Energy and Load Based Routing Protocol for Mobile Ad-Hoc Networks

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Energy and Load Based Routing Protocol for Mobile Ad-Hoc Networks

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by

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based on research carried out

under the supervision of

Prof. Dr. Suchismita Chinara

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Department of Computer Science and Engineering
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Dedication

Dedicated to my parents and family

Signature

Department of Computer Science and Engineering
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Prof. Dr. Suchismita Chinara
Assistant Professor

May 21, 2016

Supervisor's Certificate

This is to certify that the work presented in the dissertation entitled *Energy and Load Based Routing Protocol for Mobile Ad-Hoc Networks* submitted by *Nandanwar Chetan Damodar*, Roll Number 711CS1026, is a record of original research carried out by him under my supervision and guidance in partial fulfillment of the requirements of the degree of *Master of Technology* in *Computer Science and Engineering.* Neither this dissertation nor any part of it has been submitted earlier for any degree or diploma to any institute or university in India or abroad.

Dr. Suchismita Chinara

Declaration of Originality

I, *Nandanwar Chetan Damodar*, Roll Number *711CS1026* hereby declare that this dissertation entitled *Energy and Load Based Routing Protocol for Mobile Ad-Hoc Networks* presents my original work carried out as a postgraduate student of NIT Rourkela and, to the best of my knowledge, contains no material previously published or written by another person, nor any material presented by me for the award of any degree or diploma of NIT Rourkela or any other institution. Any contribution made to this research by others, with whom I have worked at NIT Rourkela or elsewhere, is explicitly acknowledged in the dissertation. Works of other authors cited in this dissertation have been duly acknowledged under the sections “Reference” or “Bibliography”. I have also submitted my original research records to the scrutiny committee for evaluation of my dissertation.

I am fully aware that in case of any non-compliance detected in future, the Senate of NIT Rourkela may withdraw the degree awarded to me on the basis of the present dissertation.

May 21, 2016
NIT Rourkela

Nandanwar Chetan Damodar

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Abstract

A Mobile Ad-hoc Network (MANET) is a network with no infrastructure, operating on wireless mobile nodes. MANET consist of quickly deployable, independent as well as self-configuring nodes with no centralized administration. There is no precise topology and have limited energy and computing resources. Jitter, a random, small variation in timing is widely used in between periodic transmission of the control message in wireless communication protocols. It is an especially important technique during route discovery process when a process may cause a situation where adjacent nodes have to broadcast concurrently, then the use of jitter makes a protocol able to avoid concurrent packet transmissions over the same channel by neighboring nodes in the network. In AODV jitter, i.e., a small delay during the flooding of a control message is used during route discovery process to avoid simultaneous packet transmission by neighboring nodes, which might result in the collision between these packets. The proposed energy and load based protocol (ENL-AODV) introduces energy and load factor in the calculation of jitter while forwarding of route requests(RREQ), making it select the path with enough energy to transfer the data packet. As simulation results describe, ENL-AODV improves the efficiency of ad-hoc networks, increases packet delivery ratio, throughput and network lifetime, also decreases average end-to-end delay.

Keywords*: *Jitter*; *AODV*; *ENL-AODV*; *Energy*; *Load.

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Chapter 1

Introduction

1.1 Introduction to MANET

A network is a collection of system or organizations or people who share their data collectively for their business purpose. It acts as a group of entities connecting each other. In Computer technology, the networks are defined as a similar group of computers or routers or hosts rationally attached to the sharing of services (like multi-tasking, print services, etc.) or information. The networks of computers were initially developed to fulfill the need of sharing files and printer but eventually the use of computer networks took a different turn from file and printer sharing to application sharing and logic's in business exchange.The networks used can be labeled as fixed or temporary (cabled, permanent). A system of networks may be wired or wireless depending on physical connectivity. Wireless can be differentiated from wired by observing physical connectivity between nodes or routers participating in the system of network.

A mobile ad-hoc network (MANET) acts as an independent network [1] of freely moving nodes. It is a collection of mobile nodes connected through wireless media where the nodes dynamically form a system of a network to transmit information with no use of any existing fixed infrastructure of a network. To establish a network of mobile nodes i.e., MANET, all needed is a source node willing to send data and destination or target node ready to receive data while communication will occur between a source node and the destination node. An individual mobile node in ad-hoc network functions in two ways. It acts as a host by being a destination node and serves as a router by being an intermediate node. As an intermediate node, it forwards packets generated by a source node to those nodes which are not in the transmission range of source node, i.e.; it helps in routing packet towards the destination.

In local area networks(LAN), MANET is approach with no infrastructure. MANET itself is a self-configuring network of mobile nodes and routers having a dynamic topology and connected by wireless links. Mobile ad-hoc networks operate in a standalone fashion where nodes and routers are free to move and arrange themselves

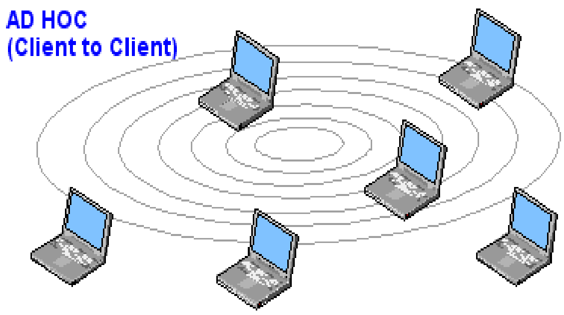

Figure 1.1: Manet Network

randomly. Dynamic topology of MANET makes them very adaptive and suitable for many types of applications because they set up a temporary communication with no previously installed infrastructure. For a mobile node in an ad-hoc network, a circular region about the node is defined for transmitting information which is called as communication range of the node. The radius of transmission(communication) range depends on the transmitter power, propagation loss model, and receiver sensitivity. In a case when the destination node is not in the circular region, i.e., not in the communication range of the source node, then the mobile ad hoc network functions as a multiple-hop network with intermediate nodes acting as router to deliver packets to the destination.

In wireless mobile ad-hoc networks communication range of mobile nodes is restricted, so data packets are forwarded in multi-hop[2] fashion to route it towards destination. So for data transmission there exists three types of traffic in MANETS

- Peer - to - Peer: Single hop communication between two mobile nodes.
- Remote to Remote: Multi-hop communication with existence of stable route.
- Dynamic Traffic: Frequent reconstruction of routes while nodes move dynamically in the network.

