Agency (DARPA) initiated research of using packet- switched radio communication to provide reliable communication between computers and urbanized PRNET. Basically PRNET uses the combination of Areal Location of Hazardous Atmospheres (ALOHA) and Carrier Sense Multiple Access (CSMA) for multiple access [2].

The PRNET was then evolved into the Survivable Adaptive Radio Network (SURAN) in the early 1980's. SURAN provided some benefits by improving the radio performance (making them smaller, cheaper and power thrifty). This SURAN also provides resilience to electronic attacks.

Around the same time, United State Department of Defence continued funding for programs such as Globe Mobile Information System (GloMo) and Near Term Digital Radio (NTDR). GloMo make use of CSMA/CA and TDMA, and provides self-organizing and self-healing network (i.e. ATM over wireless, Satellite Communication Network). The NTDR make use of clustering and link state routing and organized an ad hoc network. NTDR is worn by US Army. This is the only "real" ad hoc network in use. By the growing interest in the ad hoc networks, various other great developments took place in 1990's.

The functioning group of MANET was born in Internet Engineering Task Force (IETF) who worked to standardized routing protocols for MANET and have developed various mobile devices like PDA's , palmtops, notebooks, etc . Meanwhile the Development of Standard IEEE 802.11 (i.e. WLAN's) benefited the ad hoc network. Some other standards are also developed that provide benefits to the MANET like Bluetooth and HIPERLAN.

1.3 Applications of MANETs [2]

With the increase of portable devices as well as progress in wireless communication, ad-hoc networking is gaining importance with the increasing number of widespread applications. Ad-hoc networking can be applied anywhere where there is little or no communication infrastructure or the existing infrastructure is expensive or inconvenient to use. Adhoc networks allow the devices to maintain connections to the network as well as easily adding and removing devices to and from the network. The set of applications for MANET is diverse, ranging from large-scale, mobile, highly dynamic networks, to small, static networks that are constrained by power sources. Besides the legacy applications that move from traditional infrastructure environment into the ad hoc context, a great deal of new services can and will be generated for the new environment. Typical applications include [11, 28]

- **Military Battlefield:** Military equipment now routinely contains some sort of computer equipment. Mobile Adhoc networking would allow the military to take advantage of commonplace network technology to maintain an information network between the soldiers, vehicles, and military information headquarters. The basic techniques of ad hoc network came from this field.
- **Commercial Sector:** Mobile Adhoc Networks can be used in emergency/rescue operations for disaster relief efforts in fire, flood, or earthquake etc. Emergency rescue operations must take place where non-existing or damaged communications infrastructure and rapid deployment of a communication network is needed. Information is relayed from one rescue team member to another over a small hand held. Other commercial scenarios include ship-to-ship ad hoc mobile communication, law enforcement, etc.
- **Local Level:** Mobile Adhoc Networks can autonomously link an instant and temporary multimedia network using notebook computers or palmtop computers to spread and share information among participants at conference or classroom. Another appropriate local level application might be in home networks where devices can communicate directly to exchange information. Similarly in other civilian environments like taxicab, sports stadium, boat and small aircraft, mobile ad hoc communications will have many applications.
- **Personal Area Network (PAN):** Short-range MANETs can simplify the intercommunication between various mobile devices (such as a PDA, a laptop, and a cellular phone). Tedious wired cables are replaced with wireless connections. Such an ad hoc network can also extend the access to the Internet or other networks by mechanisms e.g. Wireless LAN (WLAN), GPRS, and UMTS. The PAN is potentially a promising application field of MANET in the future pervasive computing. MANET-VoVoN: A MANET enabled version of JXTA

peer-to-peer, modular, open platform is used to support user location and audio streaming over the JXTA virtual overlay network. Using MANET-JXTA, a client can search asynchronously for a user and a call setup until a path is available to reach the user. The application uses a private signaling protocol based on the exchange of XML messages over MANET-JXTA communication channels.

1.4 Research Issues and Challenges in MANETs

The emergence of MANETs has made a tremendous impact on IT industry over the past few years. MANETs provide a cheap, flexible and reliable ways of computing to IT industry. MANETs is in initial stage, with many issues still need to be addressed [12, 27].

- **Routing:** Since the topology of the network is constantly changing, the issue of routing packets between any pair of nodes becomes a challenging task. Most protocols should be based on reactive routing instead of proactive. Multi cast routing is another challenge because the multi cast tree is no longer static due to the random movement of nodes within the network. Routes between nodes may potentially contain multiple hops, which are more complex than the single hop communication.
- **Security and Reliability:** In addition to the common vulnerabilities of wireless connection, an ad hoc network has its particular security problems due to nasty neighbor relaying packets. The feature of distributed operation requires different schemes of authentication and key management. Further, wireless link characteristics causes also reliability problems, because of the limited wireless transmission range, the broadcast nature of the wireless medium (e.g. hidden terminal problem), mobility induced packet losses, and data transmission errors.
- **Quality of Service (QoS):** Providing different quality of service levels in a constantly changing environment will be a challenge. The inherent stochastic feature of communications quality in a MANET makes it difficult to offer fixed guarantees on the services offered to a device. An adaptive QoS must be implemented over the traditional resource reservation to support the multimedia services.

- **Inter-networking:** In addition to the communication within an ad hoc network, inter-networking between MANET and fixed networks (mainly IP based) is often expected in many cases. The coexistence of routing protocols in such a mobile device is a challenge for the harmonious mobility management.
- **Power Consumption:** For most of the light-weight mobile terminals, the communication-related functions should be optimized for lean power consumption. Conservation of power and power-aware routing must be taken into consideration.
- **Multicast:** Multicast is desirable to support multiparty wireless communications. Since the multicast tree is no longer static, the multicast routing protocol must be able to cope with mobility including multicast membership dynamics (leave and join).
- **Location-aided Routing:** Location-aided routing uses positioning information to define associated regions so that the routing is spatially oriented and limited. This is analogous to associatively-oriented and restricted broadcast in Associate Based Routing (ABR).

1.5 Network Management

Network management is a process of controlling a complex data network so as to maximize its efficiency and productivity [8]. This process involves two main management activities, monitoring and configuring. As shown in Figure 1.2, the management process represents a function that takes as input both objectives, observer states, and eventually the old-settings configuration. It returns as output the proper configuration parameters applied to the managed system. Through this loop control, we can see that management process is similar to the concept of an automatic control system. Management applications in MANETs include network monitoring, configuration and control of network and node resources (like battery life and bandwidth). The research work addressing to monitoring resides in measuring performance metrics, collecting the measurement data and processing these measurements. The configuration of ad-hoc networks must be performed in a self-organized manner to ensure robustness and scalability. A basic expectation in configuring ad hoc networks lies on the auto-configuration of network devices including the allocation of their IP addresses. Unlike traditional fixed networks, MANETs rely on wireless connections between mobile nodes, which mean high rate of disconnections between nodes, limited network and node resources. So, there is a great need for new management architecture able to cope with MANETs constraints.

