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Improving DSR protocol in MANET using power-aware passive clustering

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This is to certify that the thesis prepared by *Yekoye Tigabu,* titled: *Improving DSR protocol in MANET by using power-aware passive clustering* and submitted in partial fulfillment of the requirements for the Degree of Master of Science in Computer Networking compiles with the regulations of the University and meets the accepted standards with respect to originality and quality.

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Abstract

Mobile ad hoc network is infrastructure less wireless network designed to provide service where other networks are not available or not possible to construct. Nodes are capable of acting as both router and host. Some of the difficulties of this network are mobility, lack of central controller, frequent topology change. Nodes in Ad hoc networks mainly uses blind flooding to find route to destination that introduces too much control overhead. In the network that nodes are energy constrained, it is good to reduce control overhead in the network so that nodes can be parts of the network for long time. In our modified DSR routing protocol we have limited the number of control packets propagated in the network. To limit the number of control packets we have used passive clustering by adding energy and distance as an additional parameter. We have modified the previously used passive clustering technique and applied to our modified DSR routing protocols. When nodes in the network have clustered, each node is assigned one of the following states such as head, gateway and ordinary. After the cluster has formed only head and gateway nodes are able to forward route requests so that routing overhead is minimized. We have created clustering header, which consists of node ID, state and energy. Clustering header is appended to the route request prepared. Besides, clustering header is also appended to the data packet while actual data packet is forwarding towards the destination. When a node receives the route request, it extracts information from the clustering header and store in its own neighbor list and determine its state based on its neighbor information. At the time when it receives clustering information from its neighbor, it computes the distance between them to easily detect when the node becomes outside of its transmission range. We have implemented our proposed solution on NS2.35. To show how efficient our work is, we have used packet delivery ratio, routing overhead, throughput and average end-to-end delay as a performance metrics. We have compared our modified DSR routing protocol with the existing DSR routing protocol based on the above-mentioned performance metrics and it has showed better performance.

Keywords: MANET, DSR, Clustering, Routing

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Table of contents

List of figures

List of tables

Acronyms

AODV	Ad hoc on-demand distance vector
DSDV	Destination-Sequenced Distance Vector Routing
DSR	Dynamic source routing
MAC	Medium Access Control
MANET	Mobile Ad-Hoc Network
NAM	Network Animator
NS2	Network Simulator 2
O-DSR	Optimized Dynamic Source Routing
OLSR	Optimized link state routing
OTCL	Object Tool Command Language
RREP	Route Reply
RREQ	Route Request
TCL	Tool Command Language
TORA	Temporally Ordered Routing Algorithm
Wi-Fi	Wireless Fidelity
ZRP	Zone Routing Protocol

CHAPTER ONE: INTRODUCTION

1.1 Background

Mobile Ad hoc network [4] is a type of network in which nodes communicate with each other without the help of any fixed infrastructure. This kind of network allows communication in the environment where deploying an infrastructure-based network become impossible. In Mobile ad hoc network nodes acts as both router and host. Nodes play the role of the router when forwarding packets for another node in the network, when source and destination nodes are not in each other's transmission range [2].

It is a multi-hop wireless network meaning when a certain node wants to send a data packet to some other node which is not within its communication range, it has to use other nodes to reach the data packet to the intended destination. The challenging thing in this kind of network is establishing an efficient route between source and destination due to the mobility of nodes.

Several routing protocols have been developed for MANET.A routing protocol [5] is needed whenever a packet needs to be transmitted to a destination via number of nodes. To find a route for packet delivery and deliver the packet to the correct destination these protocols are used.

For our thesis we have chosen dynamic source routing (DSR) protocol. DSR protocols [1, 6] uses source routing technique. The source node has to put all nodes in the path to destination explicitly in the packet header. When the intermediate node receives data packets form its neighbor, looking at the packet header to determine where to forward next. Route discovery technique used by DSR to builds routes on demand. A source initiates route discovery by flooding the query messages throughout the network to seek a route to the destination. Each of the query messages carries the sequence of hops it passed through network in the message header. When query packet reaches to the destination, the reply packet is sent back by storing the routing information stored in the query packet. Then, the source node uses the path in the route replay packet to send its data packets. An error packet is sent back to the source on detection of route failure by an unsuccessful message transmission. The error packet deletes all routes stored in the route caches of all intermediate nodes on the path which consists of the failed link. New route discovery will be initiated when the path to the destination failed. Routing loops are not formed as route is part of packet itself. And can also be easily detected and eliminated.

DSR uses flooding of the network to find the route to send data packet. Flooding results in high route discovery overhead. To minimize route discovery overhead DSR uses caching mechanism, but here in the case of no route is found in the cache the route discovery request may potentially reach all node which forms the network. For the aim of minimizing route discovery overhead the authors of O-DSR [3] proposed list construction mechanism to limit the number of route discovery packet to be broadcasted.

The authors that proposed O-DSR does not take into account the stability of the path when forming the list to sub divided the network into different branch and does not consider the node which can be reached via different alternative paths. We are going to modify the existing DSR protocol by forming cluster which has been proven to be efficient in terms of resource utilization. In clustering approach nodes in the network takes different responsibilities. Node can be head, ordinary and gateway. We also consider the energy of nodes while giving the node some responsibilities. If a node is selected as a gateway, there might be the chance of being over utilized. Since nodes in MANET are battery operated, we need to utilize their energy in an efficient manner to boost the network lifetime by distributing tasks among gateways which connects the same pair of cluster heads.

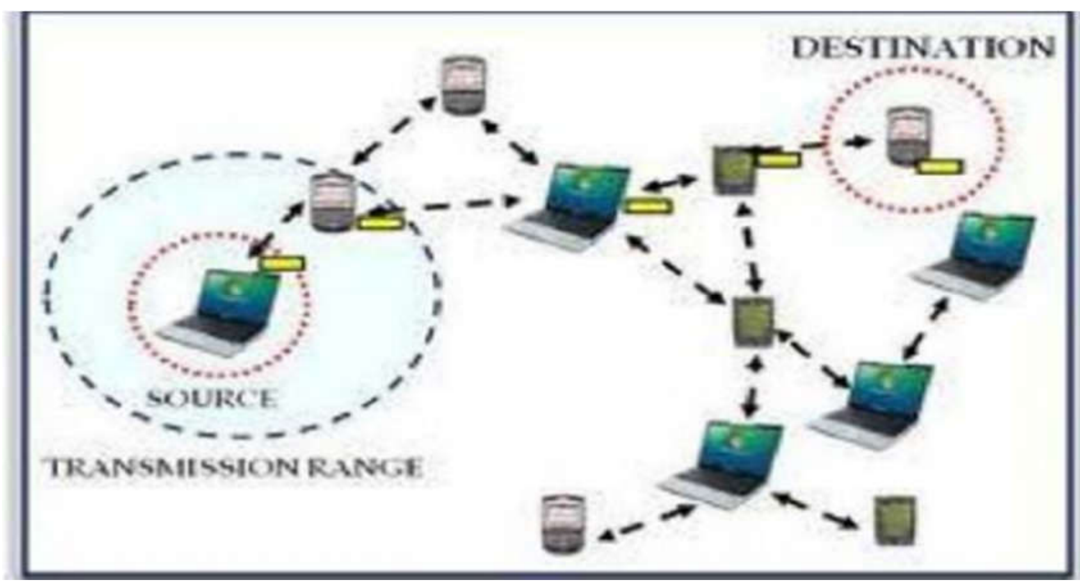

Figure 1.1: MANET WORKING [7]

1.2 Statement of the Problem

Reactive routing protocols generally discover a routing path only when it is needed so that the source node takes time to discover the path to reach the desired destination before sending the actual data packet. Several works have been done on this area to reduce route discovery operation which is taking place when no route is found to the destination to find path.

The main problem in MANET occurs at the route discovery phase, in the route discovery phase to find out all the routes from source to destination. In conventional on demand routing protocol, the node which needs to discover the route should broadcast the Route Request packet (RREQ) packet to all the neighbors which are in that node's transmission range in the network. The receiving nodes blindly rebroadcast that Route Request packet (RREQ) until it discovers the route to the destination. This broadcasting is known as blind flooding [12].

In the case of no route is found from source to the destination, the source node broadcast RREQ packets to discovery route(s). This technique is costly for bandwidth limited wireless networks. Though DSR uses controlled flooding to discover routes, its performance starts to drop as more and more number of nodes join the networks, i.e., traffic overhead significantly increase with the size of network and node mobility. Node Mobility is also the other major factor for the poor performance of DSR. On the other hand, DSR is an ideal protocol for small size networks and for relatively static networks. In these scenarios, DSR outperforms AODV and other reactive routing protocols. One of the features introduced in DSR is caching multiple routes for each destination node. This greatly reduce traffic overhead which is happen during route discovery provided that size of network is small and node mobility is low. The performance of DSR is sensitive node mobility, i.e., all the cached routes become stale in the presence of even modern mobility. As a result, nodes launch route discovery using flooding. Which in turn increase overhead on the protocol.

So, is there any better mechanism other than flooding that we can use for DSR protocol during route discovery? In other word, which routing technique enable DSR protocol work better in presence of mobility?

Hence, we proposed this work to answer this research work.

DSR routing protocol uses route caching strategy to save the discovered routes to be used for future use. The goal is to reduce the overhead due to route discovery.

As nodes in Mobile Ad hoc networks have limited resources like bandwidth, energy, it is important to utilize them efficiently. As the control packet flooded to the network minimizes, the performance of the network increases. To reduce routing overhead during route finding, we are going to form cluster in the network. After the cluster is formed, only some set of nodes can process and forward the route request packet generated until the destination is found.

1.3 Objectives

1.3.1 General Objective

The main objective of this thesis is to enhance DSR protocol using clustering algorithm.

1.3.2 Specific Objectives

To make the general objective possible, the following specific objectives should be performed.

- Reading a survey and identifying the problem that exists in the existing protocols.
- Selecting the performance metrics to evaluate the protocol.
- Designing an algorithm for cluster formation.
- Selecting simulation software which is more appropriate.
- Implementing the proposed work using the simulation software selected.
- Examining the proposed work using different performance metrics to see whether the proposed work improves the existing work.

1.4 Methods

We use a methodology to achieve our general and specific objective. The research method used for our thesis consists of three key components: a literature survey and a critical analysis of the related work, simulation and an evaluation of the proposed solutions.

1.4.1 Literature Review

We need to study literatures related to our area of study to have a clear understanding about the area and be able to fill the gap identified. We need to read different materials like journal papers, books, articles and other related materials. The major task here is studying the work done before on DSR routing protocol with different improving technique.

The literature review forms a key starting point for research it does not terminate once the research transitions into the next phase, the design phase. Surveying the relevant literature is a key component of the research method. The literature is regularly reviewed throughout the duration of our research, with newly published work taken into consideration where necessary.

1.4.2 Design of model

We need to design a model or an algorithm to improve the existing work after reading literatures and other materials which are relevant to our study.

1.4.3 Simulation

To evaluate our work in comparison with the existing one we need to know suitable simulation software. We need to read about the simulation software we are going to use to simulate our work. We need the following simulation tools to support our work with simulation.

- Ns2 simulation tools
- TCL scripts writing code
- AWK scripts to generate result of different metric
- Nam used to display graphical representation

1.6 Scope (Limitations and Delimitations)

The scope of this study is to improve the existing DSR routing protocol in MANET. To achieve our goal, we will use passive clustering algorithm by taking energy and distance parameters into consideration. Reducing routing overhead is the major task of this thesis. Security issues are out of the scope of this study. For this study nodes are assumed to be trusted and willing to give the service of forwarding data packets addressed to some other nodes.

1.7 Application of Results

In recent times, Mobile Ad hoc networks become very vital for our day to day activities. It is basically necessary in the situation where installing infrastructure is impossible like military. Which also allows different users to share information without the need of deploying infrastructure. Improving the protocols used is necessary to give better service for the user of mobile devices. The proposed work increases the network lifetime by reducing the number of routing request packet broadcasted during route finding to the destination. Reducing routing overhead can potentially save mobile node's energy consumption. Since the proposed work enables the network stay stable, the packet delivery ratio will increase.

1.8 Thesis organization

Our thesis consists of six chapters. The first chapter describes general overview about the area, statement of the problem, objective, scope, significance and methodology used. Chapter two consists of the description of what MANET is, characteristics and challenges in MANET. It also covers description of basic proactive and reactive routing protocols with their respective advantage and disadvantage. It also describes about clustering algorithm available in MANET for use. Chapter three describes works that has been done before which is related to what we are doing in our thesis. Chapter four gives the architecture of the existing routing protocol and the modified routing protocol. It also gives detailed description of each components of the architecture. Chapter five provides implementation details of the proposed routing protocol. It also gives results in comparison with the existing routing protocol. Chapter six gives conclusion of what we have done in our thesis and recommendations.