1.2 Wired and Wireless Networks

These days various types of networks are available, where mainly networks are classified as wired and wireless networks.

1.2.1 Wired Networks

In wired networks, participating devices are physically connected by wires. Mainly cables like CAT5 and CAT6 are used as connecting media between the networks. With

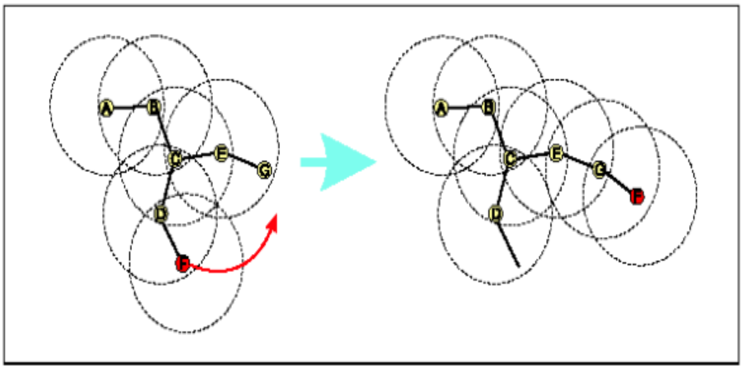

Figure 1.2: Multi-hop mobile ad-hoc networks

the assistance of physical devices like Switches and Hubs, connections are settled so as to build the quality of the association. Due to the presence of wires at physical layer wired networks are much secure than their counterparts wireless network also they are usually more productive and much faster than remote systems. Once the connection is established, the chances of detachment of cable are very less till it gets broken.

Advantages of Wired Networks

- Connection speeds ranging from 100Mbps to 1000Mbps
- There are rare chances of interference and fluctuations as wired networks have physical, fixed wired connections.
- Bandwidth availability.

Disadvantages Over Wireless Networks

- Maintenance cost of wired networks is very high. Once the system is broken, to due to the involvement of many cables within computer systems. Somehow there occurs a failure in the wire or cable, it is very difficult to repair or replace that particular cable as it will cost a lot for it.
- Devices like laptops are used for a reason that, they can be moved around wherever we want but using a wired network with laptop restricts the logical reason for using mobile devices like a laptop.

1.2.2 Wireless Networks

In wireless networks, there are no physical connections between nodes under operation. Device or nodes participating in wireless networks communicate through various radio signals present in the air. Wireless networks eliminate the need for laying our cables and maintaining them as it is very expensive.

Advantages of Wireless Networks

- Using wireless networks for communication mobile users can access real-time information even when users are away from their home or office.
- The process of establishing wireless system is very easy and time saving. In setting up wireless networks we dont have to draw out cable and wires through ceilings.
- Wireless networks can be set up at the places where it is impossible to set up wired networks.

Disadvantages of Wireless Networks

- Wireless networks operate on radio frequencies in air so there is high chance of interference due to other radio frequency devices. Also, weather and obstacles like walls plays major role in destructing wireless signals.
- In presence of multiple connections throughput gets affected.

Problems with Wireless Network

There are some problems in wireless communication like path loss, multi-path propagation, limited frequency spectrum, and interference. Path loss happens when a signal sent by sender gets attenuated before reaching the destination.

Wireless network operates in different radio signal in the air so in an active transmission source sends a radio signal toward destination so as to communicate. In the medium between source and destination if there is a presence of an obstacle, then radio signal gets diverted from its direct path due to reflections, diffraction, refraction, and scattering. This diversion of direct path is called as multi-path propagation.

Less bandwidth availability due to limited frequency spectrum is an issue in wireless communication. In wireless communication data is transferred by exchanging radio signals in air while availability of frequency spectrum is less, so does the bandwidth. Also, due to shared nature of wireless network many signal interact with each other, which means interference of radio signals.

1.3 Features of MANET

1.3.1 Restricted physical security

There are more chances of threats in mobile ad-hoc networks than fixed, wired networks. Often varied existing techniques are applied to make links more secure so as to make wireless networks secured from threats.

1.3.2 Operations under constrained power

Every mobile node forming mobile ad-hoc network get energy from their batteries. So power conservation becomes the most critical criteria for mobile nodes.

1.3.3 Bandwidth-constrained, variable capacity links

Wireless networks possess less capacity as compared to wired networks. There is limited availability of bandwidth while congestion is significant issue in performance of wireless networks.

1.3.4 Dynamic Topologies

As discussed in the earlier sections, MANET networks have dynamic topology, where nodes move freely in arbitrary directions. So topology changes rapidly at unpredictable times. Change in different parameters also affect the topology of MANET networks.

1.4 Uses of MANET

1.4.1 Communications in Infrastructure less Regions

Military usually works in infrastructure less regions where there is no facility to establish connections through wires so in such a place mobile ad-hoc networks are deployed for communication purposes. Also in a destroyed regions mostly ad-hoc are deployed. This shows that mobility of ad-hoc networks has many benefits. This case also applies in the ocean, in the air or even in space (for satellites).

1.4.2 Extending Coverage of access point

Access points have restricted coverage region, so MANETs are used to extend the range of access point so that a single access point is made accessible to out of range devices. So, using MANET we can reduce the number of access point saving cost of deploying them.

Figure 1.3 describes, with the use of Ad-Hoc network model single access point is made accessible to out of range devices by extending a range of wireless network. We can observe that in the absence of the ad-hoc model, only node A could get the access to Internet through the access point as it is in the transmission range of access point, while using ad-hoc networks each node which are in transmission range of node A can access the Internet. Here node B can get access from the node and node C from node B.