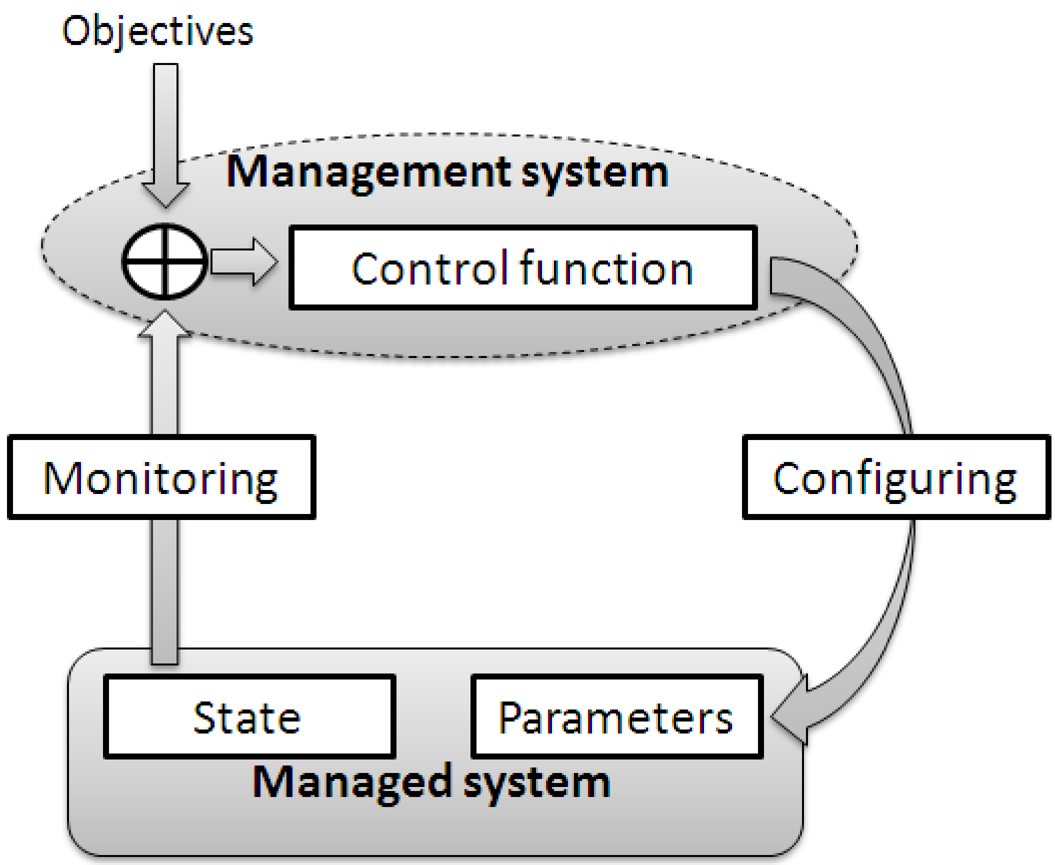


Figure 1.2: Management process

1.6 Research Motivation

The nodes in the Mobile Adhoc Networks are normally power curb because of their dependency on power. In wireless communication, especially in MANETs, remarkable amount of energy is consumed not only in transmission among the nodes but also in overhearing of the packets sent from other nodes [5]. As green computing is emerging, so it is required to formulate a routing protocol which is energy efficient. The one of the most important objectives of MANETs routing protocol is to maximize energy efficiency, since nodes in MANETs depend on limited energy resources. The possible energy consumption states are: transmit, receive, idle and dead.

The main objectives of MANETs routing protocols are to maximize throughput (network), energy efficiency, network lifetime and to minimize the delay. The network throughput is usually measured by packet delivery ratio while the most significant contribution to energy consumption is measured by routing overhead which is the number or size of routing control packets.

1.7 Organization of Thesis

The rest of the thesis is organized as follows:

Chapter 2 – This chapter describes in detail the literature survey done to study routing in MANETs, various protocols used to route the packets in MANETs (mainly proactive and reactive) and analyse their types.

Chapter 3 – This chapter describes the problem analysis of the thesis work. It gives the gap analysis and problem statement.

Chapter 4 – This chapter gives the methodology used and solution of the problem.

Chapter 5 – This chapter focus on the implementation details and experimental results of the solution proposed in this thesis.

Chapter 6 – This chapter describes the conclusion, contribution to the work done and future research work possible.

Chapter 2

Literature Survey

This chapter discuss about various existing protocols, their comparison and research issues available for routing in Mobile Adhoc Networks (MANETs).

2.1 Routing Protocols

"Routing is the process of information exchange from one host to the other host in a network."[4]. Routing is the mechanism of forwarding packets to the destination using most energy efficient path. The primary objectives of MANETs routing protocols are to maximize network throughput, to maximize energy efficiency, maximize network lifetime, and to minimize delay. The network throughput is usually measured by packet delivery ratio while the most significant contribution to energy consumption is measured by routing overhead, which is the number or size of routing control packets. In order to achieve Quality of Service (QoS), several routing models have been proposed. Routing protocol for ad-hoc network can be categorized in two strategies.

a) Proactive
b) Reactive routing protocol.

2.2 Proactive Routing Protocols [1]

In proactive routing scheme every node continuously maintains complete routing information of the network. This is achieved by flooding network periodically with network status information to find out any possible change in network topology. Current routing protocol like Link State Routing (LSR) protocol (open shortest path first) and the Distance Vector Routing Protocol (Bellman-Ford algorithm) are not suitable to be used in mobile environment.

Destination Sequenced Distance Vector (DSDV) routing protocol and Optimized Link State Routing (OLSR) protocol were proposed to eliminate counting to infinity and looping problems of the distributed Bellman-Ford algorithm and widely used in mobile environment [20].

2.2.1 Destination Sequenced Distance Vector (DSDV) Routing

This protocol is based on classical Bellman-Ford routing algorithm [10, 23] designed for MANETs. Each node maintains a list of all destinations and number of hops to each destination. Each entry is marked with a sequence number. It uses full dump or incremental update to reduce network traffic generated by route updates. The broadcast of route updates is delayed by settling time. The only improvement made here is avoidance of routing loops in a mobile network of routers. With this improvement, routing information is always available, regardless of whether the source node requires the information or not. With the addition of sequence numbers, routes for the same destination are selected on the basis of following rules [2]:

1. A route with a newer sequence number is preferred.
2. If the two routes have a same sequence number, the one with a better cost metric is preferred.

The routing table of DSDV maintains following list of fields as shown in Table 2.1:

Table 2.1: Fields of DSDV routing protocol

DESTINATION	NEXT HOP	NO. of HOPS	SEQUENCE NO.	INSTALL TIME

The sequence number is used to distinguish stale routes from new ones and thus it avoids the formation of loops. The stations periodically transmit their routing tables to their immediate neighbours. A station also transmits its routing table if a significant change has occurred in its table from the last update sent [26]. So, the update is both time-driven and event driven.

Each row of the sent update is of the following form:

<Dest. IP address, Dest. Sequence number, Hop count>

After receiving an update, neighbouring nodes utilize it to compute the routing table entries. Following figure resolves the route failure of DSDV [16].

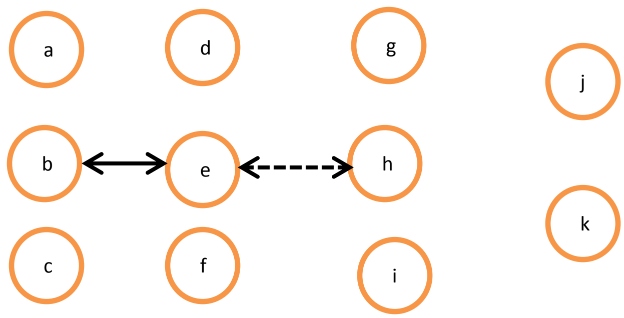


Figure 2.1 (a): Link from e to h breaks

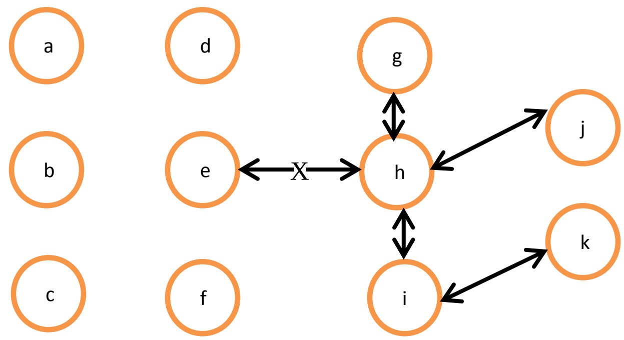


Figure 2.1 (b): A broadcast request to the neighbours

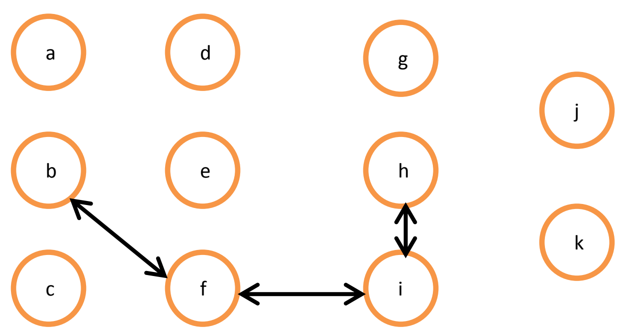


Figure 2.1(c): Link Established

Figure 2.1(a) shows that link between e and h has broken. Figure 2.1(b) shows that a broadcast request has been made to the neighbours to update the routing tables. Figure 2.3(c) shows that new links have been established.

2.3 Reactive Routing Protocols [1]

Every node in this routing protocol maintains information of only active paths to the destination nodes. A route search is needed for every new destination therefore the communication overhead is reduced at the expense of delay to search the route. Rapidly changing wireless network topology may break active route and cause subsequent route search [7, 18]. Most effective routing protocols are AODV, DSR.

2.3.1 Adhoc On-demand Distance Vector Routing (AODV)

Ad hoc On-demand Distance Vector Routing (AODV) is an improvement of the DSDV algorithm discussed in section 2.2.1. AODV minimizes the number of broadcasts by creating routes on-demand as opposed to DSDV that maintains the list of all the routes [25, 26].