Chapter Two: Literature Review

2.1 Overview

The technological advancement of mobile devices such as laptop, cellphones and the like has increased the popularity of wireless network. Wireless network classified into two broad categories as infrastructure based and infrastructure less network. One of the major types of wireless networks is Mobile Ad hoc networks (MANET) which is infrastructure less wireless network that is formed on the fly.

A Mobile Ad hoc NETwork (MANET) [4, 5,15] is a collection of wireless mobile nodes which works cooperatively without central administrator. All nodes are free to move about arbitrarily. Nodes configure themselves. In other word, it is a collection of independent mobile nodes that can communicate to each other via radio waves. Each node has its own transmission range which defines how far it can communicate without the need of intermediate nodes. Let us consider two nodes, source node and destination node. If the source and destination are in each other's communication range, they can communicate directly. If they are not in each other's transmission range, they need intermediate nodes to be able to communicate. They use wireless channel to communicate.

In MANET, each node acts both as router and host. The topology of network may also change rapidly. The mobile behavior of mobile nodes in MANET caused topology change. Frequent topology change makes routing difficult in Mobile Ad hoc Network. Thus, routing algorithms should adapt quickly to the topology change to be effectively working in such kind of network. The growth of wireless networking have made MANETs a popular research topic. Since nodes are battery-powered, it is very important to use this resource as effectively as possible to reduce battery drainage problem. Nodes can be any device with the capability of receiving and forwarding data packet like cellphones, PDAs and laptop.

2.2 Characteristics of MANETs

According to Aarti and Dr. S. S. Tyagi [15], MANET basically has the following features:

Distributed operation: There is no central administrator in mobile ad hoc network so that tasks or operations are distributed among nodes in the network. As no central controller is available in mobile ad hoc network, nodes need to work together to make the communication possible.

Multi hop routing: Mobile ad hoc network basically uses multi hop approach to make nodes which are not in each other's communication range to communicate.

Autonomous terminal: In mobile ad hoc network, nodes can act as a host and router independently. Each node has the capabilities of forwarding and receiving packets.

Dynamic topology: Due to node's mobile behavior in mobile ad hoc network, topology changes more frequently. Nodes form network on the fly. Nodes can join and leave the network without any restriction. This dynamic behavior makes routing difficult. Therefore, routing protocols need to be good enough to adapt the topology change quickly.

Light-weight terminals: Nodes in mobile ad hoc network have limited resource. They work with limited power. They have also limited storage and less CPU capabilities. Therefore, routing protocols should be efficient in utilizing the limited resources of nodes.

Shared Physical Medium: Nodes in mobile ad hoc network use wireless communication medium. Any node with required equipment can access the wireless communication medium which results in interference.

2.3 Advantages of MANETs

The advantages of an Ad hoc network [15] include the following:

- Users of mobile nodes can exchange information regardless of where they are. At the time when infrastructure is not available, ad hoc network can be formed among mobile nodes.
- Independence from central network administration. Self-configuring network, nodes are also act as routers. Less expensive as compared to wired network.
- Scalable: accommodates the addition of more nodes.
- Improved flexibility.
- Robust due to decentralize administration.
- Network can be formed among mobile nodes whenever required.

2.4 Applications of MANETs

According to [15], some of the typical applications include:

- **Military battlefield:** In battlefield most of the time installing infrastructure based network is not that easy. Therefore, ad hoc network is the best solution as it does not require infrastructure. Ad hoc network can be formed between armies and exchange information regardless of the environment.
- **Collaborative work:** MANET is also used for business meeting. Regardless of the place where business partners meet, they are able to exchange information among them. The way to share information will not be their issue when they plan to meet somewhere to business ideas.
- **Local level:** We can also form mobile ad hoc network to share information in class room or conference. We do not need to have infrastructure-based network to exchange information.
- **Personal area network and Bluetooth:** It spans small area, mobile devices which are in short-range to each others can establish network among them. For example, nodes can connect to each other via Bluetooth to share information to each other.
- **Commercial Sector:** The required infrastructure may not be available where an accident happened. During this time ad hoc network can be utilized for disaster relief operations. Some of the disaster that can happen are fire, flood and earthquake.

2.5 Challenges of MANETs

Some of the challenges of MANETs [15] are:

Dynamic Topology: its dynamic nature results in route changes and packet loss.

Limited bandwidth: In general, wireless networks have limited bandwidth which results in poor performance compared to wired network.

Hidden terminal problem: This problem occurs when two nodes which are not in each other's transmission range want to send to the receiver which is in the transmission range of sender nodes.

Mobility-induced route changes: As mobile ad hoc network is dynamic in nature, it brings frequent path breakage which in turn results in frequent route change. As routes change more frequently, packet loss will increase.

Energy constraints: as network mobile nodes are battery powered delivering a data packet to the intended destination for the extended amount of time is a challenging issue in mobile ad hoc network.

Security threats: As nodes in mobile ad hoc network uses multi-hop approach to reach the destination which is not directly reachable, it results in security issue. There are different security issue for example, flooding attack. Flooding attack floods nodes in the network unnecessarily that makes the network performance very poor. Some nodes my not be also willing to forward packets.

2.6 Routing and Routing Protocols in MANETs

Routing [17] is the act of moving information from a source to a destination in an internetwork. Routing protocol firstly finds the path to reach the destination from the source and then route packets with the path obtained.

A routing protocol [5] is needed whenever a packet needs to be transmitted to a destination via number of nodes and numerous routing protocols have been proposed for such kind of ad hoc networks. To find a route for packet delivery and deliver the packet to the correct destination these protocols are used. Routing protocols consider different criteria to identify the optimal path for transferring data packets to the destination. There are different mechanisms used to select the best path to route packets, some of them are number of hops, mobility and energy. The studies on many functionalities of routing protocols have been an active area of research for many years. Basically, routing protocols can be classified into two types as proactive and reactive routing protocols.

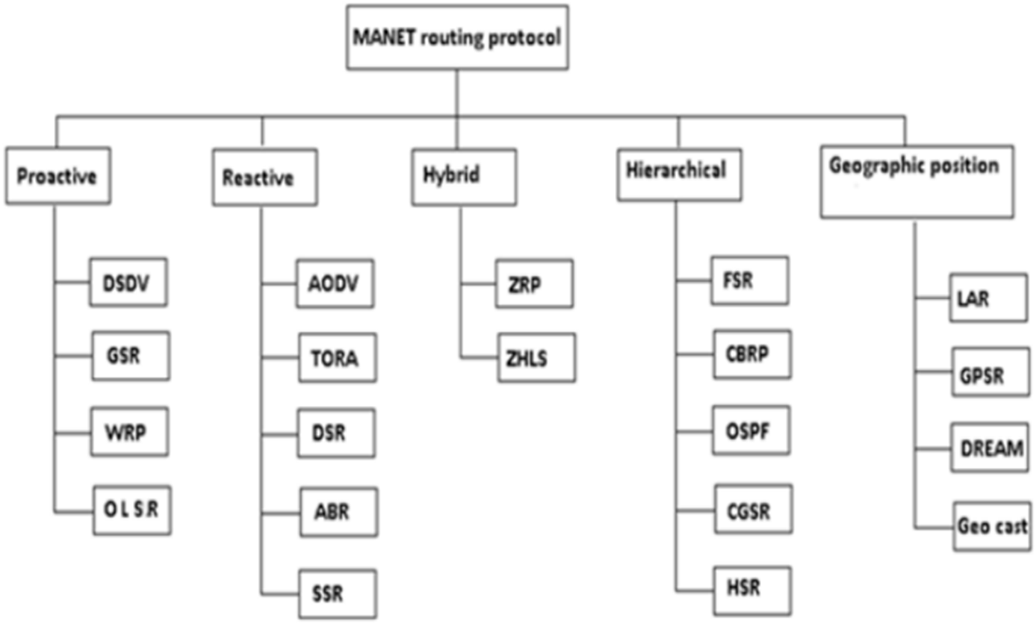

Figure 2.1: Classification of routing protocols [35]

2.6.1 Proactive routing protocols (Table driven)

Table Driven or Proactive Protocols [5]: Each node stores routing information which allows to reach every nodes in the network. Nodes keep updating their routing information to have the recent view of the network. Whenever an update occurs, nodes of the network sends a broadcast message to all nodes and then, each node refreshes their routing information stored in their routing table [18].

As routing packet is exchanging every time in proactive routing protocol to have the newest path to every nodes, its routing overhead is higher as compared to reactive routing protocol. There is no latency for setting up a route when there is a packet to be sent since every possible route is available whenever needed.

Destination Sequenced Distance-Vector Routing Protocol (DSDV) [20] and Optimized Link-State Routing (OLSR) [21] are the two commonly used proactive routing protocols.

2.6.1.1 Destination Sequenced Distance Vector routing (DSDV)

Destination Sequenced Distance Vector routing protocol modifies Routing Information Protocol (RIP) and brings it to mobile ad hoc network.

Destination-Sequenced Distance-Vector (DSDV) [24] is a proactive routing protocol in mobile ad hoc networks which uses bellman-ford algorithm. Every node in the network has a routing table which stores destination and number of hops needed to reach the destination. Besides, it stores the sequence number together with number of hop and destination which enables the node to send information using the freshest path. At the time when destination sequence number of routes are the same, their hop count will be considered to choose the one with lowest number of hop to reach the destination. Update packets are periodically propagated throughout the network. Receiving nodes of the update packet updates their routing table based on the routing information that it gets from its neighbor. In this fashion, all nodes of the network can get the updated information. DSDV basically utilizes two ways of updating routing information such as full-damp and incremental. Incremental update packet is the update procedure that propagates the only changes after the last full update. Full damp update packet propagates all the routing information throughout the ad hoc network. Mobility of nodes in ad hoc network results in link breakage which in turn initiates an update packet to be propagated throughout the network. It adds sequence number to the existing routing information protocol. The sequence number added helps to identify the freshest route and avoid the routing loop [19].

2.6.1.2 Optimized Link-State Routing (OLSR)

Optimized link state routing [22, 23] is one of the most commonly used proactive routing protocol. Its overhead is high as update packet is propagated whenever a change is noticed. Multi Point Relays (MPRs) is used to reduce the number of control packets transmitted. Only nodes which are selected as a relay are allowed to forward control packets so that number of nodes to be flooded with control packets are limited. The purpose of MPRs is to reduce the overhead introduced to the network while updating routing information. When the link on the way to the destination broken, the source node does not come to know immediately. The source node knows that the link is broken when the relay node sends out the next broadcast message. As optimized link-sate routing protocol has flat structure, each node acts in the network in the same fashion. No central administrator is required. This protocol is best fit for the network with high density. The drawback of this protocol is the need of transmitting update packets periodically which utilizes bandwidth improperly. To overcome this problem, multi point relays are used to minimize the nodes which can forward further the received routing information.

2.6.2 Reactive (On demand) routing protocols

On Demand or Reactive Protocols: Routes are constructed on demand by flooding the network with route request packets. The major disadvantage of reactive routing protocol is that it introduces high latency time in route finding since the route is discovered when needed. The route obtained is used until the route is not needed anymore. Some of the on-demand routing protocols are listed as follows: DSR [8], [9], AODV [4], [5], TORA [13], [12].

2.6.2.1 Ad hoc On-Demand Distance Vector Routing (AODV)

One of the benefits of Ad hoc On-Demand Distance vector routing protocol [23] is that routes are constructed when needed. It uses destination sequence number to identify the newest path to the particular destination. Both unicast and multicast packet transmission is possible in AODV routing protocol. It adapts to the topological changes quickly and only nodes that has been affected needs to be updated by using RRER message. It utilizes hello message to keep routes up-to-date and propagated periodically in the network. The drawback of AODV protocol is that route request packet is getting received by all nodes which are in the transmission range of the sending node. Routes become stale after a certain time period, determining the optimal expiry time is a difficult task in this protocol. The reason behind the difficulty of determining the optimal expiry time in AODV routing protocol is that nodes in Ad hoc network are dynamic in nature and have different mobility speed. Its performance getting low as the size of the network increases. It has both route discovery and route maintenance phases. Route discovery phase is used to find the route to destination incase no route is found to the desired destination. Route maintenance phase used to detect the changes in the network and act accordingly to update routing information's.

2.6.2.2 Dynamic Source Routing (DSR) protocol

Dynamic source routing (DSR) protocol is one of the most commonly used reactive ad hoc routing protocol which utilizes source routing technique. Source routing means the source (originator) node puts nodes along the path to destination in the packet header explicitly. The receiving node simply looking at the packet header to determine where to forward the received data packet. No need to have stored route to be able to forward data packets.