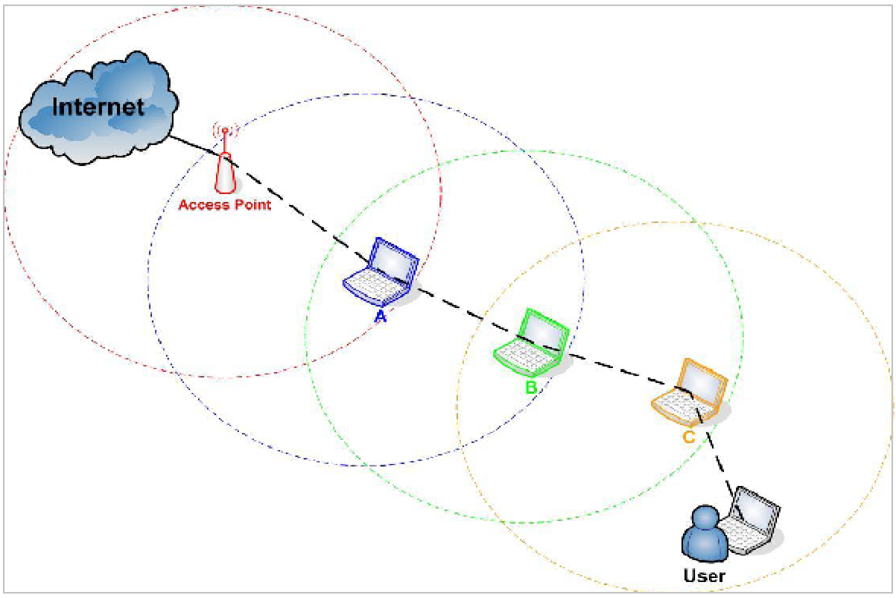

Figure 1.3: Extending Coverage of access point using mobile ad-hoc networks

1.5 Problems in MANET

1.5.1 Bandwidth

Limited and unreliable bandwidth availability is a critical issue in wireless networks. These networks depend on radio signal in air for communication, so many parameters such as mobility, obstacles, interferences, ...etc can directly affect the radio links. There are various access methods which enable the network to utilize as much as available bandwidth by using mechanisms like collision avoidance. It has been proved that on a wifi link, in practice, only 50% of the theoretical bandwidth is available, and tests showed that latency is more important than on wired networks.

1.5.2 Security

Security is an important issue in establishing mobile ad-hoc networks over a particular region. MANET operates on the signals diffused in the air, which makes it as shared medium. Therefore, it is accessible to everyone. If people have devices, that can access diffused signals in the air; then there is high chance that they may interfere with our established network and get information which is not supposed to be shared outside. It makes wireless signal less secure for transmitting confidential information. Using wireless signal to communicate seems like we are standing on the top of roof and shouting all the information. There are different mechanisms which can be used to secure wireless channel such as encryption (encoding information). Data can be encrypted at the sender site using a particular key and can be decrypted at the receiver site with that key only.

1.5.3 Energy

In wireless network energy, i.e., battery power of node plays a significant role in overall network performance[3], and the only source of energy for nodes participating in the network is their installed battery. Thus, energy is in the limited amount. During communication energy is used for handling and processing the data packet. If there is no energy left in the node then it becomes useless to the network and somehow during active communication nodes gets exhausted[4] connection will be disrupted, and data packets will be dropped. Thus, increase in overall delay and decrease in network lifetime.

1.5.4 Dynamic Topology

MANET is a collection of freely moving nodes in arbitrary directions. Therefore, topology is dynamic so as routing. Nodes participating in a mobile ad-hoc network are continuously changing their positions where there is also a chance that medium properties might change momentarily. Due to such dynamic nature of MANET, routing which works on routing table also needs to have dynamic nature. Routing table should reflect these changes as topology variations.

1.5.5 Interference

Due to shared nature of MANETs, interference is a significant problem. There exist many connections in the same network region so one connection might interfere with another. In the case of a mobile ad-hoc network, one mobile node might listen to transmission from other mobile nodes, which will result in loss of connection and transmission damage.

1.5.6 Routing Overhead

In case of topology MANETs have dynamic nature, so mobile nodes of leave their static positions and move around in arbitrary directions. So old routes gets generated in the routing cache table resulting in unnecessary routing overhead.

1.6 Thesis Organization

The remaining thesis is organized as follows: In chapter 2, the literature survey is discussed thoroughly routing in MANETs, ad-hoc routing protocol, and especially

AODV routing protocol. Chapter 3 includes proposed routing scheme, i.e., ENL-AODV routing protocol and it also includes performance evaluation and results. Chapter 4 concludes the overall thesis work.

Chapter 2

Literature Survey

In this chapter mainly routing in mobile ad-hoc networks is discussed. It includes detailed information about various types of routing protocols used for path discovery process, especially reactive routing protocol. Further AODV (Ad-hoc on demand distance vector) routing protocol is explained including jitter considerations in reactive routing.

2.1 Routing in MANET

2.1.1 Definition

In wireless networks, routing is a process of discovering paths between two devices who wants to communicate. Among te seven layers of OSI model, routing is performed at the network layer. In ad-hoc networks, nodes are located at different locations and dynamically moving, so by using routing a path is found between two nodes who wants to exchange information. It serves the same purpose in the network as road map serves in real life. In both cases, we need to locate the destinations, and we go for best and optimized route towards the destination. It especially has a significant role in military communications, as the Internet was first designed for it.

2.1.2 Routing Problems in Ad-Hoc Networks

In Mobile Ad-hoc networks topology changes continuously, thus no permanent links between devices. As at certain moment if a device wants to send information to another device but unfortunately due to topology variation there is a change in its position so that packet may be lost. Also, if a device doesn't have sufficient energy to forward the packet, then it will drop that packet. Loss of packet affects the performance of the network in many ways. Among all these rapid energy depletion on node leading to exhaustion of that node affects the whole network and decreases the lifetime.

2.1.3 Ad-Hoc Routing Protocols

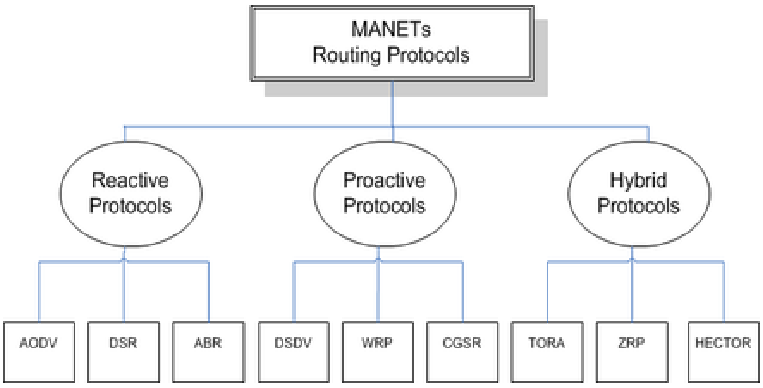

Figure 2.1: Classification of MANET routing protocols

There are various approaches for finding path in ad-hoc networks. Three main approaches are: 1. Proactive, 2. Reactive[5] and 3. Hybrids. In proactive routing protocol[6] nodes require to exchange routing information periodically, and on the basis of that compare routes between any nodes in the network. This routing mechanism consumes a lot of energy resources also, bandwidth may be wasted, which seems undesirable in MANETs where the resources are limited. On the other hand, reactive routing protocol [5]mostly uses on-demand i.e. here nodes don't exchange routing information periodically but find routes only when it needs for the exchange of information between two nodes or end-user. A Hybrid Protocol will apply the two above algorithms.