To find a path to the destination, the source broadcasts a route request packet [10, 22]. The neighbours in turn broadcast the packet to their neighbours till it reaches an intermediate node that has recent route information about the destination or till it reaches the destination (Figure 2.2(a)) [30]. A node discards a route request packet that it has already been seen. The route request packet uses sequence numbers to ensure that the routes are loop free and to make sure that if the intermediate nodes reply to route requests, they reply with the latest information only [7, 23].

When a node forwards a route request packet to its neighbours, it also records in its tables the node from which the first copy of the request came. This information is used to construct the reverse path for the route reply packet. AODV uses only symmetric links because the route reply packet follows the reverse path of route request packet. As the route reply packet traverses back to the source (Figure 2.2(b)) [30], the nodes along the path enter the forward route into their tables. If the source moves then it can reinitiate route discovery to the destination. If one of the intermediate routing nodes move then the moved nodes neighbour realizes the link failure and sends a link failure notification to its upstream neighbours and so on till it reaches the source upon which the source can reinitiate route discovery if needed.

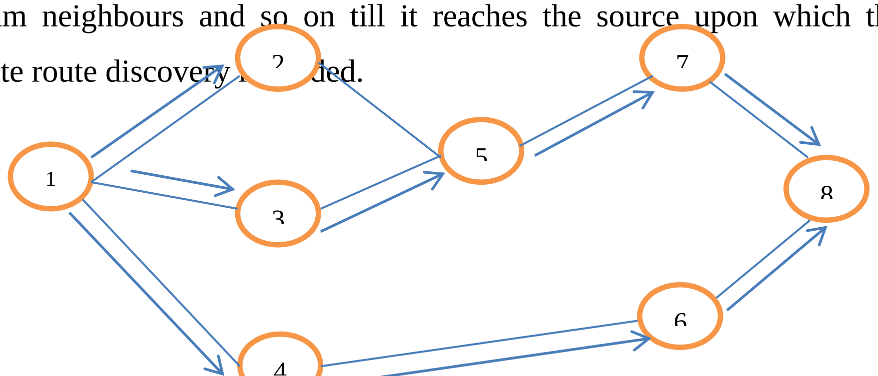


Figure 2.2(a): Propagation of route Requests (RREQ) Packets

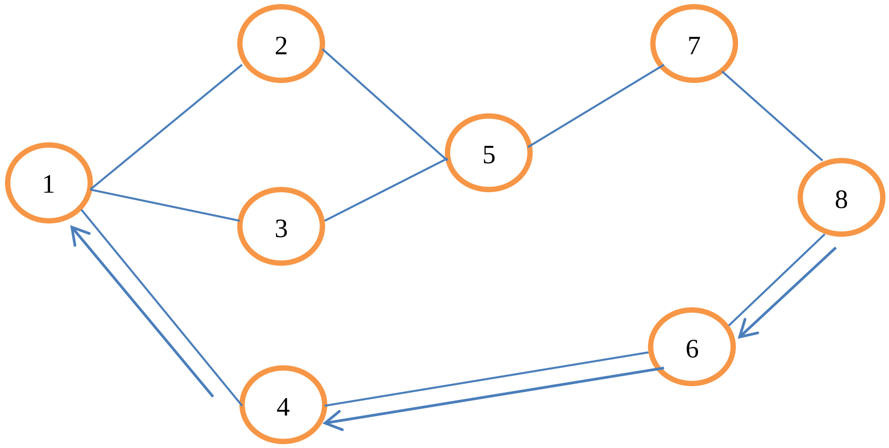


Figure 2.2(b): Path taken by the Route Reply (RREP) Packets

2.3.2 Dynamic Source Routing (DSR)

The Dynamic Source Routing Protocol is a source-routed on-demand routing protocol. A node maintains route caches containing the source routes that it is aware of. The node updates entries in the route cache as and when it learns about new routes.

The two major phases of the protocol are: route discovery and route maintenance [10, 23]. When the source node wants to send a packet to a destination, it looks up its route cache to determine if it already contains a route to the destination. If it finds that an unexpired route to the destination exists, then it uses this route to send the packet. But if the node does not have such a route, then it initiates the route discovery process by broadcasting a route request packet. The route request packet contains the address of the source and the destination, and a unique identification number [25, 26]. Each intermediate node checks whether it knows of a route to the destination. If it does, it appends its address to the route record of the packet and forwards the packet to its neighbours. To limit the number of route requests propagated, a node processes the route request packet only if it has not already seen the packet and its address is not present in the route record of the packet.

A route reply is generated when either the destination or an intermediate node with current information about the destination receives the route request packet. A route request packet reaching such a node already contains, in its route record, the sequence of hops taken from the source to this node.

Figure 2.3(a) [30] shows building of route during route discovery and Figure 2.3(b) [30] shows propagation of route reply with the route record.

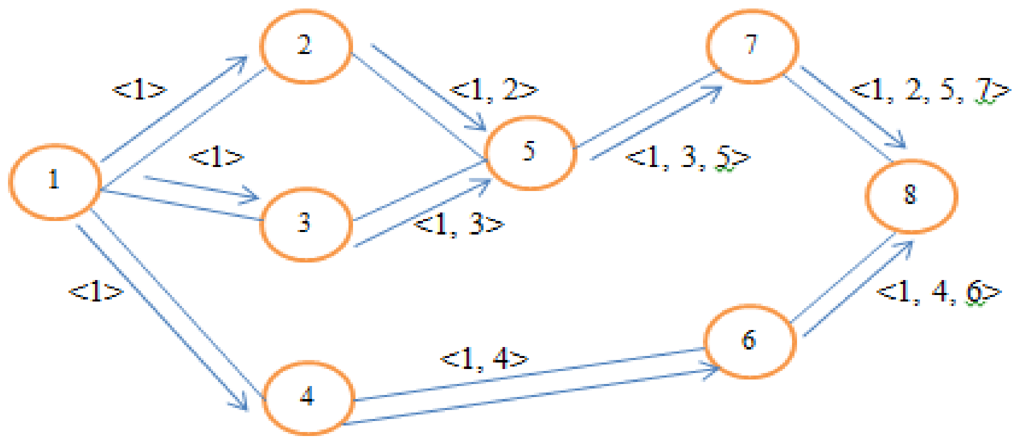


Figure 2.3(a): Building Record Route during Route Discovery

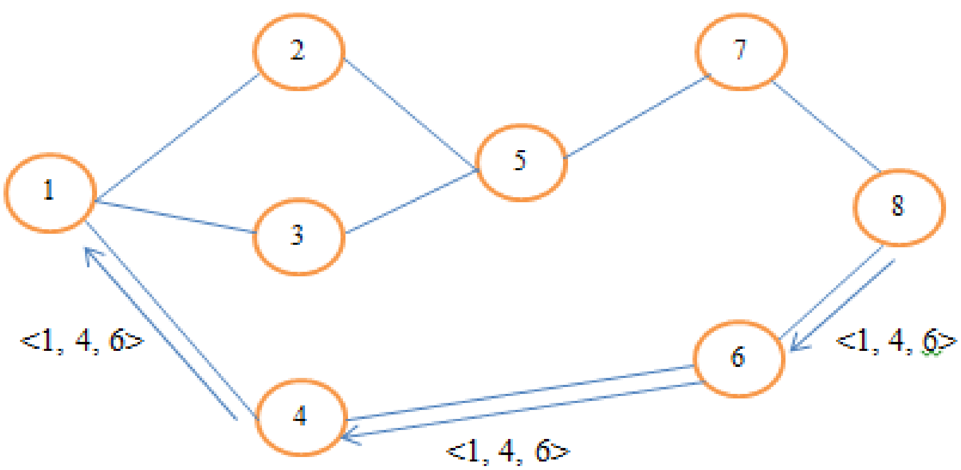


Figure 2.3(b): Propagation of Route Reply with the Route Record

2.4 Comparison between Proactive Routing and Reactive Routing Protocols

There are many routing classes. Comparison between these classes w.r.t. proactive routing protocols and reactive routing protocols is shown in Table 2.2 [14].