Every packet in DSR [6] contains nodes required to reach the destination from the source. It not effective as the network size is large as too much control packets flooded in the network which consume much of the bandwidth. As nodes in ad hoc networks have limited bandwidth, the protocol must use it efficiently. DSR protocol uses cache to store routes for future use. Nodes first check their cache if there is a path to destination before sending out route request packet to find route to destination so that route discovery overhead can be reduced via this introduced feature in DSR. The problem occurred during nodes mobility is high as the route stored in the cache become stale fast which in turn requires new route discovery operation. Having initiated new route discovery increases routing overhead. In low mobility environment using cache is efficient as the path can be usable for longer period of time. It does not require periodic routing information exchange. This feature helps to utilize the available bandwidth in an efficient manner. In DSR protocol nodes utilize route discovery and route maintenance phase to be able to communicate each other.

2.6.2.2.1 Route Discovery

This phase of DSR protocol is required to get the path to the destination at the time when no route is available to route packets towards the destination. Nodes having data packet to be sent initiates route discovery phase by preparing route request packet to be broadcasted to all nodes in the transmission range and also all the receiving nodes re-broadcast the route request whenever it has not passed through it before. Every packet includes unique identifier, source node and destination node. Nodes receiving route request checks their route cache to determine where route to the specified destination in the route request destination field available. If route available in their cache, it prepares a route replay packet and unicast to the source of the route request. The second condition that route reply is prepared and unicast is when the route request packet is received by the destination node. Each node in the network adds their address when forwarding to nodes in its transmission range. The packet header length increases as the network size increases unlike AODV routing protocol.

2.6.2.2.2 Route Maintenance

DSR protocol uses route maintenance phase to detect if error happened during communication taking place between the source and destination nodes. As nodes are mobile communication link broken in the path to destination. At the time when link is failed or broken somewhere along the path, DSR tries to use packet salvaging mechanism before attempting to announce the source node the broken link. Packet salvaging feature of DSR routing protocol checks whether an alternative path is available when link broken. If alternative path exists to the destination, it utilizes the alternative path obtained rather than announcing the source about the failure. This feature reduces route discovery overhead during failure in the path happened. It tells the source node at the time link failure happened and alternative path to the destination is not available. After the source node come to know the link is failed via route error packet used in route maintenance, it initiates another route discovery operation. All the path in the cache having the broken link will be removed from the cache.

2.6.2.2.3 Advantages of DSR

- Routes needs to be up-to-date between nodes which are communicating so that overhead introduced to the network to maintain the path will be reduced.
- Route cache feature is introduced which can minimize routing overhead.
- Nodes can reply from their cache, which enable the node has more than one route to the destination.

2.6.2.2.4 Disadvantages of DSR

- As nodes in the network appends their address when forwarding route request packet, packet header increases as the network size increases due to its source routing nature.
- As DSR protocol utilizes blind flooding to obtain path to destination, more likely every nodes in the network can be flooded with the route request packet generated by the source node. It is costly for network type which is bandwidth and energy limited.
- Collusion happened as no boundary in wireless communication between nodes
- Routes stored in the cache become stale when mobility of nodes become high which in turn initiates new route discovery operation.

2.6.2.2.5 Optimization

Optimization techniques have been implemented to the DSR routing protocol [25] to make it effective. The following are some of the optimization techniques applied.

Data Salvaging: Link failure happened more often in the network which is dynamic in nature, data salvaging technique try to route a packet via alternative routes in the cache to minimize route discovery overhead.

Gratuitous Replies: At the time when packets are transmitted between source and destination, the node listen to the transmission and knows that packets can be transmitted through it to make routing efficient announces the source node via using gratuitous replay packet.

Route Snooping: When the node which listens the data transmission between source and destination detects that the route in the packet header is not available in its cache, stores it in its local cache to use it sometime in the future.

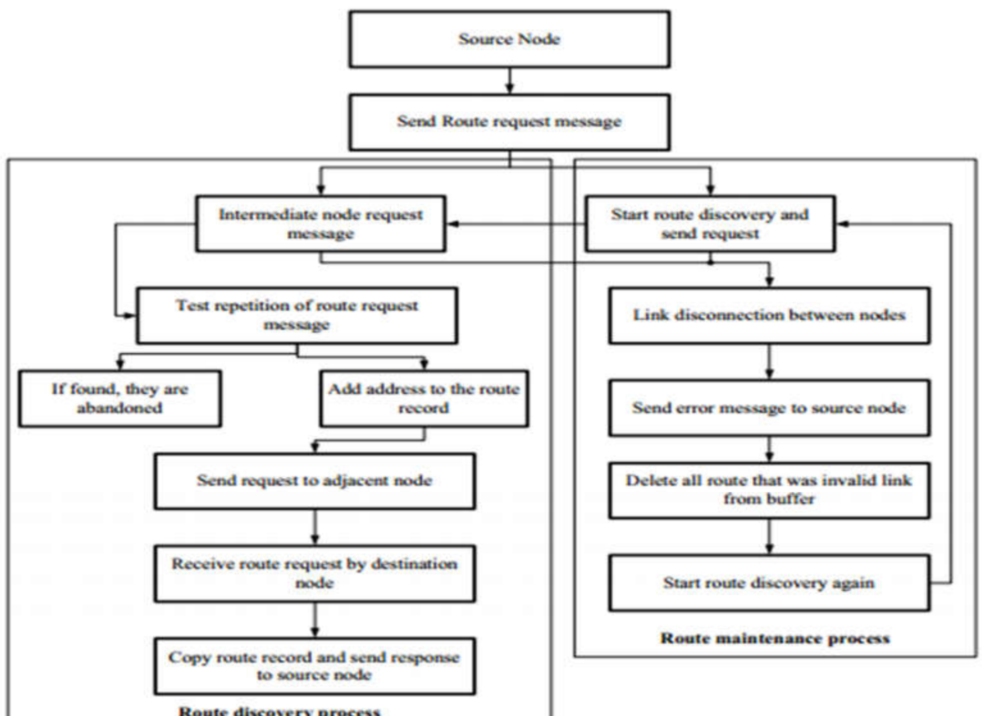

Figure 2.2: General architecture of DSR routing protocol [33]

2.6.2.3 Temporally Ordered Routing Algorithm (TORA)

It is a source-initiated on-demand routing protocol [34], which utilizes link reversal algorithm and gives loop-free multipath routes to a target node. In this protocol, each node stores its one-hop away topology information. It is capable to function in a highly dynamic networking environment. Control messages is sent to only some nodes near the occurrence of topological change so that number of control messages sent to the network is minimized.

The protocol performs route creation, route maintenance and route erasure. At the time of route creation and route maintenance phase, nodes use height metric, which establishes a Direct Acyclic Graph (DAG) rooted at the destination.

2.6.3 Hybrid routing protocols

Hybrid routing protocol uses both reactive and proactive routing protocol together in combination. It takes the advantage of both reactive and proactive routing protocols.

2.6.3.1 Zone Routing Protocol (ZRP)

The Zone Routing Protocol (ZRP) is one of the most commonly used hybrid routing protocol. It uses proactive approach to maintain routing information about its region or zone. Therefore, when the destination is within the zone of the source node, it will available right away. The source node uses reactive approach for the destination which is not in its zone so that routes are not available right away. The given network gets divided into different logical zones so that it becomes more efficient as the network size increases [27].

2.6.4 Clustering approaches in Ad hoc networks

Different kinds of clustering schemes have been proposed for Ad hoc routing protocols. Clustering [26] is an important technique to divide the large network into several sub networks. Clustering provides several benefits in MANETs. Some of them are: Efficient resource allocation, enhances process of routing and stabilization of dynamic network topology due to mobility of nodes. Some of the commonly used clustering algorithms are:

2.6.4.1 Lowest ID Cluster algorithm (LIC)

In this clustering algorithm each node is assigned a unique id. The node which has lowest ID chosen as a cluster head. Each node periodically broadcast nodes in its transmission range in addition to itself. After a node is assigned an ID, its id does not change so that once lowest ID is given to a node, that node more likely chosen as a cluster head. Therefore, Nodes with lowest id are prone to power drainage due to serving as a cluster head for long period of time.

2.6.4.2 Highest Connectivity Clustering algorithm (HCC)

In this algorithm each node must be aware of its own neighbor (the node in its transmission range). Degree of node’s connectivity is determined by the number of neighbors that a node has. The node which has maximum number of neighbors is chosen as a cluster head. Cluster head does not change very frequently, but throughput is low.

2.6.4.3 Mobility Based Metric for Clustering

In this clustering algorithm the node with low speed compared to its neighbor becomes a cluster head. As node have different mobility speed in different direction, grouping them according to their mobility and movement direction minimizes frequent path breakage. Thus, a selected cluster head can normally promise the low mobility with respect to its member nodes. However, as nodes move in random fashion, the performance of the network may become low.

2.6.4.3 Power-aware clustering

Nodes in mobile ad hoc networks are battery operated, so we need to use their energy efficiently so as to increase the network lifetime. Therefore, nodes compute to be a cluster head based on their residual energy and also other metrics might be considered together with it. Each of node aware of residual energy of other nodes and its own.

2.6.4.4 Passive clustering

Passive Clustering (PC) protocol is a resource efficient way of clustering nodes in the network in which nodes have limited resource like bandwidth and energy. PC constructs and maintains clusters using on-going data packets instead of extra explicit control messages where as active clustering uses explicit control packets to construct and maintain the cluster formed so that it introduces additional control overhead. Nodes states in this clustering scheme are initial, head_ready, cluster-head, gateway and ordinary. Once the cluster is formed only some set of nodes participate in forwarding route request packet generated by the source node to get path to destination. It is an energy efficient mechanism to partition the given network into groups.

2.7 Categorization of mobility models

Mobility models are basically divided into two categories such as traces and syntactic models [36]. Traces are those mobility patterns that are observed in reality systems. Traces provide accurate information, especially when they involve an oversized number of participants and an appropriately long observation period. However, new network environments (e.g. ad hoc networks) aren't easily modeled if traces haven't yet been created. During this sort of situation it's necessary to use synthetic models. Synthetic models try and realistically represent the behaviors of MNs (Mobile nodes) without the utilization of traces. During this paper, we present several synthetic mobility models that are proposed for (or used in) the performance evaluation of ad hoc network protocols. A mobility model should try and mimic the movements of real MNs. Changes in speed and direction must occur and that they must occur in reasonable time slots. For instance, we'd not want MNs to travel in straight lines at constant speeds throughout the course of the complete simulation because real MNs wouldn't travel in such a restricted manner.

There are a number of mobility models that have been proposed for mobile ad hoc network protocols for performance evaluation. The two most commonly used mobility models are Random Walk Mobility Model and Random waypoint Mobility model**.**

2.7.1 Random Walk Model

In this mobility model, an MN (Mobile Node) moves from its present location to a brand new location by randomly choosing a direction and speed within which to travel. The new speed and direction are both chosen from pre-defined ranges, [speedmin, speedmax] and [0,2π] respectively [37]. It is used to model random movement of mobile nodes. In ad hoc network nodes move with random speed and direction so that that this mobility model is used to model this nature of mobile nodes. Upon reaching its chosen destination, new destination will be chosen randomly.

The Random Walk Mobility Model could be a memoryless mobility pattern because it retains no knowledge concerning its past locations and speed values [38]. The present speed and direction of an MN is independent of its past speed and direction [39]. This characteristic can generate unrealistic movements like sudden stops and sharp turns.

2.7.2 Random waypoint Model

The Random Waypoint Mobility Model includes pause times between changes in direction and/or speed [40]. An MN (Mobile Node) begins by staying in one location for a specific period of your time (i.e., an intermission time). Once this point expires, the MN chooses a random destination within the simulation area and a speed that's uniformly distributed between [minspeed,maxspeed]. The MN then travels toward the newly chosen destination at the chosen speed. Upon arrival, the MNpauses for a specified period before starting the method again. We note that the movement pattern of an MN using the Random Waypoint Mobility Model is comparable to the Random Walk Mobility Model if pause time is zero and [minspeed, maxspeed] = [speedmin, speedmax]. The Random Waypoint Mobility Model is additionally a widely used mobility model. Additionally, the model is typically simplified. As an example, [41] uses the Random Waypoint Mobility Model without pause times. In this mobility model setdest tool could be used to specify the destination and speed at which mobile nodes move towards the specified destination.

2.7.3 Gauss-Markov Model

In this mobility model the movement of entities are initially assigned with the required speed and direction by the developer at fixed interval of your time, updated time and direction is configured for the nodes for each steps. In Gauss Markov Model if the nodes/entities are moving outside of the range, they quite their movement and also the node selects a brand new destination and start to move towards to the destination [42].

2.7.4 A Boundless Simulation Area Model

In this mobility model, a correlation between the previous direction of travel and velocity of an MN with its present direction of travel and velocity exists [43]. The Boundless Simulation Area Mobility Model is additionally different in how the boundary of a simulation area is handled. Within the above-mentioned mobility models, MNs reflect off or stop moving once they reach a simulation boundary. Within the Boundless Simulation Area Mobility Model, MNs that reach one side of the simulation area continue traveling and reappear on the other side of the simulation area. This system creates a torus-shaped simulation area allowing MNs to travel unobstructed.