2.2 Related Works

2.2.1 On-Demand (Reactive) Routing Protocols

When there is no active communication in the network, reactive routing protocols don't maintain routing information at the nodes. If a node in the network wants to communicate with another node in the same network, then in reactive routing protocol routes are found on-demand of a source node. First route discovery process starts by the flooding of route request packets in the network. When route request packet reaches the target node route gets established and after that data transfer starts. AODV and DSR are well known[7] reactive routing protocols.

2.2.2 AODV: Ad-Hoc on-demand distance Routing Protocol

AODV is on-demand routing protocol developed for mobile ad-hoc networks. In MANET where topolgy changes dynamically AODV acts as very efficient in finding the routes and transmitting data from source to destination. Wireless networks have limited availability of bandwidth, so AODV is developed particularly to overcome this problem. AODV is mostly derived from DSR (Dynamic Source Routing) and DSDV(Destination Sequenced Distance Vector) routing protocols. The on-demand discovery of route, hop-by-hop routing and route maintenance from DSR. Node sequence numbers[8] method from DSDV, which makes the protocol cope up with topology and routing information. On-demand route discovery in AODV makes it very beneficial and efficient for finding paths in MANETs [5].

Working of AODV

In mobile ad-hoc networks, each node acts as a router so if one node wants to communicate with other then routes are obtained on demand which makes network self-starting. Every mobile node has a routing table. It is maintained with the information entries of neighboring nodes. Also, there are two separate entries: a node sequence number and a broadcast-id. If a source node wants to transfer the data packet to a destination node, then it makes a route request by broadcasting route request packet (RREQ) and increments its broadcast-id. The RREQ includes the following fields:

- src-addr - source IP address
- src-seq - to maintain latest information about the route to the source.
- dst-addr - destination IP address
- dst-seq - specifies how recent a route to the destination must be before it is accepted by the source.
- hp-cnt - Number of hops

src-addr and the broadcast-id pair is used as a key to uniquely identify the RREQ. Then at all the nodes dynamic route table entry establishment begins in the network that is on the path from source to destination.

Right when the source node has to send data packets , it searches for its routing cache table. In the routing cache table, if there is a section that contains a route to the destination node, then data packets are sent by the source node. However, the source node particularly broadcasts an RREQ. When an intermediate node gets an RREQ, it does the following operations[9]:

1. In case the node isn't the destination node, then move to **Step 3**. otherwise, move to **Step 2**.

2. In case the destination node is the first time to get the RREQ, the destination node will insert the value of RREQ's requesting source address field and the value of RREQ's requesting broadcast ID field in the broadcast ID cache table, then set up the reverse route with its last hop node. Then, move to **Step 7**. Otherwise, the RREQ will be discarded by the destination node. By then, jump to **Step 8**.

3. According to the values in the source address field and broadcast ID field of the RREQ, it looks for its broadcast ID cache table. In case, there is a broadcast ID cache entry which has the same value of request broadcast ID field and request source address field as those of the RREQ, move to **Step 6**. Otherwise, move to **Step 4**.

4. Since the node is the first time to get the RREQ, it will insert the value of RREQ's requested source address field and the value of RREQ's requested broadcast ID field into the broadcast ID cache table, then set up the reverse route with its last hop node.

5. If the node has a route to the destination node, then move to **Step 7**, else the node will randomly make a delay [10]. As soon as the delay has arrived, the node will broadcast an RREQ. then, move to **Step 2**.

6. Since the node got an RREQ some time as of late. The node will discard the got RREQ which comes from its last hop node, rather than set up the reverse route with its last hop node. Then, move to **Step 8**.

7. The node sends an RREP to the source center. The establishment of the route is done.

8. The node does nothing.

Advantages of AODV

AODV is very efficient in routing in MANET networks. Its advantages are as follows:
itemize

Extremely less space complexity:AODV is on-demand protocol, so routes are found only if they are needed. So if nodes are not a part of active path, then AODV makes sure that those nodes doesn't have any information about the active routes. In route discovery process, an intermediate node gets an RREQ and it again floods that RREQ to its neighbors so, anyhow it doesn't receive RREP from its neighbors then it removes the recorded information from its routing cache table.

Maximum utilization of bandwidth: Wireless network has limited bandwidth availability, so AODV is designed in such a way that maximum amount of available bandwidth should be used. In AODV, a sequence counter is used which increases monotonically with fresher routes, so there is no chance of selecting an old route. In active path, all the intermediate nodes continuously refresh their routing table so as to utilize maximum bandwidth.

Simple and effective routing information: If an intermediate node delivers an RREP, and later it receives an RREP with less hop count than RREP it has previously delivered, then it updates its routing information. This way AODV gives optimized routing information with simple technique of hop count.

Most current routing info: AODV is on-demand routing protocol, so routes are found only if they are needed. Once the route is determined, it can be updated with another route, if later source node receives an RREP with higher destination sequence number than previously active route. Thus data transmission can be done with optimized routes.

Loop free routes: In AODV, if an intermediate node receives the packet with same broadcast id which it has already forwarded then it just discards that packet which AODV successful in maintaining loop-free routes.

Coping up with dynamic topology and broken links: Due to change in topology or breakage of the link in the active path transmission stops. So in such a condition a mobile node that discovers broken link transmits an RREP packet. After receiving RRER packet source node re-initializes the route discovery process. This technique ensures quick response to link breakage

Highly Scalable: AODV routing protocol, when compared with DSDV, shows broadcasts avoidance and minimum space complexity, thus making it highly scalable for routing.

Advanced uses of AODV

- Due to on-demand reactive nature of AODV; it can handle vehicular ad-hoc networks having vast dynamic behaviour[11].
- Can be used for unicast as well as multicast behavior. There are various modifications of AODV using multicast mechanism[12].

Limitations of AODV

- **High route discovery latency:**In large scale mesh networks, the number of participating devices and number of connections is in vast amount. So in on-demand route discovery of AODV may result in high route discovery latency.