Table 2.2: Proactive Routing Protocol vs Reactive Routing Protocol

Routing Class	**Proactive(Table-Driven)**	**Reactive(On-Demand)**
Routing structure	Both Flat and hierarchical	Mostly Flat.
Availability of route **Control Traffic volume**	Always available Usually high	Determined when needed Lower than proactive routing protocols
Periodic updates	Yes, some may use conditional.	Not required. Some nodes may require periodic beacons.
Control Overhead	High	Low
Route acquisition delay	Low	High
Storage Requirements	High	Depends on the number of routes kept or required. Usually lower than proactive protocols
Bandwidth requirement	High	Low
Power requirement	High	Low
Delay level	Small since routes are predetermined	Higher than proactive

Scalability problem	Usually up to 100 nodes.	Source routing protocols up to few hundred nodes. Point-to-point may scale higher.
Handling effects of mobility	Occur at fixed intervals. DREAM alters periodic updates based on mobility	Usually updates ABR introduced LBQ AODV uses local route discovery

Routing Class	Proactive (Table- Driven)	Reactive (On-Demand)
Quality of service support	Mainly shortest path as the QoS metric	Few can support QoS , Although most support shortest path

Chapter 3

Problem Statement

In previous chapter analysis of various routing protocols such as DSR, AODV and DSDV for Mobile Adhoc Networks (MANETs) has been carried out. In this chapter, various research gaps have been illustrated.

3.1 Gap Analysis

Based on literature survey done in previous chapter, there are certain critical aspects of the protocols which have been mentioned below but none of them guarantees energy efficient routing over MANETs.

i. Dynamic Source Routing (DSR)

This routing protocol was first given in 1985 and the parameters configured for simulation of DSR is shown in Table 3.1 [31].

Table 3.1: Parameters configured for simulation of DSR

PARAMETER	VALUE
Time between retransmitted requests.	500ms
Size of source route header carrying n addresses	4n + 4 bytes
Time out for non – propagating search	300ms
Time to hold packets awaiting routes	30s
Maximum rate for sending replies for a route	1/s

Some of the drawbacks of DSR are:

- Packet header size grows with route length due to source routing
- Flood of route requests may potentially reach all nodes in the network

- Potential collisions between route requests propagated by neighboring nodes
- Insertion of random delays before forwarding RREQ
- Increased contention if too many route replies come back due to nodes replying using their local cache
- Route Reply *Storm* problem
- Stale caches will lead to increased overhead.

ii. Adhoc On – Demand Distance Vector (AODV) Routing

This routing protocol was first given in 1992 and the parameters configured for simulation of AODV is shown in Table 3.2 [31].

Table 3.2: Parameters configured for simulation of AODV

PARAMETER	VALUE
Hello interval	1.5s
Active route time – out	300s
Route reply life – time	300s
Allowed HELLO loss.	2
Request retries	4
Time between retransmitted requests.	3s
Time to hold packets awaiting routes.	8s
Maximum rates for sending reply for a route.	1/s

Some of the drawbacks of AODV are:

- AODV doesn't allow handling unidirectional links.
- Multiple Route Reply packets in response to a single Route Request packet can lead to heavy control overhead.
- Periodic beaconing leads to unnecessary bandwidth consumption.

iii. Destination Sequenced Distance Vector (DSDV) Routing

This routing protocol was first given in 1994 and the parameters configured for simulation of DSDV is shown in Table 3.3 [31].

Table 3.3: Parameters considered for simulation of DSDV

Periodic route update interval	15s
Periodic updates missed before link declared broken	3
Route advertisement aggregation time.	1s
Maximum packets buffered per node per destination.	5

Some of the drawbacks of DSDV are:

- Storage requirement is high.
- Control overhead is high.
- Bandwidth requirement is high.
- Power requirement is high.

3.2 Problem Statement

Mobile Adhoc Networks (MANETs) is a collection of independent mobile nodes that can communicate to each other via radio waves. The mobile nodes that are in radio range of each other can directly communicate, whereas others need the aid of intermediate nodes to route their packets. The protocols described before do not ensure energy efficiency. When we discuss about MANETs our first concern should be energy efficiency. One distinguishing feature of energy efficient adhoc routing protocol is its use of power for each route entry. Given the choice between two routes to a destination, a requesting node is required to select one with better power status and more active. But the existing protocols for transmission of data packets from source to destination do not focus on energy efficiency aspect.

The energy efficiency of a node is defined by the number of packets delivered by a node in a certain amount of energy. The nodes in an ad hoc network are constrained by battery power for their operation. To route a packet from a source to a destination involves a sufficient number of intermediate nodes. Battery power of a node is a precious resource that must be used efficiently in order to avoid early termination of a node or a network. Efficient battery management [3, 4, 5], transmission power management [6, 7] and system power management [8, 9] are the major means of increasing the life of a node. These schemes deal in the management of energy resources by controlling the early depletion of the battery, adjust the transmission power to decide the proper power level of a node and incorporate low power consumption strategies into the protocols. Following are few reasons for energy management in MANETs are:

- MANETs have been developed to provide communication for an environment where fixed infrastructure cannot be deployed. Nodes in MANETs have very limited energy resources as they are battery powered.
- In so many situations like hostile territory, it is very difficult or almost impossible to replace the battery or recharge it.
- There is no central coordinator in case of adhoc networks as a base station in cellular networks.

The aim of this thesis work is to propose a new efficient routing scheme for MANETs which will provide an energy efficient and reliable execution of the data packets.

Chapter 4

Proposed Work

As green computing is emerging, so it is required to formulate a routing protocol which is energy efficient. In this chapter, a new routing algorithm has been articulated which has been observed to be an energy efficient technique. The research work has been classified into three cases based on the number of nodes. First case when n = 20, second case when n = 25, third case when n = 50.

4.1 Assumptions and System Models

1. Transmission Energy

Energy required for transmission of packets. It is denoted by Et. Here, the value of transmission energy is assumed as Et = 0.32.

2. Processing Energy

Energy required for processing of packets. It is denoted by Ep. Here, the value of processing energy is assumed as Ep = 0.25.

During routing Et > Ep … … … (A)

Also transmission energy and processing energy of each node would be same as the network is homogenous.

3. Total Energy

Total energy is denoted by T.E. Total energy for all the intermediate nodes is taken as T.E. = 10 Joules. For source node and destination node it is taken to be T.E. = 50 Joules.

4. Energy Utilized

While transmission of data packets energy utilized at each node = number of data packets each node can handle * (Transmission energy + processing energy) i.e.

$$E.U = n * (Et + Ep) \quad \dots \quad \dots \quad \dots \qquad (1)$$

$$\therefore\ E.U. = n * (0.32 + 0.25) \quad \dots \quad \dots \quad \dots. \qquad (2)$$

5. Remaining Energy

The remaining energy of each node would be E.R. = Total energy – Energy utilized i.e.

$T.E.- E.U.= 10 - n * (0.57)$ ... ... (3)

6. Maximum Packets

Maximum number of packets which each node can handle without failure when number of nodes is 10 has been calculated as shown below:

$10 - n * (0.32 + 0.25) = 0$……………………... (4) which comes out to be ≈ 17. So if a node tries to handle equal to or greater than 17 packets it would be considered as dead node in the network. Also, the total amount of data that can be simultaneously transmitted for one hop increases linearly with the total area of the ad hoc network.

7. System Model

The routing algorithm proposed in this thesis has been designed using Dijkstra's Algorithm for graphs. First of all, energy utilization of each mobile node of the Mobile Adhoc Network has been calculated as described above. Also, an incidence matrix edge[][] is created for the network connectivity. Now for two nodes i, j if an edge exist then edge[i][j] = 1. The energy utilization for each node would become the weight of the edges, i.e. for two node i, j w[i][j] = E.U. Let S1 be our source node and let S2 be our destination node. Now, using the above parameters path from S1 to S2 with minimum energy utilization has been calculated.

After calculating the path we would the number packets routed from source to destination which actually reached destination (say P). Total number of packets in to the network from source was (say Q). So delivery ratio would be as follows:

Delivery ratio (D) = Packets actually reaching destination/total number of packets.

$D = P/Q$ ... ... (5)

Here, dynamic network topology for mobile nodes has been created. Connectivity of the network has been shown using the incidence matrix. After calculating the energy utilization (E.U.) for each node the values are stored in array E.U[][]. Also number of packets that each node can handle successfully was calculated and stored in an array Packets []. Now a text file "Data.txt" has been created and the following data was written into it using commands available for file handling. Data written in text file are number of nodes (n), the end points for all the edge connections between various nodes based on incidence matrix, the energy utilization array E.U [] and number of packets stored in array Packets [].

Now the entire data from the text file Data.txt was read and using it we have calculated the shortest path for the dynamic network. Actually, Dijkstra's technique is the basis to calculate the shortest path from source to destination using energy utilization (E.U.) as an optimization parameter for each node. Number of edges gets stored in a variable named e. End points for all edges goes into variables u , v and correspondingly, energy utilized gets stored in a static 2_D array say energyutil [u][v], number of packets gets stored in packets [] array. User specifies the source (say S) which wants to send the data packets and would start the connection and destination (say D) which would receive the data packets. Now we pass source (S), destination (D) and energyutil[][] array to our shortest energy path function named shortest(int S, int D, float energyutil [][]).