Chapter Three: Related Work

Many research works have been implemented in Mobile Ad hoc NETworks (MANETs). In this section we discuss works done before which are more likely related to my thesis.

According to Stojmenovic I and Lin X., [29], the authors adds residual energy of nodes as a parameter to improve the existing dynamic source routing protocol. Nodes with residual energy greater than the threshold value are allowed to forward the received route request packet else the packet simply dropped. Even there is a node with lower residual energy than the threshold value along the route, the route request packet is dropped. At the time when the route request originator cannot receive the route reply after a certain timeout period, the source node reinitiate the route request by minimizing the threshold value besides it advances the sequence number so that when the neighbor nodes receives the same request packet with increased sequence number, they simply adjust the threshold value and start forwarding based on the newly set threshold value.

The main drawback in this improved routing protocol is the routing overhead introduced when route replay is not received by the source in the timeout period. When many nodes in the network has a minimum residual energy compared to the threshold value, the source will be forced to originate too many route request packets to find the path to even a single node. Therefore, routing overhead is increased. Besides, the path obtained to reach the destination may potentially lose its power quickly as it receives too much load/traffic.

According to Mr.Vaibhav Naresh Palav and Prof. Mrs. Savita R. Bhosale [31], Energy efficient AODV protocol is proposed. The transmission power required get increased as the distance between nodes get large. As nodes in MANET consists of numbers of nodes that are operated with limited battery life, taking energy into consideration while routing is very important. Threshold level is defined for each individual node. If single node fails due to battery power failure, then whole path will get down and have to repeat routing process again which will take more time which is called as delay in reception. The route request packet which arrives at the destination has maximum sum of residual energy, because delay is inversely proportional to the residual battery power.

According to Josh Broch, *et al*. [8, 9, 10], MSR routing protocol is proposed which is based on DSR protocol. The route discovery and maintenance mechanism of DSR is extended by MSR to deal with multipath routing. The load between multiple paths is distributed based on round trip time (RTT). MSR improves TCP and UDP throughput and packet delivery ratio. It also reduces end to end delay with little overhead. MSR has three elements to achieve alternate path. These are path calculation between nodes, efficient packet forwarding on calculated paths and effective end host usage of multiple paths. This protocol achieved improved throughput, less delay and minimized drop rate.

According to Rjab Hajlaoui, *et al.* [3], presented optimized DSR routing protocol for mobile Ad hoc network. O-DSR reduces the number of routing request made during route discovery phase. It does not consider a node which can be reachable via different paths during list formation.

According to T. Jiang, *et al.* [11], Route Snooping mechanism is proposed, the node which listen to data packet and does not have the route explicitly placed in the packet's header, adds the route to its cache for future use that a node that overhears the data packet can use the routing information without the need to initiate a route discovery process when it has a packet to send.

According to Philip Necsulescu* and Klaus Schilling** [13], selecting the path from source to destination based on signal strength received is appropriate to make the network stay stable for long. When using simply hop count metric to choose the best path from source to destination, the network lifetime may become short because it does not consider the distance to its immediate neighbor.

A technique to improve delay caused due to link failure resulting in route rediscovery has been proposed in [14]. In the technique the energy levels of the nodes are computed. And in the course of a transmission whenever the energy level of the node N (likely to cause link failure) goes below a certain threshold value, it sends warning message to predecessor of N for determining an alternative route so that remaining packets can be transmitted through alternative route.

According to Meng Li, *et al.* [30], the authors have proposed multi-path energy aware DSR routing protocol. In this paper the authors tried to combine energy concept and multipath concept together to improve the existing multi-path DSR routing protocol. Number of route discovery can be minimized so that end-to-end delay and bandwidth is optimized. Nodes are serving in the network according to their battery power level to prolong the network lifetime. Using more than one path is a good approach to distribute the load in the network meaning to balance the load. The existing traditional DSR routing protocol uses single route to reach the destination so that it may causes a lot of route discovery process to be taking place. The drawback in this paper is that too much control message needs to be generated.

According to Amit Barve and Ashwin Kini [28], the authors have incorporated the concept of passive clustering into the existing dynamic source routing protocol to improve its performance. In this work lowest ID is used to resolve the conflict when two nodes declare themselves as a cluster-head at the same time. The cluster-head with lowest ID continues its role and the other one gives up its role and changes to ordinary node. The drawback here is that they did not consider other QOS metrics like energy and distance. Once the ID is given to each node, it is permanent. The node with lowest ID more likely plays the role as cluster head so that its energy drains so fast. The failure of a single node affects the overall performance of the network. At the time when a node is dead due to battery power, the path which uses the failed node become down. Therefore, new route discovery operation will be initiated which in turn increases the control overhead to find route to the destination By taking network node's energy into consideration lifetime of the network can be increased. Besides, tasks are not distributed among gateways which connects the same pair of cluster heads. We have considered energy level of nodes when compute to be head at the same time since nodes have limited battery power. In passive clustering, clustering information is exchanged appended to route request packet and data packets. Since there is no separate session for cluster formation in passive clustering, nodes are unable to detect when one of its neighbor becomes outside of its communication range. Therefore, we have also considered distance parameter to enable nodes to detect nodes which is no more neighbor node since the default transmission range of nodes in Network Simulator version 2.35 is 250m. Therefore, nodes can refresh their neighbor list accordingly.

3.1 Summery

Related works to our thesis are summarized in the table below shortly. It describes the technique used in optimizing the existing work done before.

Table 3-1: Summary of related works

Author	**Title**	**Optimization technique considered**

Stojmenovic I, Lin X	Power-Aware Localized Routing in Wireless Networks	Residual energy of the node
Amit Barve, Ashwin Kini	Optimization of DSR Routing Protocol in MANET using Passive Clustering	Clustering, but it does not consider energy of nodes
Meng Li, Lin Zhang1, Victor O. K. Li, Xiuming Shan, Yong Ren	An Energy-Aware Multipath Routing Protocol for Mobile Ad-hoc Networks	Multipath and energy in combination
Rjab Hajlaoui, Sami Touil and Wissem achour	O-DSR: optimized DSR routing protocol for mobile ad hoc network	List construction to limit route request packet flooding

Chapter Four: Design of the Proposed Solution

4.1 Overview

As described in the earlier chapters, Nodes in MANET are mobile and free to move in any direction. Nodes in MANET works cooperatively means that a node needs the assistance of another node to send packet to node which is not in its own communication range. Therefore, we need to use node's resource efficiently as the node failed in the network affects the entire network lifetime. We are going to design the modified DSR algorithm. As we have mentioned, our ultimate goal is to design the modified protocol which utilizes resources effectively, in such a way that it increases the lifetime of the network by forming cluster in the network.

Mobile Ad hoc network is formed by mobile nodes like mobile phone, laptop and so on which utilizes 802.11 wireless channel to communicate each other. Since clustering nodes is our goal to enhance the working of the protocol, nodes have different responsibilities in the network. Each node has communication range. If two nodes are in the communication range of each other, they can communicate without the aid of other nodes, but when they are not in the communication range of each other they require the help of other nodes between them. We call this kind of communication multi hop since multiple nodes can be used to reach the destination. When the destination node is far from the source node communication range, the source node uses flooding to find route to reach the destination in the normal DSR routing protocol. Such flooding consumes too much resources. So, we are going to limit the flooding by forming cluster among nodes in the network.

In our modified DSR routing protocol route request packet is modified in such a way that it minimizes routing overhead. When the source node prepares route request packet when not having route in its own cache to reach the destination, the node adds additional information helping to form cluster in the given network and then broadcast to its neighbor. Those information's are node's state, energy, cluster head claim time. All nodes in the network are initial at the beginning. Once the cluster is formed only cluster head and gateway nodes participate in processing the route request packet.

In the following section the general architecture of our enhanced routing protocol is presented. We also discussed methods used to form the cluster.

4.2 Architecture of proposed solution

In the proposed solution we will form cluster in the network to minimize route request packet to be sent over the network. The architecture of the proposed solution is depicted in figure 4.1.

Route discovery process consists of router request and route replay. Our modification is done on the route request part.

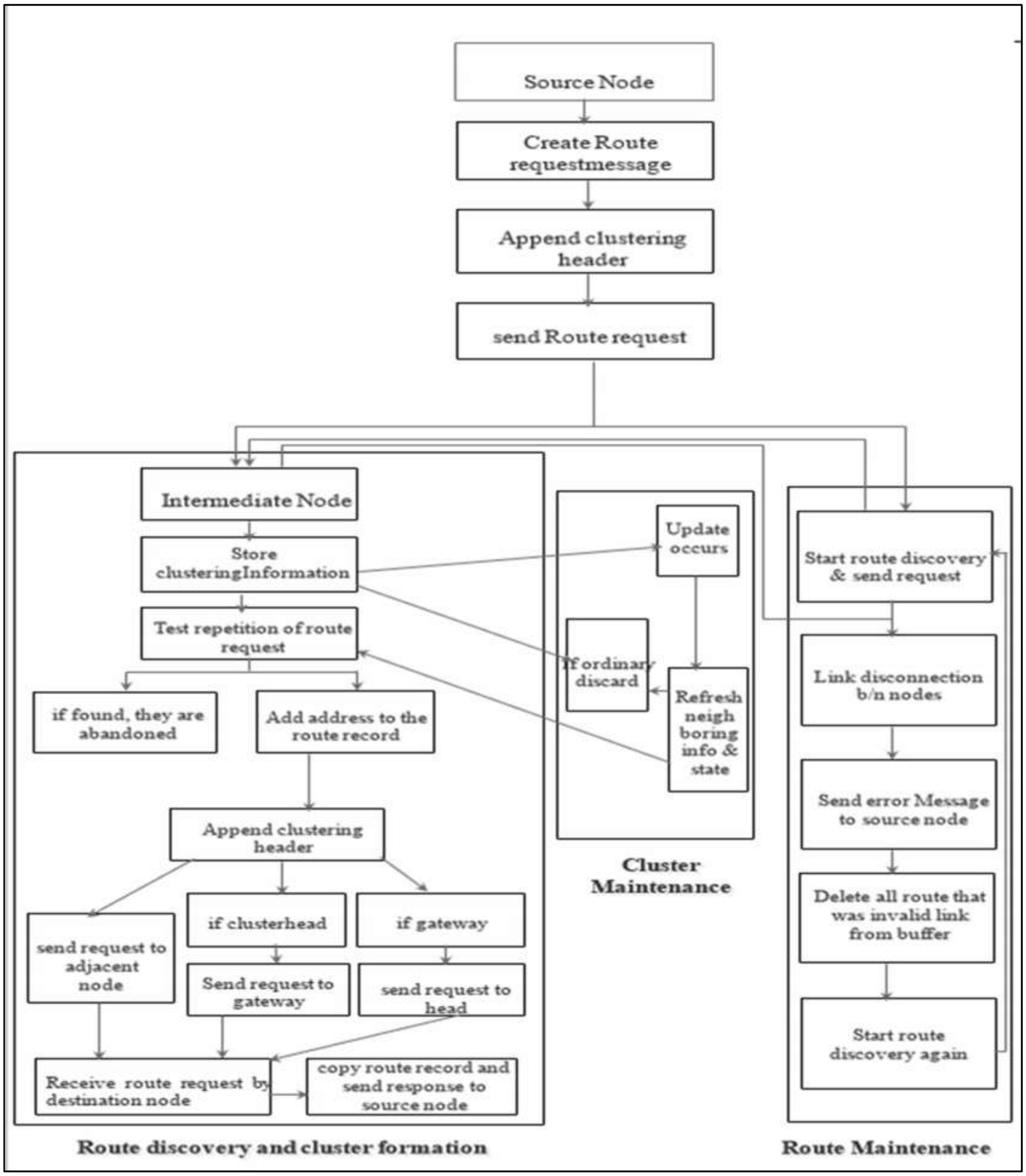

Figure 4.1: Architecture of the proposed solution

The above architecture depicts the modified routing protocol, from the components in the architecture our added components are cluster formation and cluster maintenance. Clustering information is added to route request when a node want to transmit and has no route in its own route cache. The components in the architecture are explained in the following sub section.

4.2.1 Clustering information

Clustering information's are collected when a node initiates a route request or forwarding a packet destined to a certain destination. When a node has a packet to be sent to which the path is not known, it initiates route request packet and find its own state, energy. Finally, the obtained state and energy value is appended to the route request. Initially before any network activities taking place all nodes are in initial state, meaning they are not belonging to any cluster. Clustering header is a header which consists of clustering information.

4.2.2 Cluster formation

In this section we explain how cluster is formed. Cluster formation procedure is initiated when a node broadcast a route request packet to find route to destination in case no route is found in its own cache. We use power-aware passive clustering which sends clustering information along with an outgoing data packet. Passive clustering does not require explicit control packet so that cluster formation overhead is minimized. Nodes takes one of the three roles such as cluster head, gateway and ordinary based on their resource. The head node is a representative of the particular cluster where as gateway nodes are the bridge between two cluster heads, that means they enables cluster heads to communicate. Ordinary nodes do not take part in any network activities. Each node in the network stores its own neighboring information.