- **No reuse of routing information:** In AODV routes are always found on-demand which means during new route formation old routing info is hardly used.

- **AODV lacks support for high throughput routing metrics:** AODV works on the principle that shortest hop count path always supersede. This shortest hop count metric chooses small, long bandwidth links over short, high-bandwidth links.

- **It is vulnerable to misuse:** AODV is less secure in case of insider attacks including route disruption, route invasion, node isolation, and resource consumption[13].

- **No use Load of node during route formation:** AODV doesn't consider[14] the capacity of node to store number of packets in its buffer i.e., load level of node plays important role in flooding as well as data transfer. While AODV doesnt consider load level of node in routing.

- **No consideration of energy:** In AODV, energy[15] of a mobile node is not considered[16] in route discovery or data transmission stage. If a node that involved in a route establishment has little energy, this later will break the route soon. Also, this can have an impact on the network lifetime[3] likewise: there are a few nodes that will dead quicker than other ones.

2.3 Jitter Consideration in Routing

In a mobile ad-hoc network, during route discovery process participating nodes broadcast the control packets to their neighboring nodes. While concurrent packet transmissions by neighboring nodes should be avoided because there may occur collisions on the wireless channel and this might lead to losing of transmissions on receivers. Although medium access (MAC) layer maintains the reliability by retransmitting the unacknowledged packet, collisions at wireless channel can result in loss of packets or extended delays. In certain situations MAC protocol can prevent such collisions by collision detection techniques and retransmissions at the link layer. But collision avoidance mechanism should also be implied at the higher layer of a network. At the network layer, routing protocols are used to find the path from source to destination. A jitter [10] is (a random, small transmission delay) is included in the interval between the periodic transmission of control messages. In RFC5148[17], the utilization of jitter is prescribed for MANETs as one collision-avoidance technique. It should be used in the routing protocol to avoid collisions at wireless channel due to concurrent transmissions of adjacent nodes.

2.3.1 Jitter Technique for Flooding

Wireless medium is a shared medium so, there is more probability of collisions at wireless channel which may lead to packet loss. To prevent collisions at wireless channel, the RFC5148[17] recommends the use of jitter in a situation where a packet is supposed to be transmitted concurrently. In a wireless medium, flooding is a case where packets are transmitted simultaneously to neighboring nodes and on receipt neighboring nodes instantly retransmit to their neighboring nodes. Instead of this instant transmission, RFC5148[17]recommends that each node which has a packet to be broadcasted holds that packet for a random, small delay before flooding (forwarding) it into the network. Holding a packet for short delay helps in avoiding collision in a case of simultaneous transmissions. The RFC 5148 recommends that delay should be chosen such as it should follow uniform random distribution lying between 0 and a maximum jitter value, J_{max}.

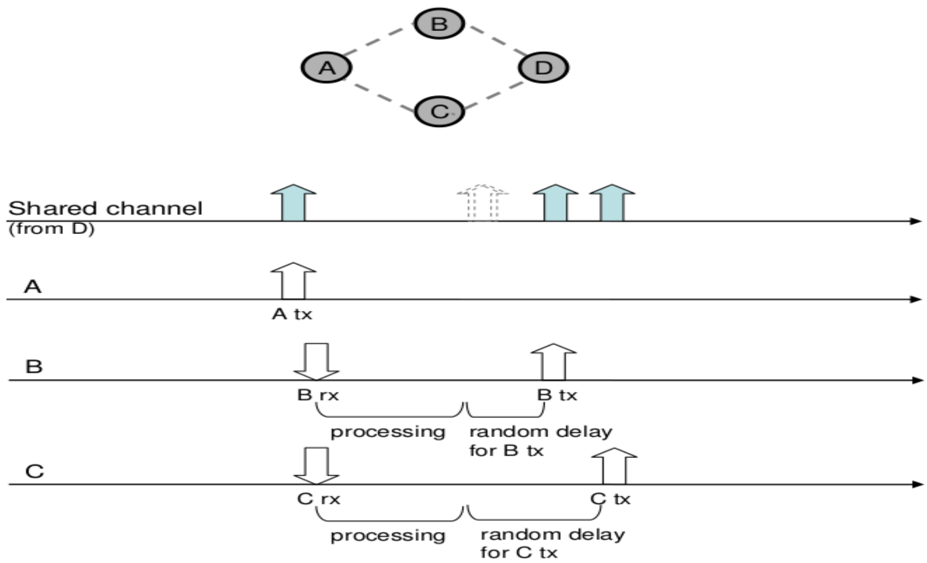

Figure 2.2: Use of jitter for flooding

Figure 2.2 shows the use of jitter for flooding. According to the topology, Node A broadcasts packets to its neighboring nodes B and C. Assuming node B, and node C have roughly same processing time; they receive the packet from node A at the same instant as they both lie at the same distance from A. After receiving packet from node A, both will retransmit the packet instantly to node D. Now node D is at the same distance from both nodes B and C, so in the absence of jitter, there occurs a collision (the shadow in the shared channel) at node D due concurrent transmissions from node B and node C. While in the presence of jitter at intermediate nodes B and C, the probability of a collision due to simultaneous transmissions can be considerably reduced.

As we learned from the previous paragraph, Jitter is mainly used as collision avoidance mechanism in simultaneous transmissions by adjacent nodes (from B and C, in figure 2.2), other than that presenting jitter in flooding has two quick disadvantages (i)It slows the flooding procedure and (ii) Nodes need bigger buffer to spare packets which have been received, however not yet sent. These drawbacks and the decrease in the likelihood of collisions can be controlled by method for the length of the jitter interim, J_{max}.

2.3.2 Route Discovery in Reactive Routing Protocol using Jitter Mechanism

In route discovery process of reactive routing protocol, source node broadcasts an RREQ message in the network so as to find a route towards the destination. A jitter is included between periodic retransmissions of RREQ messages in the reactive routing protocol as collision avoidance mechanism. However, there are some drawbacks with a random delay (jitter) of RREQ messages reaching their destination regarding selection of sub-optimal path and traffic efficiency.

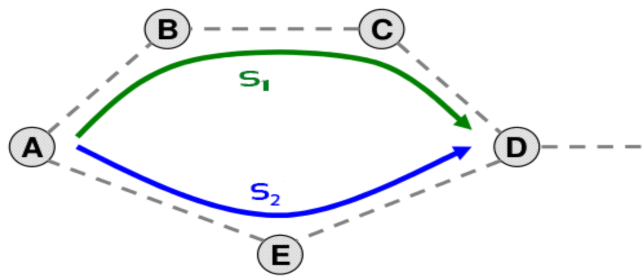

Figure 2.3: Topology example. Node A tries to broadcast an RREQ packet through two different paths S_1 and S_2.