Now here energyutil [][] will act as the initial weights of the graph S as the source. The final values of energies gets stored in an array energy [].

4.2 Proposed Algorithm

Initially energy [] = ∞ and energy[s] = 0. Integers i, k, mini are variables whose value changes while program gets executed.

Visited [] is an integer array. Its value is either 0 or 1 depending upon whether the element has been visited or not. For example: Visited [i] =0 if i-th element has not been visited.

Pathindex [] array stores the indices of the mobile nodes in increasing order of their energy utilization value after shortest path algorithm is called.

Pathfinal [] stores the shortest path from source to destination.

Edge [][] carries either value 1 or 0, 1 where there is an edge between the two vertices and 0 if there is no edge between them.

Experimental results show that this approach gives better results in term of energy efficiency as compare to other approaches. Hence, this approach has been used in our algorithm for extracting energy efficient solution.

For reliable and energy efficient execution of routing in MANETs the technique proposed by us in this thesis is very effective.

EEUR Algorithm

```
For each i ← 0 to n do
      energy [i] ← ∞.
      visited [i] ← 0
End loop.
energy [s] = 0.
For each k ← 0 to n - 1 do
     mini ← -1
     For each I ← 0 to n - 1
       If  !(visited [i]) && ((mini == -1) || (energy[i] < energy[mini]))  do
          mini = i.
       End if
     End for
     visited [mini] = 1
     For each i ← 0 to n - 1 do
       if energyutil [mini][i]
         If energy [mini] + energyutil [mini][i] < energy [i]
           energy [i] ← energy[mini] + energyutil [mini][i].
         End if.
       End if.
     End for
End for.
```

The running time complexity for the algorithm varies from O (n*(lg(n)) in best case **to** O(n^2) in average case**.** Here, the running time complexity is O (n^2).

Pause Time: - Time taken for the system to compute the shortest path is called pause time. In our case it is O (n^2) where n is the number of nodes and the pause time is directly proportional to square of n i.e. Pause time (Pt) ∝ n. Following is the table of pause time for n = 20, 25 and 50.

Table 4.1: Number of Nodes and corresponding Pause Time for EUUR

Number of nodes (n)	**Pause time (Pt)**
20	400 ms
25	625 ms
50	2500 ms

The proposed algorithm can further be optimized and the pause time could be reduced to k * n (log (n) by Partition-Based Speed-Up of Dijkstra's Algorithm where k is a small constant (say 0.4521). Following is the table of pause time for n = 20, 25 and 50.

Table 4.2: Number of Nodes and corresponding Pause Time partition based Speed-Up of Dijkstra's scheme

Number of nodes (n)	**Pause time (Pt)**
20	11.7639 ms
25	15.8002 ms
50	38.4052 ms

Clearly, Partition Based Speed – Up of Dijkstra's Algorithm lead to a factor 34 improvement of time.

Now array energy[] carries the minimum energy values. Based on the values of energy[], the shortest path for transmitting data packets is calculated and stored in an array pathfinal[]. dest is an integer variable which carry the destination node value. In order to calculate shortest path first of all array energy[] is sorted in increasing order using any of the sorting techniques and the result are stored in an array sortenergy[]. Next the values of energy[] are compared with the values of sortenergy[] and the index in the former array are checked and the results are stored in array pathindex []. Now the elements of pathindex are checked in consecution to find whether they are connected or not. If any of them is not connected then be would be deleted element. This result will get stored in pathfinal[] array and we will get our shortest path. Here, the node which is farthest from the root i.e. the node at position n as the destination node, dest = n. The pseudo code is as follows:

Shortest Path Pseudo code

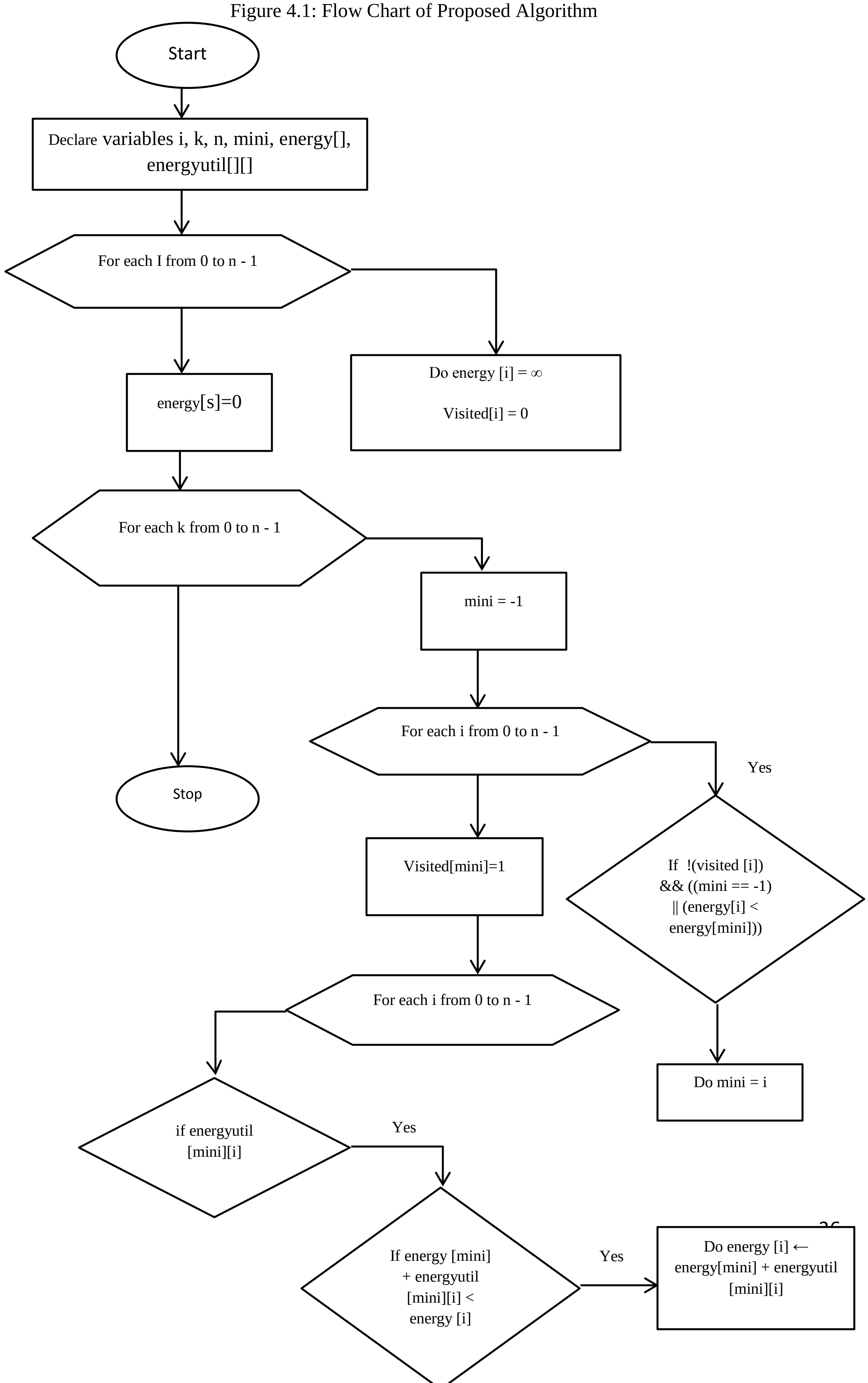
```
sortenergy []← insertion sort(fenergy []).
k ← 0.
Temp ← sortenergy [0].
For each i ← 0 to n - 1 do
    If !(temp == sortenergy [i] && i>0) do
        For each j ← 0 to n - 1 do
            If sortenergy [i] == energy[j] do
                pathindex [k]← j.
                k ← k+1.
            End if.
        End for
    End if
End for
i ← 0 and k ← 1
pathindex [i1] ← pathfinal [i]
a ← pathindex [i]
i ← i+1
b ← pathindex [i]
while pathindex [i]!=pathindex [n]
    if edge [a][b]!=1 then
        pathindex[i1] ← b
         i1 ← i1+1
```

```
        a ← b
        i ← i+1
        b ← pathindex [i]
    else
        i ← i + 1
        b ← pathindex [i]
    End if else
End while
if edge[pathfinal[i1-1]][pathindex[n-1]]==1 then
    pathindex [i1] = path [n-1]
else do
    while(edge[pathfinal[i1-1]][pathindex[n-1]]!=1)
        i1=i1-1
    End while.
End if else.
pathfinal[i1]=pathindex[n-1]
End.
```

Hence, the shortest path form source to destination is achieved. The process for routing the packets described above concerns majorly with energy utilization of nodes for transmitting and processing the packets and route them to a destination node. Hence it would be called Energy Efficient Unicast routing protocol (EEUR).