Clustering nodes in the network has been proven to be more efficient than not. The algorithm we use forms clustering without explicit control packet. We explain in detail how nodes get their state.

Algorithm to form clusters

```
Source node S

IF (the node does not take part in the network activities) then

Node state becomes"initial"

ELSE

    Check its state and

    Obtain its residual energy
```

```
S sends RREQ piggybacking clustering header (consists of
state and residual energy of the node)
  IF (Intermediate node) then
    IF (receive from initial and its state is initial) then
         Node state becomes" head_ready"
    IF (receive from initial and its state is head_ready")
then
      Node state becomes" head"
    IF (node receive from head) then
       Node state becomes" Ordinary" and
     IF (node hears 2 or more heads) then
        Node state becomes" gateway"
        Calculate its residual energy
        Finally, append and propagate
        A node which claims to be head first become head
     IF (more than one node claim to be head at the same
time) then
      One with highest energy will take the role
IF (Destination)
                    Call Sendroutetorequester() method and
                    unicast the route to the requester for
                    route
```

4.2.3 Cluster maintenance

Once cluster has been formed, it needs to be up-to-date and maintain the current status of neighbor in the network. Clustering information is forwarded every time a node forwards a data packet and route request so that a node can update its own list of cluster head, gateway and ordinary node accordingly. Besides, the node removes the neighbors from the list when it becomes outside of its own communication range. When more than one gateways are available between the same pair of cluster heads, we compare their energy level and if their energy level is the same, we chose the closest one. When there are passive gateways which have better energy compared to the one serving right now, will take up the role. Passive gateway is a gateway which is not serving right now and active gateway is a gateway which is serving currently.

Algorithm to maintain the cluster

```
IF (state is” ordinary” and head moves away) then
        State becomes” initial”
IF (state is” gateway” and head becomes one) then
        State becomes” ordinary”
IF (state is” ordinary” and
 head becomes more than one) then
        State becomes” gateway”
IF (More than one gateways are available
  to connect the same pair of cluster heads) then
     The one with highest energy take up the role and
     its status changed into active and the rest
     to passive
If they have the same energy level then
the closest one will take the role of serving as a gateway
IF (state is” gateway and all heads go away”) then
        State becomes” initial”
IF (state is” head” and all its neighbors go away) then
        State becomes” initial”
```

4.2.4 Improved Route Request Packet

If the node has a packet to transmit, it first checks its route cache and then if no route found to the destination it automatically initiates a route request packet and broadcast to all of its neighbor. Whenever a node receives the route request packet from its neighbor, it checks whether its address with the address specified as a destination. If the node is not a destination it simply adds their address and forward to all its next. If it is a destination, it sends the route to the originator of the packet (source node) via route replay packet which is unicasted rather than broadcasting.

In the improved route request only cluster head and gateway nodes can propagate a route request once the cluster is formed. Each time the node receives a route request, it checks its state and then decide to forward further or not to forward accordingly. If the node is allowed to forward it appends its status to route request to let the neighbor know its status. Gateway with highest energy is selected to forward if multiple gateways exist to connect the same pair of heads. Therefore, only selected nodes take the responsibility of forwarding the route request so that nodes which does not take the responsibility will not be flooded. As nodes in the network are battery operated. It is always a good approach to use their power efficiently so as to prolong the network lifetime. The network is partitioned logically to limit the number of nodes to be flooded.

Algorithm for route request

```
Source node initiates route request
  And appends clustering information
  If (intermediate node) then
        Check its state
     If (state is head or gateway) then
           Calculate its energy and
           Appends clustering information and forward
     If (state is” initial”) then
           Broadcast to all of its neighbor
     IF (state is” Ordinary”) then
```

Discard the packet

If (Destination node) then

Prepare route replay packet and

Unicast it to the originator

4.3 MANET Scenario with modified DSR protocol

Scenario one: route request of the existing protocol

4.3.1 Route request

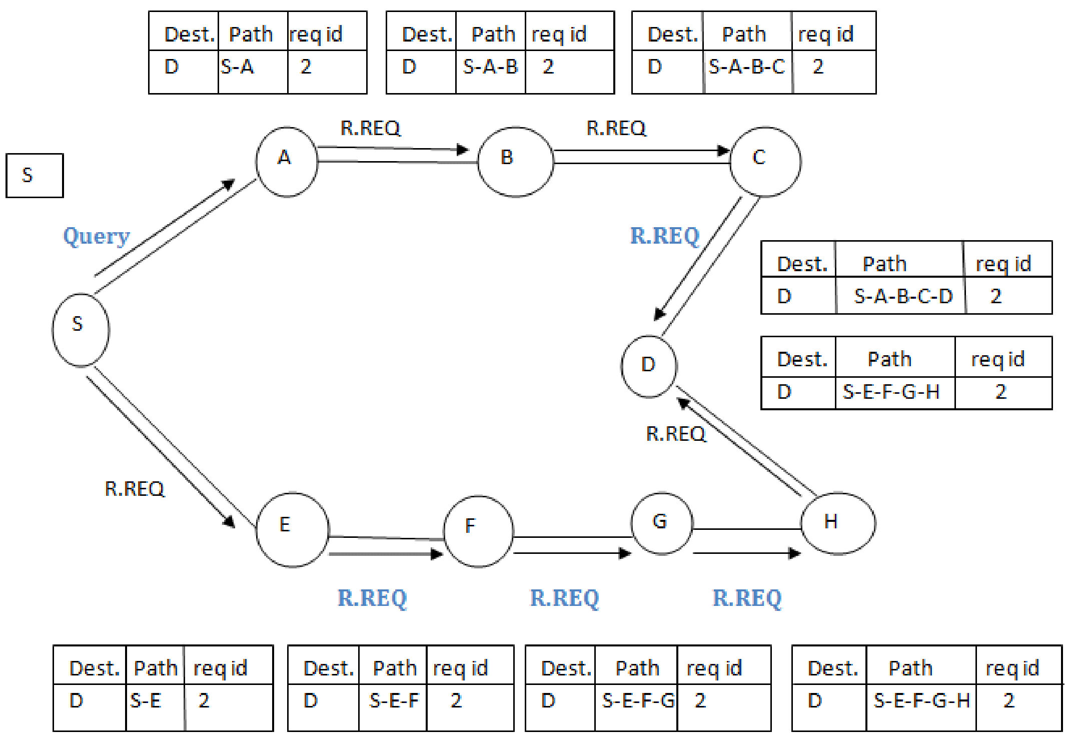

Figure 4.2: Blind flooding of route request

In the picture above node S is source node and node D is destination node. As shown in the picture above when the node receives route request it broadcast to all neighbor if it is not the desired destination or has no route to the destination in its route cache.

Scenario two: Modified route request

The modified route request is depicted by the figure given below. It shows additional information forwarded along with the existing route request format.

State of the node and energy level is forwarded each time route request is forwarded. Initially state of the node is initial.

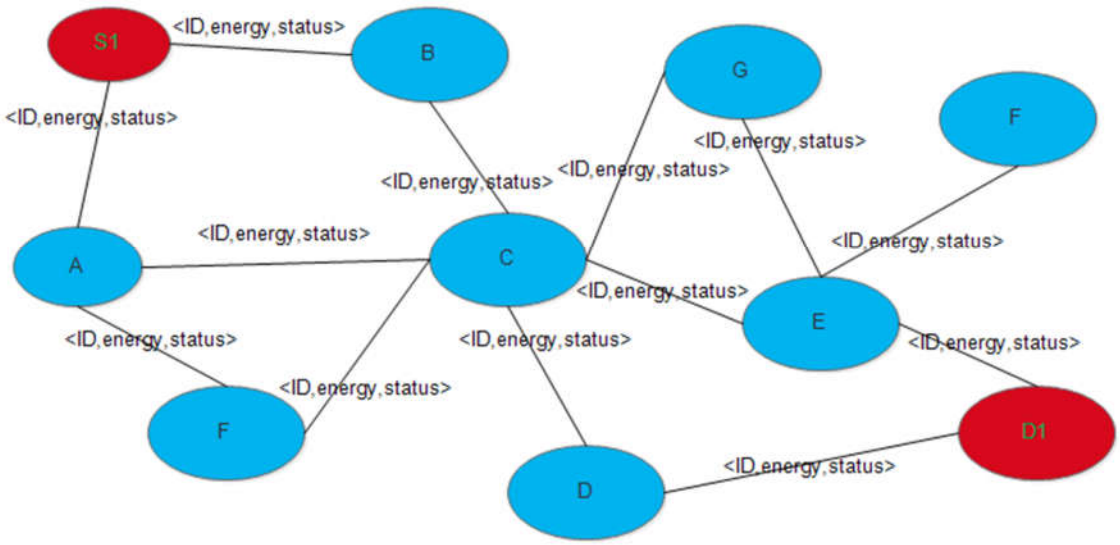

Figure 4.3: Cluster formation

In the picture above node S1 is source and D1 is destination node. When S1 initiates a route request for the first time it adds it sate as initial and calculate its residual energy level and then forward it to its immediate along with the route request initiated. When other nodes in the communication range of the source node receives the request, they need to determine their state according to the information received from the route request of the source. The mechanism that they use to determine their state is that: if their state is initial, changed into head_ready, if their state is head_ready, changed into head. If the node has state head_ready and sends out route request, it first changes its state to head before sending out. If a node receives request from two heads, its state changed to gateway. If a node receives from cluster head and its current state is initial, it changes its state to ordinary. After the cluster formed ordinary nodes do not participate in any activities of the network. If two gateways connect the same pair of heads the one with higher energy will be used to forward packet. If two nodes claim to be cluster head at the same time, the one with higher energy takes the role of cluster head.

4.4 Residual energy calculation

Nodes in mobile ad hoc network are energy constrained which makes routing a critical problem. To prolong the network lifetime, node's energy should be used appropriately. So as to prevent node from being out of battery, we have considered their energy level when giving role in the network. We have used energy model in tcl file to make the protocol works by taking energy into consideration.

```
-energyModel EnergyModel \
        -initialEnergy 100 \
        -txPower 0.5 \
        -rxPower 0.3 \
        -idlePower 0.05 \
        -sleepPower 0.03 \
```

The unit of initial energy is Joule and the rest are watt. We have considered every node has 100 joule energy. Every time the node receives a packet, it utilizes 0.3 watt of its overall energy. Every time the node transmits a packet, it utilizes 0.5 watt of its overall energy. At the time two nodes compute to be a cluster head at the same time, their remaining energy level (residual energy) will be considered. Additionally, when more than on gateways available to connect the same pair of cluster heads, the one with highest residual energy serves as a gateway, we call it active gateway and all the other nodes will be considered passive. When the residual energy level of a gateway serving right now getting low compared to the available passive gateways, the passive gateway with highest residual energy will take the role of serving as a gateway and the previously used gateway changed into passive.

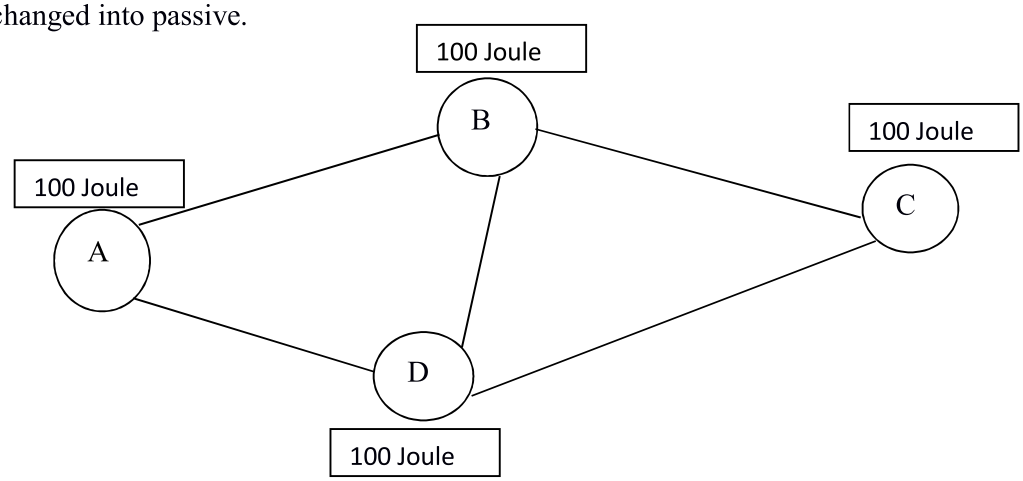

Figure 4.4: Initial energy value of nodes

Initially all nodes of the network are assumed to have 100 joule energy. Their initial energy value get decreased as packets are transmitted or received. Let us assume node A as source node and node C as destination node to illustrate how each nodes compute their residual (remaining) energy level. The following picture depicts residual energy calculation for each node when the source node sends data packets to destination node using path A-B-C (The path is assumed to be available, we did not show path finding procedure here).