Consider the topology shown in Figure 2.3; Node A wants to transfer data to node D, so node A starts route discovery process by flooding RREQ to its neighboring node. In a case of regular operation of a reactive protocol, there won't be any inclusion of jitter between broadcasting of RREQ packets by intermediate nodes. Assuming transmission timings and processing timings at each intermediate node(T_n) are same; the route request (RREQ) packet would arrive at node D through the path S_2 = [A, E, D] faster than through the path S_1 = [A, B, C, D]. In networks without notable congestion, Jitter T_{jitter} is up to the tens millisecond, so it cant be compared with the transmission time and processing time which are much lesser than jitter (generally less than one millisecond, i.e., $T_{jitter} >> T_n$). So in this case, the delay caused by jitter is only considered.

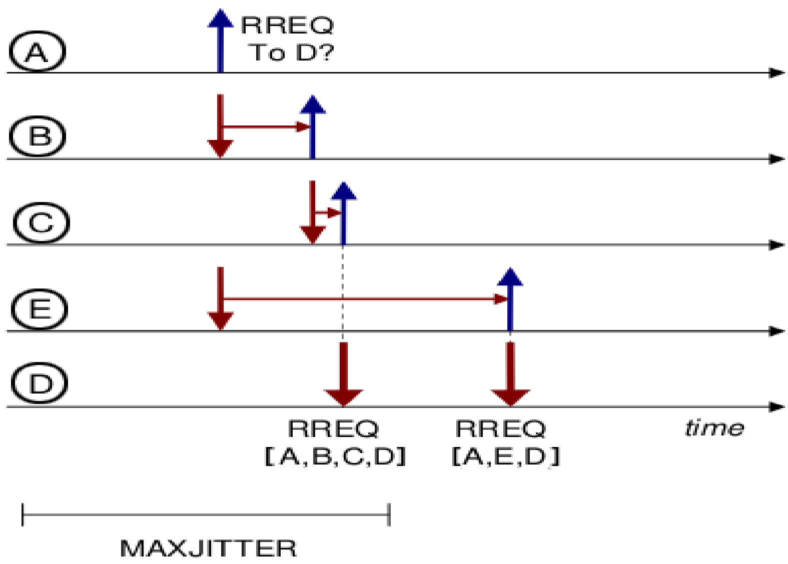

Figure 2.4: The RREQ gets transmitted through longer path A, B, C, D travels faster than the one through shorter path A, E, D

At each hop of a route, if we use uniform randomly distributed delay [0, J_{max}], so as to get jitter, i.e., additional short delay before retransmission, then control packet transmitted through the longer path (in number of hops), S_1 , may arrive at the destination faster than the packet over S_2 with a non-negligible probability.

In this example, destination node D will send a route reply (RREP) advertising through path S1, which is suboptimal. When the RREQ propagating through path p2 would reach destination node D, D would respond again to A's Route Request with the (shorter) path S2. This indicates that for a certain amount of time, suboptimal path S1 gets selected for information transfer, and it needed two RREP from D to learn the optimal path from node A to node D.

If node D is not the destination, but only an intermediate node that retransmits the RREQ message, so in the case of AODV, the intermediate node will only forward the first copy of RREQ received. The copies which are received later will be rejected as they are originated from the same source with the same sequence number. As from the topology mentioned in Figure 2.3, the later received RREQ through path S2 have lower costs but still they will be discarded as they are received late.

This example shows that using uniform random distribution for jitter values between periodic retransmission of RREQ packets in route discovery process leads to sub-optimal paths. The selection of a longer path for data transfer is called as delay inversion caused by jitter, as it turns longer (worse) paths into paths which are traversed faster. These delay inversions are wrong due to at least three unwanted effects:

- growth of needless RREQ flooded traffic.
- increase of sub-optimality of reported routes.
- growth of gratuitous RREP (unicast) traffic

2.4 Motivation

This section explains the motivation behind the proposed routing scheme. The ENL-AODV routing protocol which is a modification of existing AODV routing protocol with consideration of energy and load parameters in route discovery stage. In existing AODV protocol, there is no consideration of energy and load parameters in finding the path. MANETs have dynamically changing topology, where nodes move freely in arbitrary directions. Due to such a changing topology, there exist several paths from source to destination. If somehow, a node in the active path gets exhausted, i.e., the energy of that node becomes zero then it will disrupt the whole path of data transfer. Disruption of an active route will undoubtedly lead to packet drop at that node and source again have to start another route discovery process to transfer information to the destination. In between these changes in routes, lots of time will be consumed which will increase the average end - to- end delay of reaching packet from source to destination. Overall due to exhaustion of node in the active route will lead to lower packet delivery ratio, less throughput, and increased average end-to-end delay, which proves energy as the most critical issue in network performance.

AODV is a reactive routing protocol with on-demand route discovery. So to install energy parameters in AODV algorithm, route discovery stage is best suitable, such that optimal routes will be discovered on-demand with nodes having enough energy to transfer data packets. In AODV algorithm, if the source wants to connect to the destination then it broadcasts an RREQ packets to its neighbor. While neighboring nodes don't have a route to the destination then they again broadcast them to their neighbors, this process continues till RREQ reaches the destination. At an intermediate node, there may occur a situation where two of its neighbor forward the RREQ at the same time, which lead to the collision of RREQs at that node. Supposing the shortest paths goes through that node then due to the collision of RREQ, it will be lost, and other path gets selected, which leads to the selection of the sub-optimal path. So jitter is added to the intermediate node between broadcasting of RREQs as a collision avoidance mechanism. But uniform randomly distributed jitter will also lead to the sub-optimal path as explained in the previous section, so it is made dependent on the remaining energy and load level of a node such that only those nodes get selected which have enough energy to transfer data packet. This approach will make sure that there will be no packet drops due energy exhaustion of nodes participating in active path. Also, the delay will be decreased with increased network lifetime. If during broadcasting of RREQ, only those nodes will be allowed to broadcast RREQ which has energy above threshold energy then there is less probability that nodes will exhaust and routes will get disrupted. Overall we have installing energy and load parameters in route formation, which play critical role network performance.