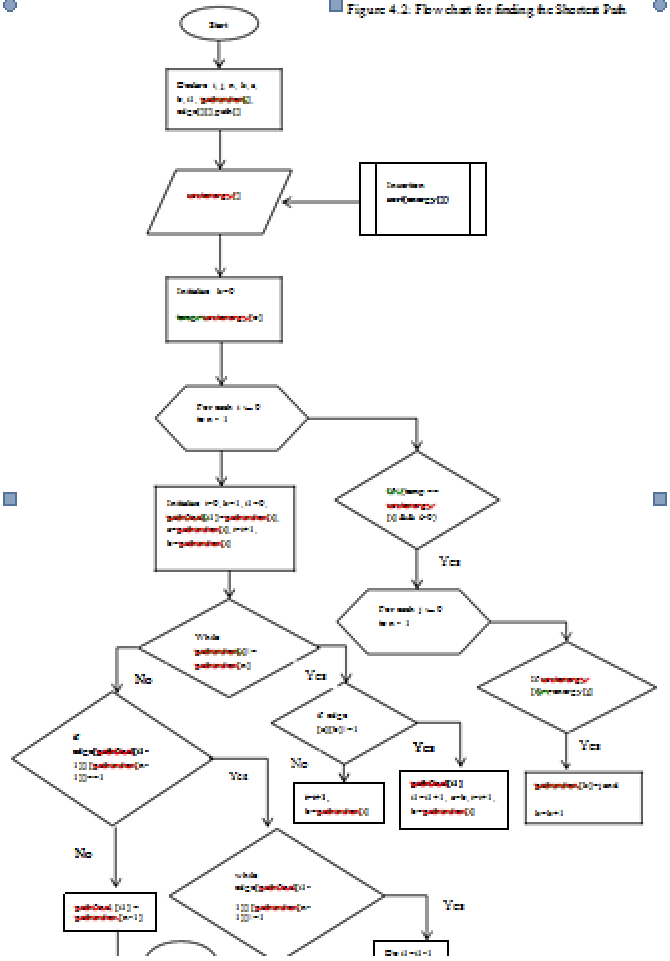
4.3 Flow Chart of Proposed Algorithm EEUR.

Figure 4.1: Flow Chart of Proposed Algorithm



4.4 Flow Chart for finding the Shortest Path.

Figure 4.2: Flow chart for finding the Shortest Path



Chapter 5
Experimental Results

This chapter gives details about tools used for creating a simulated network to analyse the protocols and compare them using various parameters.

5.1 Tools for Creating Simulated Network

We have used Network Simulator 2.35 (NS 2.35) for creating a network environment to analyse our proposed algorithm.

5.1.1 Network Simulator NS 2 [32]:

The Network Simulator 2.35 (NS 2.35) is a discrete event driven simulator developed at UC Berkeley. It is part of the VINT project. The goal of NS 2.35 is to support networking research and education. It is suitable for designing new protocols, comparing different protocols and traffic evaluations. NS 2.35 is developed as a collaborative environment. It is distributed freely and open source [33]. A large amount of institutes and people in development and research use, maintain and develop NS 2.35. NS 2.35 can run under both UNIX and Windows operating systems. There are many components needed to be installed before running NS 2.35. The user can choose to install it partly or completely. For beginners it is suggested to make a complete installation which automatically installs all necessary components at once and it requires 320 MB disk space. Installing it partly could save some disk space.

5.1.1.1 Scenario Generation

- This is done using the setdest command. There are two versions for setdest. Version 2 is most recently implemented and used.
- Version 2 signature of **setdest** command is
  setdest -v <2> -n <nodes> -s <speed type> -m <min speed> -M <max speed> -t <simulation time> -P <pause type> -p <pause time> -x <max X> -y <max Y>
    - **-v** version number; Here 2
    - **-n** number of nodes. Generated node number will be 0 to (n-1)
    - **-s** speed type (uniform, normal); **s=1** uniform speed from min to max; **s=2** normal speed clipped from min to max

- **-m** minimum speed > 0
- **-M** maximum speed
- **-P** pause type (constant, uniform); **P=1** constant pause; **P=2** uniform pause [0, 2*p]
- **-p** pause time (a median if uniform is chosen)
- **-x** x dimension of space
- **-y** y dimension of space

- After running the command a scenario will be generated.
- Example: setdest -v 2 -n 10 -m 10 -M 100 -t 20 -P 1 -p 10 -x 200 -y 400 > scen-exp1

5.1.1.2 Cbr Traffic Generation

- This is done with the help of cbrgen.tcl file executing with **ns** command
- Open terminal in ~ns-allinone-2.31/ns-2.31/indep-utils/cmu-scen-gen
- ns cbrgen.tcl [-type cbr|tcp] [-nn nodes] [-seed seed] [-mc connections] [-rate rate]
  - **-type** traffic type (tcp, udp/cbr)
  - **-nn** the highest node number(node number will be 0 to nn)
  - **-seed** seed for random variable generation which is used to create random number of source-destination pair
  - **-mc** maximum number of connections; i.e.; source-destination pair
  - **-rate** it is the inverse of the interval between packet transmission & should be <0
- After running the command a cbr traffic will be generated.
- Example: ns cbrgen.tcl -type cbr -nn 9 -seed 1 -mc 10 -rate .25 > cbr-exp1

5.1.1.3 Trace Generation

- Paste the tcl file to the ~ns-allinone-2.31/ns-2.31/tcl/ex directory
- Open terminal in ~ns-allinone-2.31/ns-2.31/tcl/ex
- Execute command ns <tclscript>
- Example: ns sample.tcl

If the simulation is successful, the desired trace file will be generated.

5.1.1.4 Animation: NAM File Generation

Animation is generated using a nam trace file. The nam trace file should contain topology information like nodes, links, queues, node connectivity etc. as well as packet trace information.

5.2 Results

Graphs for DSR, DSDV, AODV and proposed algorithm (EEUR) have been plotted and compared them on the basis of parameters such as:

i. Packets Sent for Route discovery during packets and Packets Received during Route Discovery
ii. Data Sent
iii. Data Received
iv. Delivery Ratio
v. Energy consumed during Routing
vi. Energy Efficiency during Routing

5.2.1 Packets Sent during Route Discovery and Packets Received during Route Discovery

Following table shows comparison between the protocols laid on the basis of packets sent during route.

Table 5.1(a): Comparison on the basis of Packets Sent during Route Discovery

PROTOCOLS/NODES	**20**	**25**	**50**
AODV	1224	1729	168
DSDV	0	0	0
DSR	27	13	15
EUUR	0	0	0

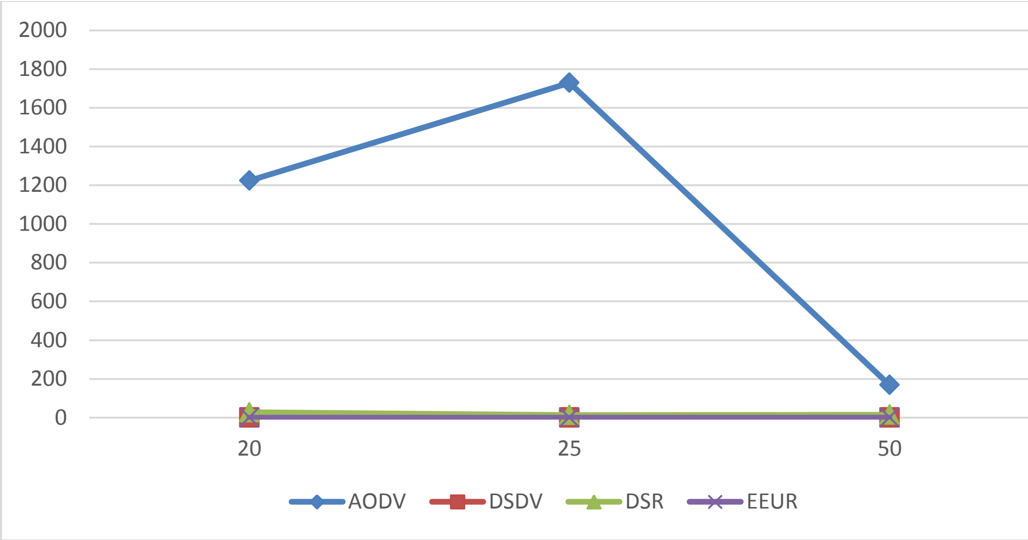


Figure 5.1(a): Packets Sent durings Route discovery

Here, the proposed protocol is more of a proactive protocol which does not send packets for route discovery and hence the time is saved. So, EEUR is outperforming the other three routing protocol

Following table shows comparison between the protocols laid on the basis of packets received during route.