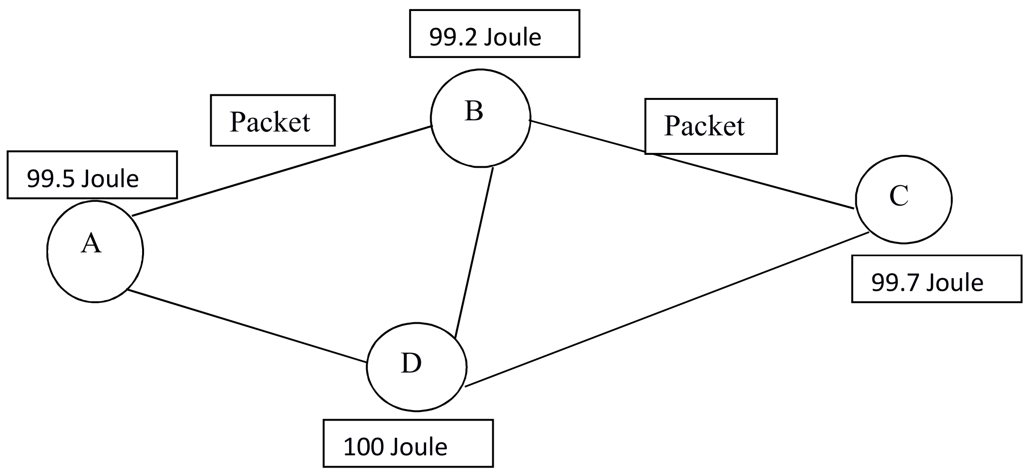

Figure 4.5: Residual energy calculation

The above picture is used to simply show how each node calculates their remaining energy when receiving and transmitting data packets. The process continues as long as packets are transmitting in the network. In the above picture node A transmits packet to node B, its remaining (residual) energy becomes its previous energy value minus 0.5 watt. Its previous energy was 100 and when we subtract 0.5, it gives us 99.5 Joule. Node B receives packet from node B, its energy becomes its previous energy level minus 0.3 watt (receiving energy) which gives us 99.7 joule. After node B receives from A and knows that it is not the destination node, it transmits to node C. Transmission energy will be subtracted from its total 99.7. Transmission energy required according to our setting is 0.5 watt. Therefore, residual energy of node B is 99.7-0.5=99.2 joule. Finally node C will receive packet from node B. Residual energy of node C is calculated as 100-0.3(receiving energy) which gives 99.7. The whole process continue as long as there is transmission among nodes of the given mobile ad hoc network.

4.5 Distance calculation

Distance between nodes is calculated based on their current position. Taking into consideration their position coordinates, distance between nodes can be computed. As nodes maintain ID of its neighbor, it can detect the current position of its neighbor easily. The position of nodes in TCL is described in three dimensional and the third dimension is always 0. The following picture depicts how each node computes the distance to its neighbor.

Distance between nodes is calculated using the following mathematical formula: Consider we have two nodes A and B with (c, d) and (e, f) coordinate respectively.

$$\text{Distance (A, B)} = \sqrt{(e-c)*(e-c)+(f-d)*(f-d)}$$

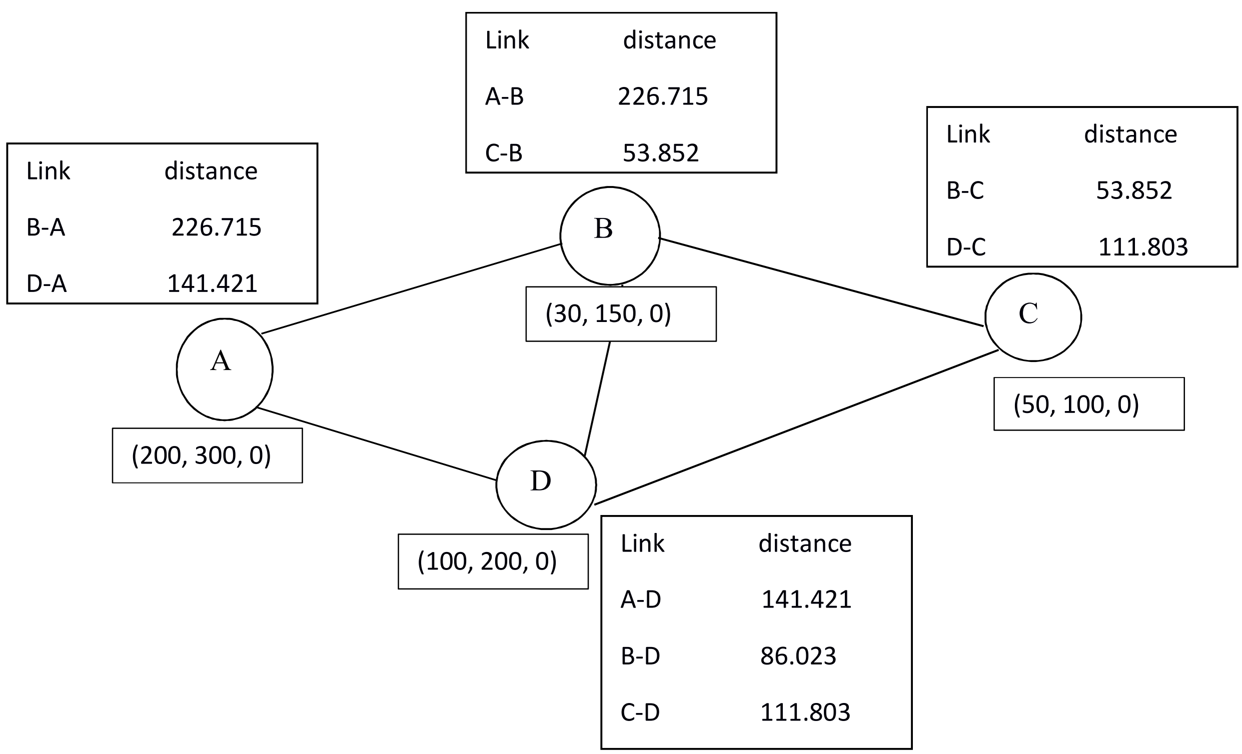

Figure 4.6: Distance calculation

As nodes in mobile ad hoc network are movable, the distance between neighbors vary over time. Therefore, nodes could leave its neighbor and join another neighbor. When a node detects that one of its neighbor is outside of its transmission range, it refreshes its neighboring information maintained.

Summary

The enhancement done on the existing DSR routing protocol has been presented in this chapter. The modification is applied on the route request part of the DSR routing protocol. Route request is simply flooded in the network without additional parameters considered due to this nature node's resource utilized improperly. We have created clusters in the network to make only some nodes takes part in forwarding the request packet so that node's resource is conserved. In clustering approach, nodes take different responsibilities unlike flat architecture in which nodes take the same responsivities. In our work nodes has either of the following states such as: cluster_head, head_ready, ordinary, gateway and initial. Ordinary nodes in the network ignore whatever they receive. Energy of nodes have been considered during cluster formation process. Energy parameter is used at the time when two nodes wants to be head at the same time and when more than one gateways connect two heads. Work load is distributed among gateways depending on their energy level so that a single gateway is not over-utilized incase other available. Therefore, network lifetime will be boosted since the failure of a certain node in the network brings disruption. The number of route request forwarded is limited as compared to the existing DSR routing protocol. The modified protocol has lists containing the status of its neighbors. The neighboring lists need to be updated to have latest information. Each time the node forward route request and data packet, updates the list according to the received clustering information. Each list has associated timer to avoid stale information from the list to make the list contains fresher information in its list. Generally, in this chapter architecture of the modified DSR routing protocol has been discussed briefly. In the next chapter implementation and performance evaluations will be explained in detail.

Chapter five: Implementation and performance evaluation

5.1 introductions

In this chapter, the way how the modified routing protocol have implemented is going to be discussed. To implement the protocol, we have used ns2.35. Network simulator version 2.35 is a discrete event driven simulation tool which is one of the best simulation tools to simulate networking researches. NS2 consists of two key languages such as C++ and OTCL. C++ is the back end of the simulation where as OTCL is the front end of the simulation which is used to configure and set up the objects as well as scheduling discrete events. TclCL is used to link both C++ and Otcl. We have prepared a scenario for our protocol using tcl. The traffic source that we have used is CBR (constant bit rate).

After simulation, results are interpreted via using AWK script. The text file generated via AWK script from trace file can be plotted with the help of Xgraph. Once the output has obtained, the next step is making a comparison with the existing DSR routing protocol. To do the comparison we have used the following evaluation metrics such as Packet delivery ratio, throughput, routing overhead and average end-to-end delay.

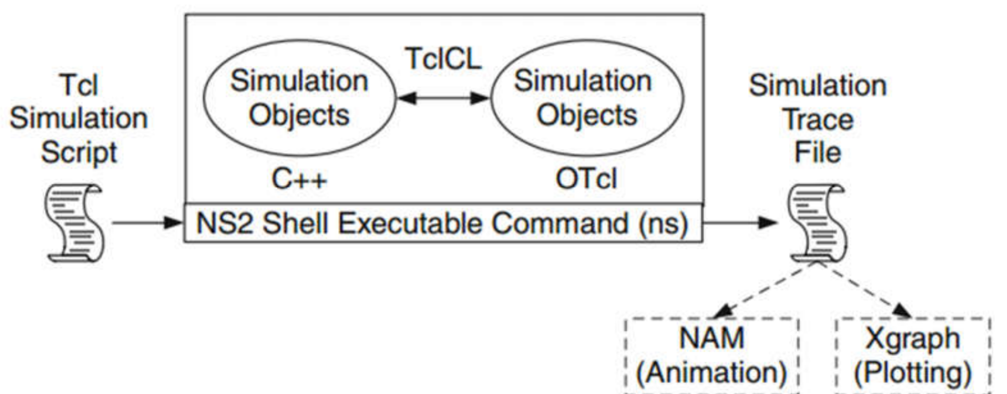

Figure 5.1: Basic architecture of NS2

5.2 Simulation environment and assumption

The table below shows the parameters used in the simulation. We have varied the number of nodes to see the effect.

1. Simulation parameters

Table 5-1: Simulation parameters

Channel Type	Channel/WirelessChannel
Radio-propagation model	Propagation/TwoRayGround
Network Interface Type	Phy/WirelessPhy
Mac Type	Mac/802_11
Interface Queue Type	Queue/DropTail/PriQueue
Antenna Model	Antenna/OmniAntenna
Max Packets in Ifq	50
Number of Nodes	20,40,60,100
Traffic Types	CBR
Transmission Range	250m
Mobility Model	Random Waypoint
Topology Size	1800 m X 840 m
Initial Energy	100 Joule
Receiving Power	0.3 Watt
Transmission Power	0.5 Watt
Idle Power	0.05 Watt
Sleep Power	0.03 Watt

2. Assumption

We have considered constant movement of nodes. All nodes are considered to be trusted and have willing to forward packets destined to some other nodes in the network.

3. Simulation scenario

To make the difference more visible we have used different number of nodes in the network such as 20, 40, 60, and 100. We have evaluated the result with different network density. In the figure below we have depicted sample screenshot for 20 nodes scenario.