Chapter 3

Proposed Work

In existing AODV routing protocol, it doesn't consider energy and load situation of nodes to establish a path in route discovery stage. As in AODV, whenever a source wants to send information to the destination, it starts route discovery process by flooding a control packet i. e. RREQ packets to its neighboring nodes. At any adjacent node if there exist a path to the destination then it sends an RREP packet to a source node. Otherwise, it holds the RREQ packet for some time and when the delay has arrived it again broadcasts to its neighboring nodes. Also, the node generates a reverse path depending on neighboring nodes that send an RREQ packet. This flooding of RREQ packet continues till RREQ reaches the destination and finally when RREQ message arrives at the destination node, a forward path is created. The delay introduced at an intermediate node is called jitter, and it is added to dodge collisions due to the concurrent packet transmissions by adjacent nodes which might result in packet drop.

In AODV routing protocol during route discovery, a uniform randomly distributed jitter is used, which leads to sub-optimal paths as explained in the previous section. Choosing a sub-optimal path for data transfer makes routes unstable. Also, lack of inclusion of energy and load situation of nodes in route discovery stage reduces the performance of the network. So in our proposed routing protocol ENL-AODV, which is a modification of AODV routing protocol we have modified the jitter during route discovery process. As in existing AODV, the jitter added is varying in uniform random distribution ($[0, J_{max}]$) which makes protocol select sub-optimal routes, so our proposed energy and load-based routing protocol make this jitter based on residual energy and load level of the node. This change makes the protocol select the path which has enough energy to transfer the data without any loss.

3.1 Proposed Routing Protocol: Energy and Load Based AODV (ENL-AODV) routing Protocol

We know in the existing AODV routing protocol a uniform random distributed jitter is added in route discovery process to avoid the collision at neighboring nodes due to simultaneous transmission of adjacent nodes. And we also know that there is no energy and load situation consideration path finding the process of AODV, so in ENL-AODV, we have added a new jitter which is dependent on residual energy and load situation of the node. Also, whenever the node has to broadcast the RREQ packet it will check for its remaining energy and if it is less than the threshold energy then it will simply drop the packet and go back to route discovery process, which will reduce the end-to-end delay caused due packet drops at nodes. While forwarding an RREQ if a node possesses an energy which is sufficient for delivering the RREQ packet but not for delivering a data packet then the path will be established for sure but during data transfer node will eventually drop the packet due to insufficient energy.

3.1.1 ENL-AODV Algorithm

In ENL-AODV, we have combined both the approaches i.e. addition of delay dependant of residual energy and load level of the node as well as dropping the control message packet below threshold energy. The operating steps at an intermediate node as follows:

1. In case the node isn't the destination node, then move to **Step 3**. otherwise, move to **Step 2**.

2. In case the destination node is the first time to get the RREQ, the destination node will insert the value of RREQ's requesting source address field and the value of RREQ's requesting broadcast ID field in the broadcast ID cache table, then set up the reverse route with its last hop node. Then, move to **Step 7**. Otherwise, the RREQ will be discarded by the destination node. By then, jump to **Step 8**.

3. According to the values in the source address field and broadcast ID field of the RREQ, it looks for its broadcast ID cache table. In case, there is a broadcast ID cache entry which has the same value of request broadcast ID field and request source address field as those of the RREQ, move to **Step 6**. Otherwise, move to **Step 4**.

4. Since the node is the first time to get the RREQ, it will insert the value of RREQ's requested source address field and the value of RREQ's requested

broadcast ID field into the broadcast ID cache table, then set up the reverse route with its last hop node.

5. If a node has the route to the destination node, move to **Step 7**. Otherwise, the node will consider its energy and will check if it is greater than or less than equal to the threshold energy. If energy is equal to or below threshold energy it will drop the RREQ and go back to path rediscovery else, the node will consider its energy and load level parameters and calculate the delay using the mathematical formula. Also, after delay has arrived, the node will broadcast the RREQ. Then move to **Step 2**.

6. Since the node got an RREQ some time as of late. The node will discard the got RREQ which comes from its last hop node, rather than set up the reverse route with its last hop node. Then, move to **Step 8**.