Table 5.1(b): Comparison on the basis of Packets Received during Route Discovery

PROTOCOLS/NODES	20	25	50
AODV	1873	3471	597
DSDV	0	0	0
DSR	84	47	319
EEUR	0	0	0

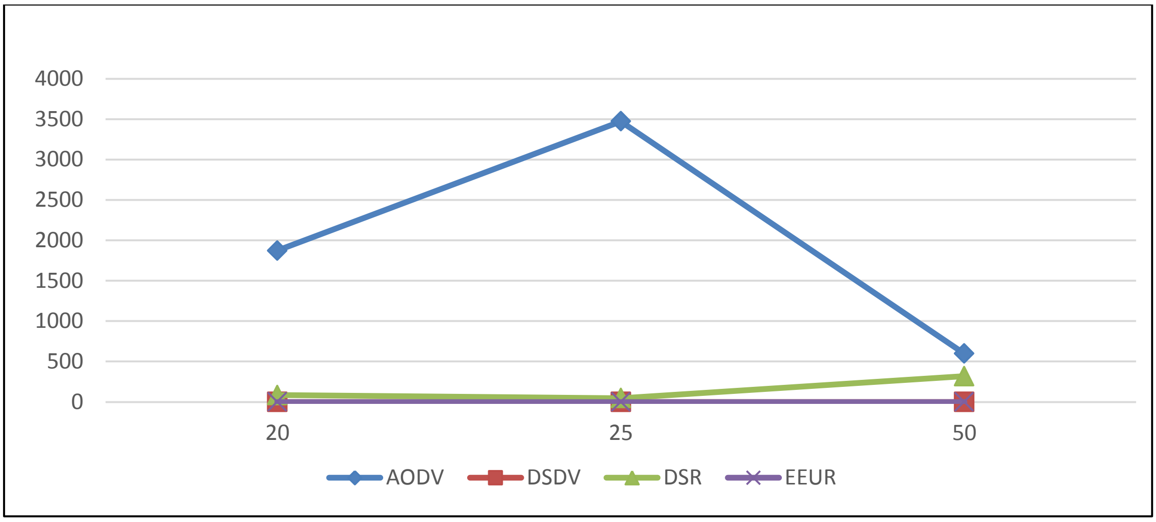


Figure 5.1(b): Packets Received during Route Discovery

Here, the proposed protocol is more of a proactive protocol which does not receive packets for route discovery and hence the time is saved. So, EEUR is outperforming the other three routing protocol

5.2.2 Data Sent

Table 5.2: Comparison on the basis of Data Sent

PROTOCOLS/NODES	20	25	50
AODV	1065	1070	25
DSDV	1076	219	449
DSR	84	47	21
EUUR	357	750	1490

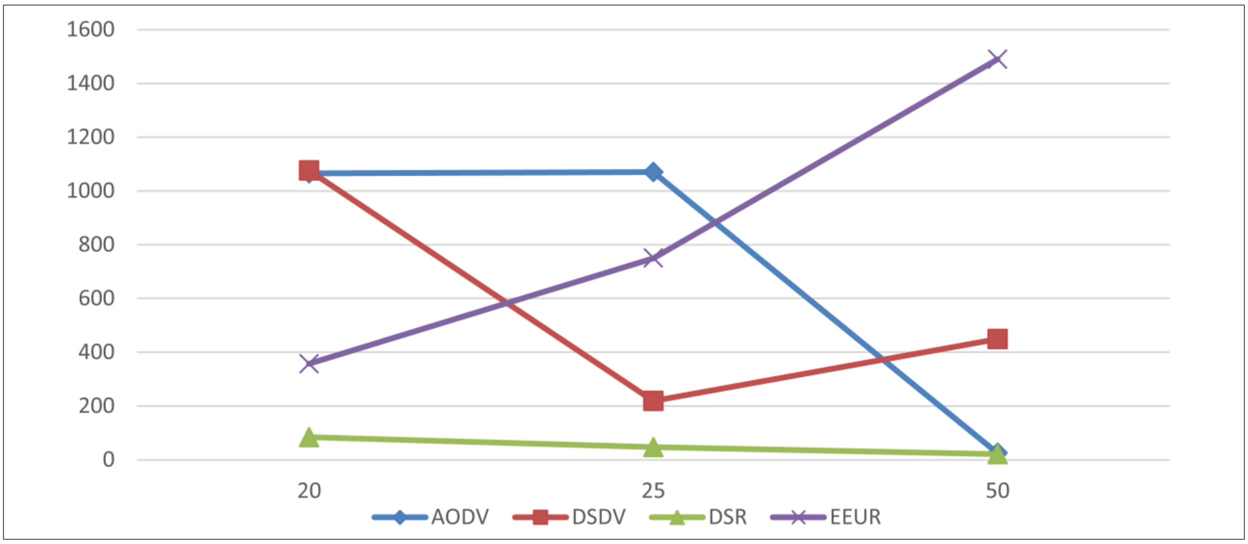


Figure 5.2: Data Sent

Here, the data sent first increases smoothly as the number of nodes increases but after certain point it increases sharply for EEUR.

5.2.3 Data received

Table 5.3: Comparison on the basis of Data Received

PROTOCOLS/NODES	20	25	50
AODV	156	190	1
DSDV	48	16	23
DSR	16	20	1
EEUR	159	290	1000

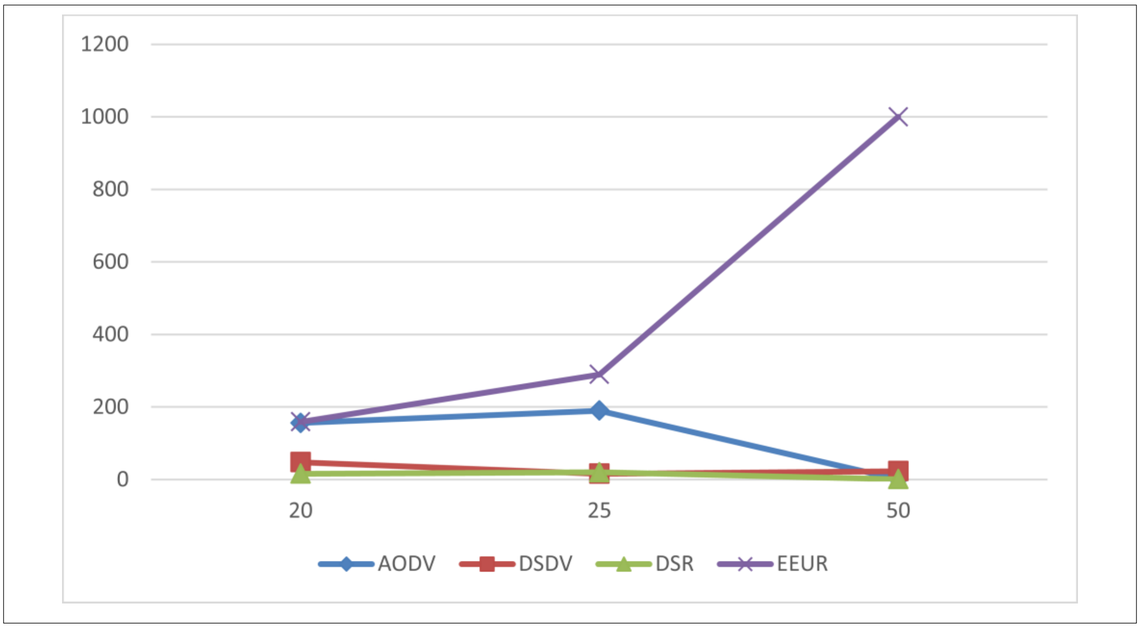


Figure 5.3: Data recieved

Here, the data received first increases smoothly as the number of nodes increases but after certain point it increases sharply for EEUR.