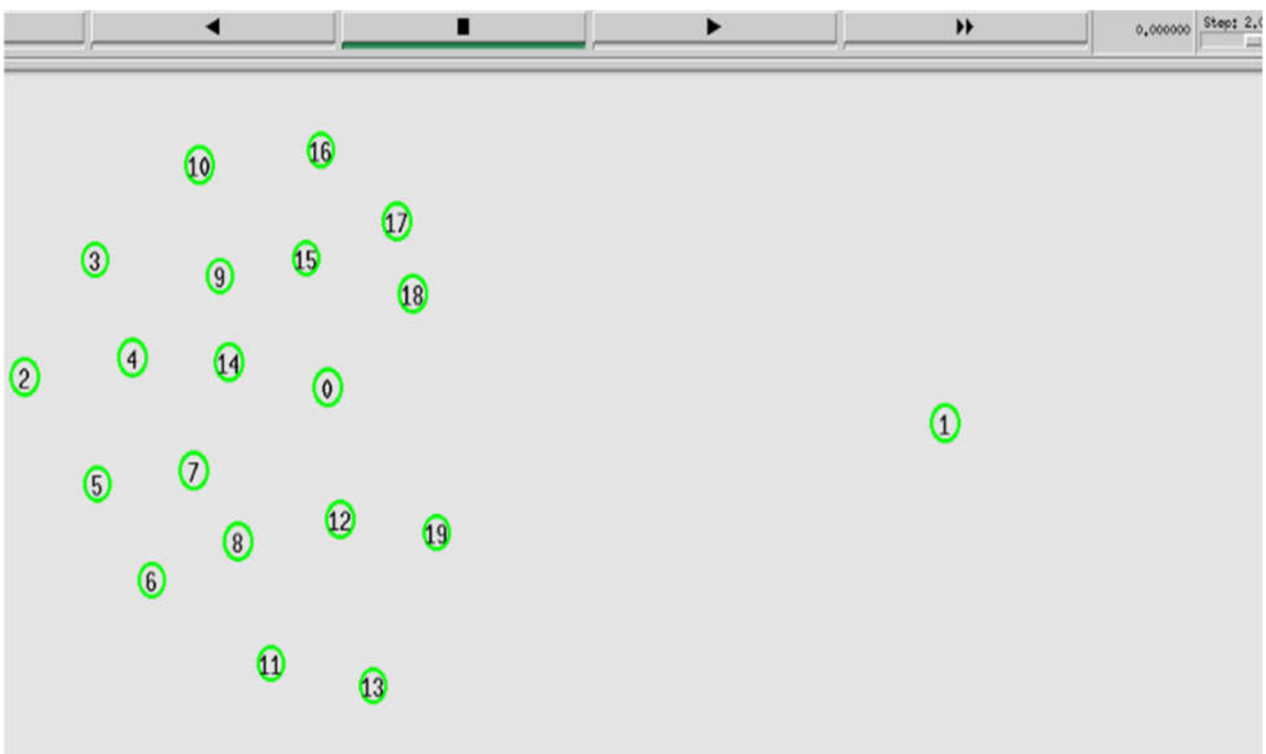

Figure 5.2: Simulation scenario

5.3 Result and evaluation

In order to evaluate the performance of the original DSR and the modified DSR protocol we have used some of the performance metrics such as throughput, packet delivery ratio and routing overhead. There is a trace file which records every event during the simulation.

To calculate the performance metrics from the trace file we have used AWK script which generates text-based output of the simulation. In the following section we are going to present the results of metrics used to evaluate the two protocols both the existing and the modified DSR routing protocol via plotting the graph using Xgraph from the text file generated by AWK script.

As the routing overhead increases, the queue may be filled with control packets and got full. At the time the queue is full with control packets, the data packets arrived late will be dropped due to no free space in the queue. Therefore, PDF of the existing work is lower than the modified one as it introduces higher overhead. In our work the major task we have done is reducing routing overhead, and it in turn increases the packet delivery ratio.

5.3.1 Routing Overhead

Routing packet overhead is calculated as a total number of control packets transmitted. As the number of control packets increase, the performance of the ad hoc-networks decrease as it consumes the bandwidth available to transfer data between nodes [32].

Routing overhead has an effect on the network's robustness in terms of the bandwidth utilization and battery power consumption of the nodes. Routing overhead is equivalent with total number of routing packets/ the overall number of data packets that were delivered. As the number of route request packet has decreased in our work, routing overhead is reduced, it is depicted in the figure below, and in turn it makes PDF better.

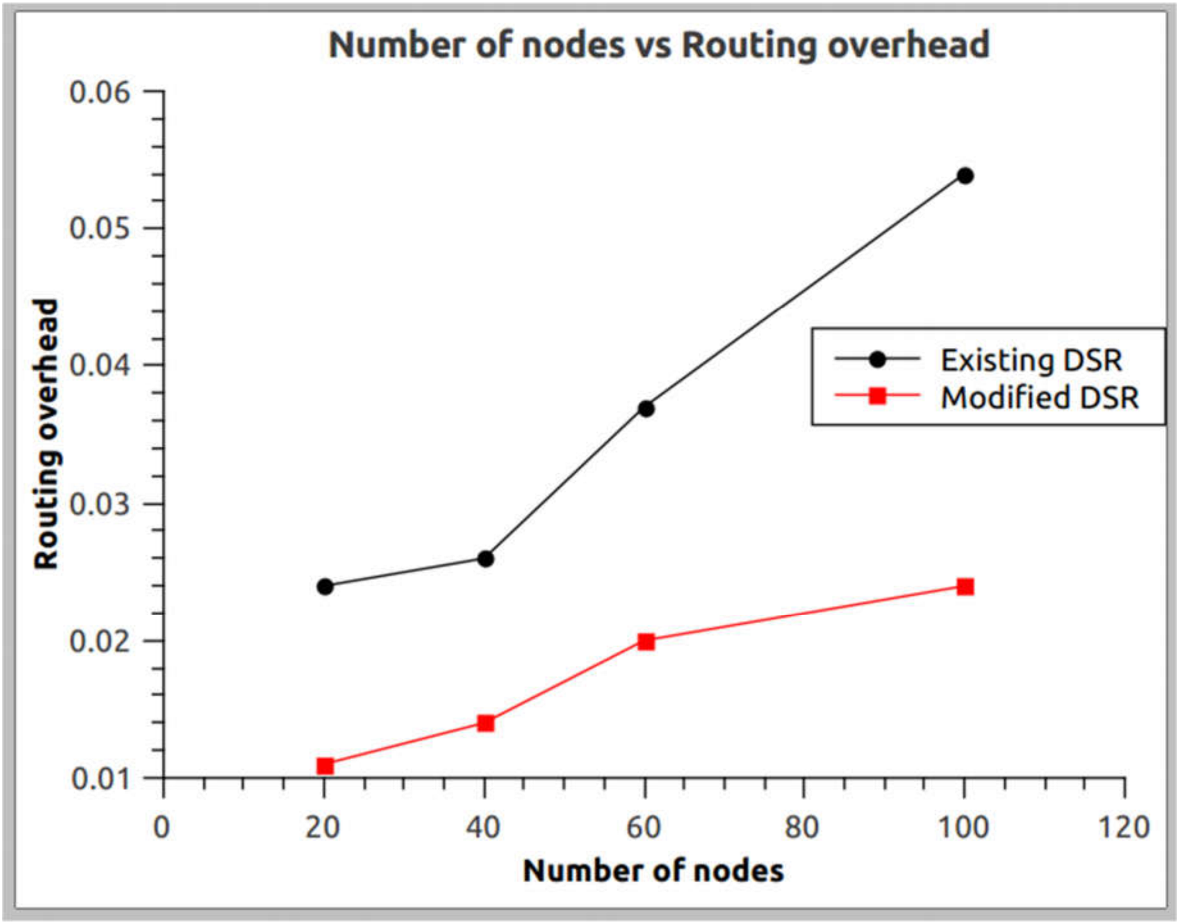

Figure 5.3: Number of nodes vs routing overhead

5.3.2 Throughout

Throughout measures the actual data packet received by the destination node. Throughout is usually defined as the number of data packets delivered to the final destination per unit of time.

Throughput = (Number of bytes received * 8.0)/Time*1000 where, Time= stop time-starting time [32].

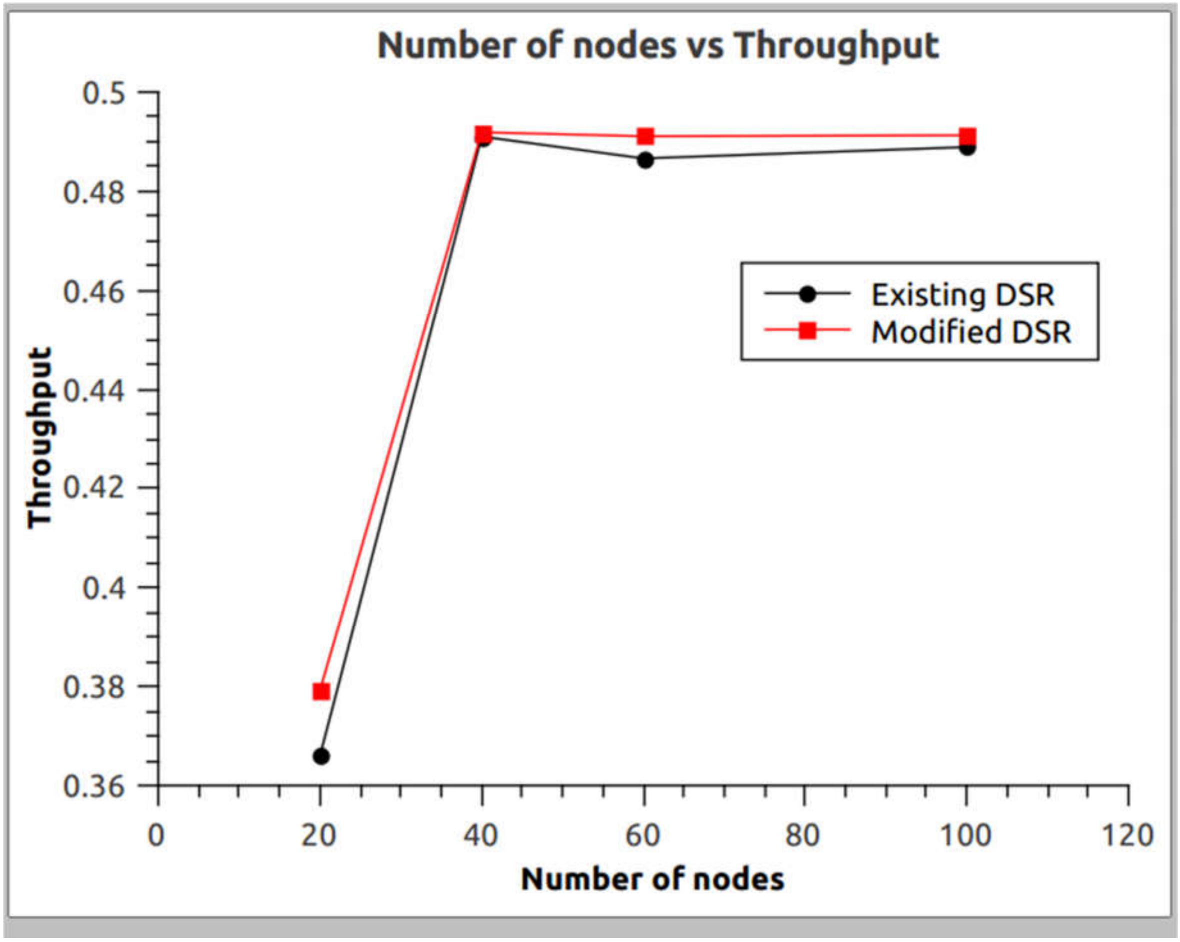

Figure 5.4: Number of nodes Vs Throughput

5.3.3 Packet Delivery Ratio

Packet delivery ratio is defined as the total number of packets delivered to the destination divided by total number of packets generated. Obtained from the trace file by using AWK script. PDF is calculated for both Modified and Existing DSR by varying the number of nodes in the given network. After result is collected, the next step is plotting using Xgraph to easily notice the difference as the density of the network vary [32]. As routing overhead of the modified protocol is decreased, its Packet Delivery ratio is better. Having too much overhead results in packet drop. In section 5.3.1, we have mentioned that the overhead of the existing protocol is higher than the modified protocol. Therefore, PDF of the modified protocol is better as depicted below.

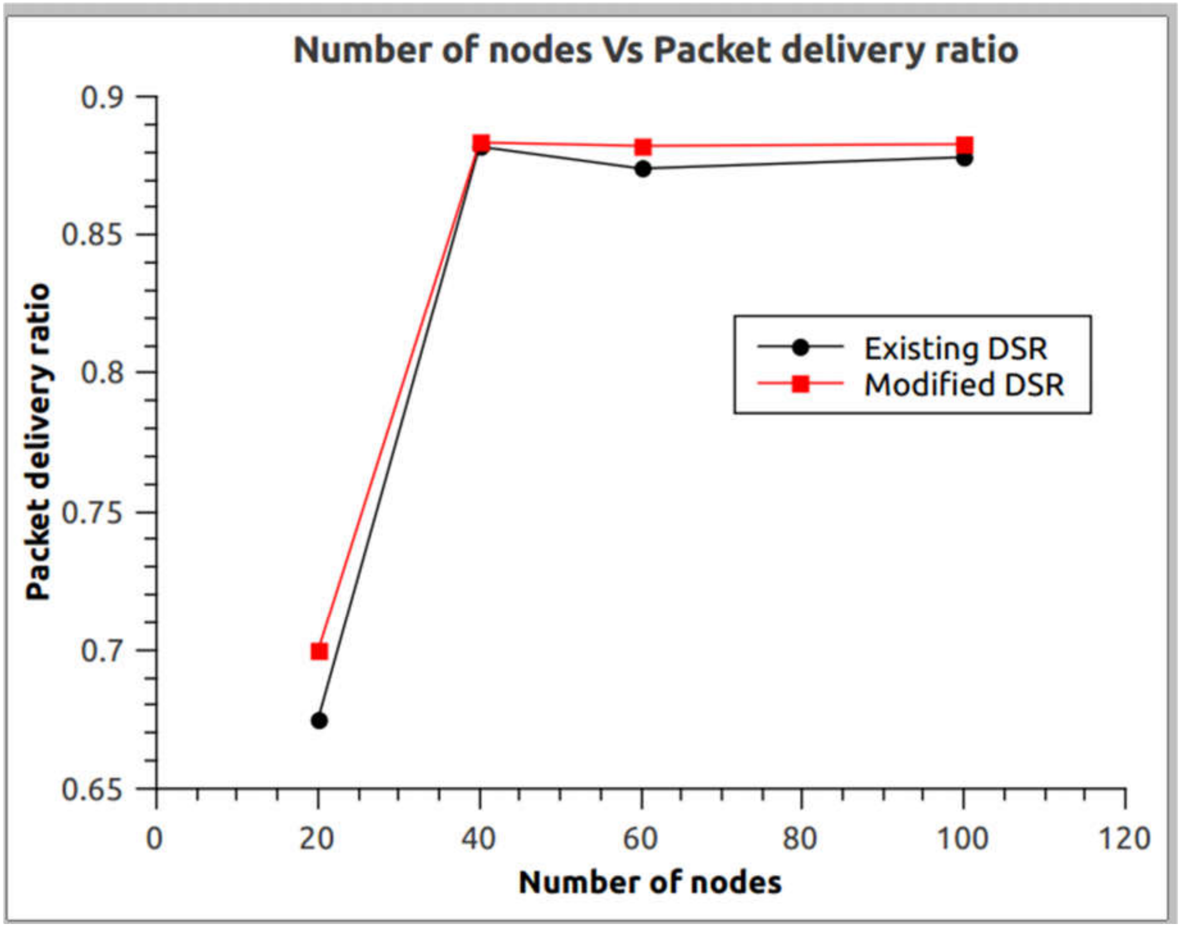

Figure 5.5: Number of nodes vs Packet delivery ratio

5.3.4 Average End-To-End Delay

Average end-to-end delay is defined as the average time interval between the creation and successful delivery of data packets for all nodes in the network, during a given period of time in the simulation. Packets that are not arrived at the destination are not considered in the end-to-end computation [32].

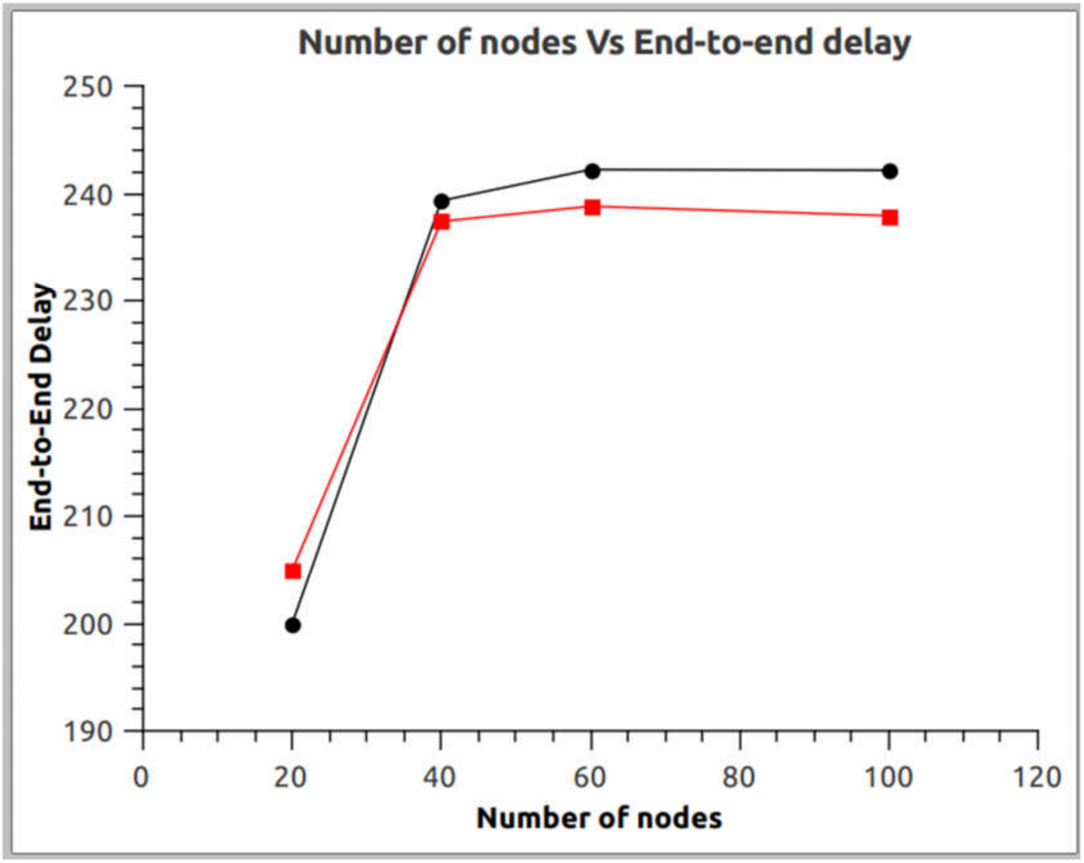

Figure 5.6: Average end-to-end delay

As we have observed from the picture above, the average end-to-end delay of the modified routing protocol getting low as the number of nodes in the network increase. End-to-end delay of the existing routing protocol is better when for small number of nodes in the network. Therefore, the modified protocol outperforms the existing routing protocol as the number of nodes are increasing in terms of end-to-end delay performance metrics.

CHAPTER SIX: CONCLUSION AND RECOMMENDATION

6.1 Introduction

In chapter five, we have discussed results of both modified and existing DSR routing protocol. In this chapter we are going to put a conclusion based on results obtained in chapter five. The modified DSR has been implemented and tested by Network Simulator version 2.35. It is one of the most commonly used simulation tools in networking researches.

As stated in the first chapter our aim was to minimize the routing overhead introduced by the existing routing protocol when finding a route to destination. To do this we have added header contains energy, role and id of the sending node. Based on the information from the clustering header cluster will be formed. According to the results obtained our modified DSR routing protocol has showed better performance in terms of both routing overhead and packet delivery ratio.

6.2 Conclusion

Mobile Ad hoc network is defined as an infrastructure less network which is formed on demand. The most challenging thing in Mobile Ad hoc network is its frequently changing topology which introduces link breakage. Blind flooding is one the mechanism to be used by most existing reactive routing protocols to find path between two communicating entities.

When using blind flooding it is obvious that the route request packet can flood all the nodes in the network so that it increases the traffic of the network. When the traffic becomes high in the network, the queue can be full and forced to drop packets coming. Therefore, packet loss ratio will increase, in other word packet delivery ratio will be minimized. Being congested affects the performance of the protocol.

The existing DSR routing protocol is used blind flooding to obtain path from source to destination incase when there is no path in its own cache. As stated in the above using blind flooding decreases the performance of the protocol. In order to limit the number of route requests broadcasted in the network we have added the concept of clustering so that the performance of the modified DSR protocol has increased since the control packet traffic in the network decreases.

When a node has a packet to be sent, it prepares and send route request packet specifying unique id, source and destination of the request. In the modified routing protocol state, energy and id of a node is appended to the route request packet prepared to find route to destination. The receiving node decides its state based on the state of its neighbor that it receives.

Clustering header is also appended to the data packet in addition to route request packet which enables the cluster to be formed in the given network. After the cluster is formed, only a subset of nodes are propagating the route request packet. Only head or gateway nodes take part in forwarding the route request packet.

Every node maintains neighboring information and update the information since the current neighbors may no longer neighbors as they can go out of its transmission range. As energy of a node is vital in Mobile Ad hoc network, we have taken energy of nodes into consideration while making clusters. We can use energy of a node efficiently by giving a role for a node with highest energy. In this manner what we can reserve is the energy used while communication.

We have used power-aware passive clustering to improve the existing routing protocol.

In our modified DSR routing protocols nodes are able to know whether neighbor nodes go out of its transmission range or not by calculating the distance between them since the default transmission range in Mobile Ad hoc network is known. In clustering approach some nodes perform too much tasks compared to the others, so it is very important to consider their energy when giving role to play to prevent them from early battery drainage. After a node knows that one of its neighbors goes out of its range, the node will be removed from its neighbor list and adjust itself accordingly. Therefore, distance between nodes have been considered in our work in addition to residual energy of nodes.

6.3 Recommendations

Our work is best fitted as the network density is increasing. Workload of a gateway has not considered while giving a role to a node to be serving as a gateway. When a node becomes gateway, which connects different pair of cluster heads, probably it might be selected by more than one head even if other gateways are available with less traffic. In the future we will also incorporate security to the network which is not considered in this work.

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Appendices

A. TCL script (sample simulation script for 20n nodes)

```
set val(chan)          Channel/WirelessChannel    ;# channel type
set val(prop)          Propagation/TwoRayGround   ;# radio-propagation model
set val(netif)         Phy/WirelessPhy            ;# network interface type
set val(mac)           Mac/802_11                 ;# MAC type
set val(ifq)           Queue/DropTail/PriQueue    ;# interface queue type
set val(ll)            LL                         ;# link layer type
set val(ant)           Antenna/OmniAntenna        ;# antenna model
set val(ifqlen)        50                         ;# max packet in ifq
set val(nn)            20                         ;# number of mobilenodes
set val(rp)            DSR                        ;# routing protocol
set val(x)             1800                       ;# X dimension of topography
set val(y)             840                        ;# Y dimension of topography

### Setting The Simulator Objects

    set ns_ [new Simulator]
#create the nam and trace file:
    set tracefd [open dsr.tr w]
    $ns_ trace-all $tracefd
    $ns_ use-newtrace
    set namtrace [open dsr.nam w]
    $ns_ namtrace-all-wireless $namtrace  $val(x) $val(y)

    set topo [new Topography]
    $topo load_flatgrid $val(x) $val(y)
    create-god $val(nn)
#  Defining Node Configuration

            $ns_ node-config -adhocRouting $val(rp) \
                        -llType $val(ll) \
                        -macType $val(mac) \
```

```
                        -ifqType $val(ifq) \
                        -ifqLen $val(ifqlen) \
                        -antType $val(ant) \
                        -propType $val(prop) \
                        -phyType $val(netif) \
                        -channelType $val(chan) \
                        -topoInstance $topo \
                        -agentTrace ON \
                        -routerTrace ON \
                        -macTrace OFF \
                        -movementTrace ON \
                   -energyModel EnergyModel \
                   -initialEnergy 100 \
                   -txPower 0.5 \
                   -rxPower 0.3 \
                   -idlePower 0.05 \
                   -sleepPower 0.03 \

### Creating The WIRELESS NODES

    set n0 [$ns_ node]
    set n1 [$ns_ node]
        …
        …
        …
    set n20 [$ns_ node]

### Setting The Initial Positions of Nodes

    $n0 set X_ 500.0
    $n0 set Y_ 517.0
    $n0 set Z_ 0.0
      ….
      ….
```

```
  ….
  ….
$n20 set X_ 741.0
$n20 set Y_ 152.0
$n20 set Z_ 0.0

## Giving Mobility to Nodes
  ……….
## Setting the Node Size

    ….
    ….
    ….

#cbr traffic source with udp
 set udp0 [new Agent/UDP]
 $ns_ attach-agent $n0 $udp0
 set cbr0 [new Application/Traffic/CBR]
 $cbr0 attach-agent $udp0
 $cbr0 set packet_size_ 512
 set null0 [new Agent/Null]
 $ns_ attach-agent $n9 $null0
 $ns_ connect $udp0 $null0
 $ns_ at 0.0 "$cbr0 start"
 $ns_ at 4.0 "$cbr0 stop"

    ….
    ….
    ….

### PROCEDURE TO STOP
proc stop {} {

        global ns_ tracefd
```

```
        $ns_ flush-trace
        close $tracefd
        exec nam dsr.nam &
        exit 0

    }

puts "Starting Simulation........"
$ns_ at 50.0 "stop"
$ns_ run
```

B. C++ code to find distance and energy of nodes inside dsragent.cc file of DSR

```
double DSRCluster::GetEnergy(nsaddr_t address) //  a function which obtains
remaining energy level of the node
 {
      Node* thisnode = Node::get_node_by_address(address);
  double energy ;
energy = thisnode->energy_model()->energy();
      return energy;
}
double DSRCluster::GetDistance(nsaddr_t from, nsaddr_t to)// a function to
calculate distance between nodes
    {
       double tz=0,ty=0,tx=0,tx1=0,ty1=0,tz1=0,dist=0;
      MobileNode *t_node=(MobileNode*)(Node::get_node_by_address(from));
      ((MobileNode*) t_node)->getLoc(&tx,&ty,&tz);
       MobileNode *t_nodee=(MobileNode*)(Node::get_node_by_address(to));
      ((MobileNode*) t_nodee)->getLoc(&tx1,&ty1,&tz1);
       dist=sqrt(pow((tx1-tx),2)+pow((ty1-ty),2));
        return dist;
  }
```