5.2.4 Delivery Ratio

Table 5.4: Comparison on the basis of Delivery Ratio

PROTOCOLS/NODES	20	25	50
AODV	14.6	17.5	4
DSDV	4.46	7.3	5.12
DSR	44.4	83.3	4.76
EEUR	44.53	38.67	67.11

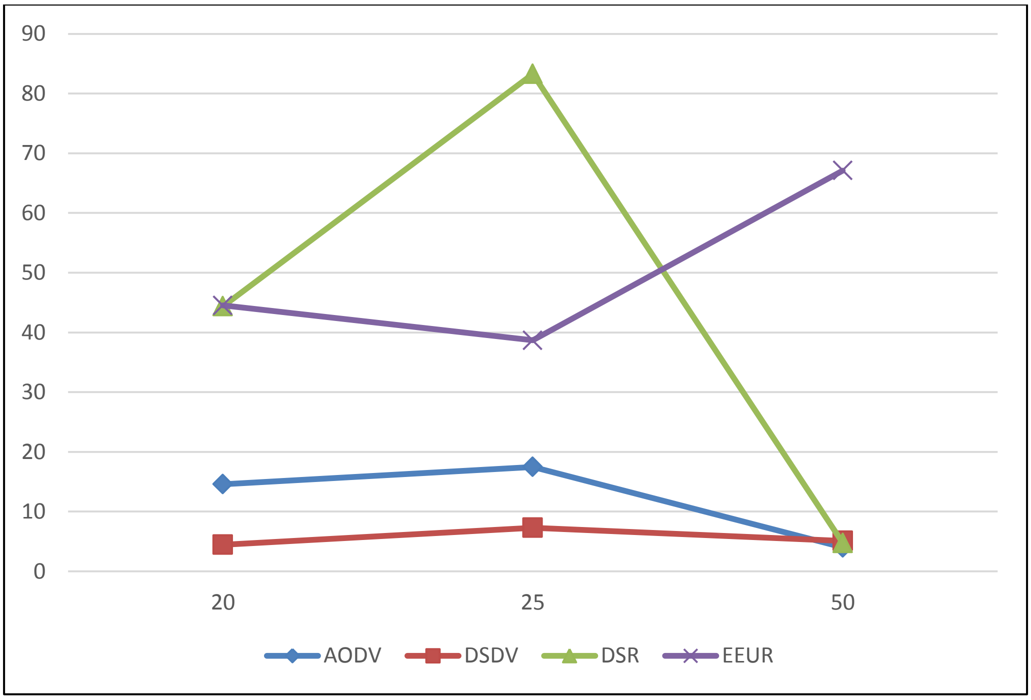


Figure 5.4: Delivery Ratio

Here, the delivery ratio for EEUR first decreases with increase in number of nodes then increases with the increase in number of nodes.

5.2.5 Energy Consumed during Routing

Table 5.5: Comparison on the basis of Energy Consumed during Routing

PROTOCOL/NDES	20	25	50
AODV	535	320	110
DSDV	570	585	300
DSR	550	425	195
EEUR	67.26	169.14	303.24

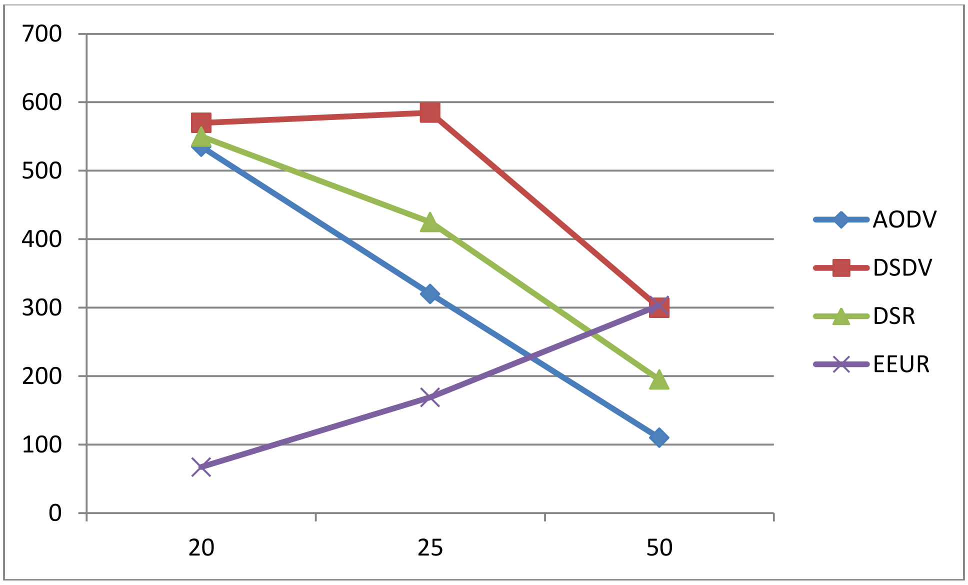


Figure 5.5: Energy Consumed

Here, energy consumed for proposed algorithm EEUR is increasing fairly with increase in number of nodes.

5.2.6 Energy Efficiency during Routing

Table 5.6: Comparison on the basis of Energy Efficiency during Routing

PROTOCOL/NODES	20	25	50
AODV	465	680	890
DSDV	430	415	700
DSR	450	575	805
EEUR	172.74	169.14	796.76

In Figure 5.6 , energy efficiency for proposed routing algorithm remains constant till number of nodes =25 then energy efficiency increases with increase in number of nodes.

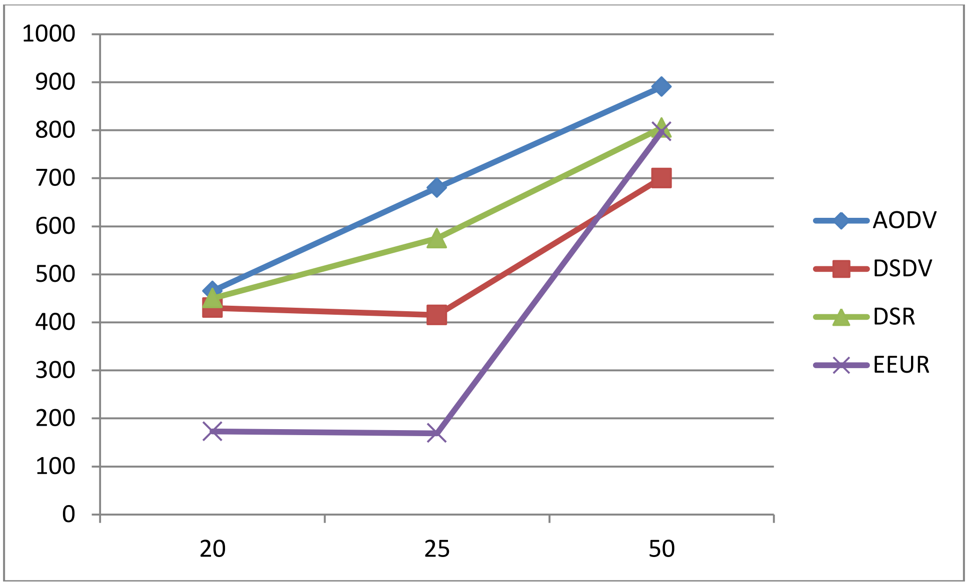


Figure 5.6: Energy Efficiency

Chapter 6

This chapter gives the conclusion of this thesis work and discuss about future direction which can be taken further.

6.1 Conclusion

From the above results based on the analysis of the four routing protocols i.e. AODV, DSDV, DSR AND EEUR it is clear that the value of delivery ratio which is data received/data sent is relatively better for the routing algorithm proposed by us (EEUR) in this thesis as compared to the other three. Since none of the routers failed so value of router drop is zero for all cases. The values of packet sent for route discovery and packets received after route discovery is zero in the case of EEUR as we haven't sent any packets for route discovery, data packets are sent directly to the intended destination travelling from node to node and it is left to the routing scheme proposed in this thesis (EEUR) to route the data packets in the most energy efficient way possible. Hence, this further decreases overhead and proves it an energy efficient routing technique. So we conclude that the routing algorithm proposed by us is more often an energy saving and an efficient technique for routing the data packets in MANET.

6.2 Thesis Contribution

1. In this thesis the existing three routing algorithms i.e. DSR, DSDV, AODV are analysed and they were found to be less energy efficient.
2. So, a new routing algorithm has been proposed using Dijkstra's technique in which we have taken energy utilization as a base for the designing of the algorithm.
3. Simulation results have been gathered and compared.

6.3 Future Scope

1. In future, the approach for energy efficient routing proposed in this thesis using Dijkstra's shortest path technique can be integrated in various other routing technologies to get optimized, better and improved results.
2. In future EEUR technique can be practically analysed to improve routing in Mobile Adhoc Networks (MANETs) on a large scale.
3. The technique for energy efficient routing proposed by us can be implemented in real time systems.
4. If possible we can decrease the pause time for finding the shortest path technique we can

get still better results and improve energy efficiency of EEUR.

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