7. The node sends an RREP to the source center. The establishment of the route is done.

8. The node does nothing.

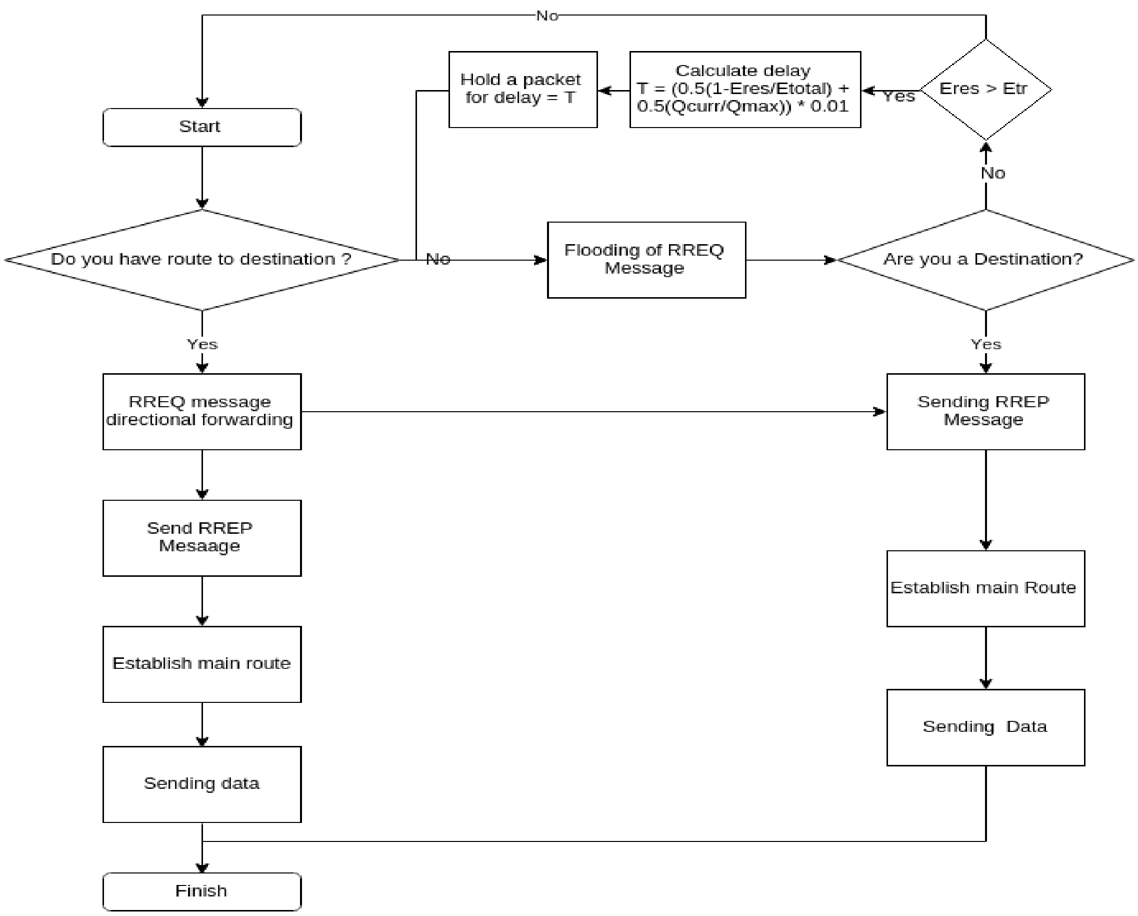

Figure 3.1: ENL-AODV Algorithm Flow Chart

3.1.2 Mathematical Model

Residual Energy consideration of Node

We suppose the selected route should have enough energy for data transfer, so that when the source node decides to send data packets, the residual energy will enable the packet not to drop during transmission and energy of network not to be depleted rapidly. Hence, when the source node wants to transmit a data packet to the destination and for path selection it broadcasts a route request, then an intermediate node which has received the RREQ will make a delay. The delay will depend on the amount of the current remaining(residual) energy of the node such that on the next broadcast the node with enough residual energy will be preferentially selected. The mathematical model to calculate the delay based on residual energy is:

Whenever node sends or receives a data packet the energy needed for transmission is measured by power required for data transmission by the node and handling time.

$$Energy = Power \times Time$$

Handling time is defined as follows:

$$Time = 8 \times PacketSize/Bandwidth$$

- Transmission Energy: E_t
- Receiving Energy : E_r
- Transmission Power : P_t
- Receiving Power : P_r

We have,

$$E_t = P_t \times Time$$

$$E_r = P_r \times Time$$

Therefore, the total energy consumed by node (E_{total}) is:

$$E_{total} = E_t + E_r$$

We suppose current residual(remaining) energy of a node is E_{res} varying between [0, E_{total}] and defined threshold energy E_{tr}, which is 30% of total energy(E_{total}). The energy weight for calculation of delay is W_{en}.

$$W_{en} = 1 - E_{res}/E_{total}$$

We know 0 $\leq W_{en} \leq 1$;

Whenever a node has to forward RREQ to its neighboring nodes, it will consider it's residual energy and check if it is below or above the threshold. So, RREQ will be dropped if $E_{res} \leq E_{thr}$, else will calculate the delay based on residual energy and load level and when the delay has arrived broadcast the RREQ.

Load Level consideration of Node

The current number of packets in the buffer queue of a node which is usually referred as load level of the node has influenced on broadcasting the control packets during route discovery.

Assume that, the maximum capacity of buffer queue is Q_{max} packets and current packet number in the buffer queue is $Q_{curr}. So the load level weight W_l$ for calculation of delay is :

$$W_l = Q_{curr}/Q_{max}$$

We know, 0 $\leq W_l \leq 1$, which describes larger the W_l is heavier the load of the node.

The Delay Model

As in the proposed routing protocol ENL-AODV, the delay depends on two metrics i.e. residual energy and load level of the node. So by combining both the approached discussed above we have mathematical model for delay (T):

$$T = (e * W_{en} + l * W_l) * T_c$$

Where e, l are constants and $0 \leq e \leq 1$, $0 \leq l \leq 1$, and T_c is a delay constant, so while selecting delay constant it should be kept in the mind that it shouldn't be too large. In the proposed algorithm it is chosen as 0.01.

3.1.3 Topology Example

In the previous section, we discussed a mathematical model of proposed protocol "energy and load based AODV (ENL-AODV) protocol," where we have added a delay (jitter) in route discovery stage while broadcasting RREQ packets. The delay is dependent on remaining energy and load situation of the node. From the mathematical model, the delay is inversely proportional to the residual energy as the initial energy of each node is constant. So the delay in the broadcasting of RREQ produced by a node will be less if that node has higher residual energy, which enables it to get preferentially selected for path formation.

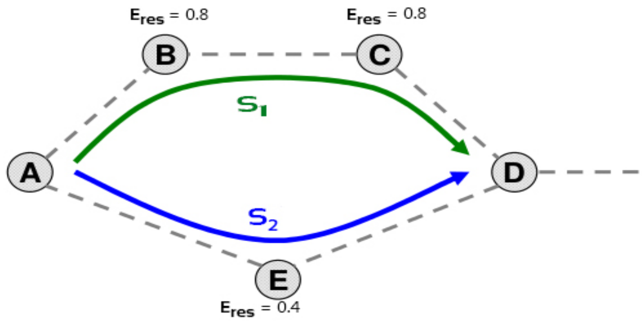

Figure 3.2: Topology example for residual energies of Nodes.

Consider the topology shown in the Figure 3.2 Node A is a source node, and two paths emerging from node A, i.e., path S_1 ([A, B, C, D])and path S_2 ([A, E, D]). Node D is an intermediate node, where the path to destination passes through node D. At a certain instant the residual energies (in Joules) of each intermediate node are as shown in the figure and initial energy of each is assumed to be 1 Joule. Also, we assume the time required for traveling control packet from node to another node as so small in comparison with delay added that it should be neglected. So whenever source node A wants to send a data packet to the destination, it starts route discovery process and broadcasts an RREQ to its neighbors. Let's consider path S_2; RREQ reaches node E, so it generates a delay which is proportional to 1-E_{res} (neglecting load situation) which results in a delay that is proportinally equivalent to 0.6. While considering path S_1 consisting nodes B and C. The delay produced by both nodes according to their residual energy is 0.4, which sum of proportionally equivalent delay produced by each of them as they have both have residual Energy 0.8 Joules.

Considering delay of both the paths S_1 and S_2 which is 0.6 and 0.4 respectively, RREQ initiated by source node A will reach node D by path S_1 earlier than S_2. As node D is an intermediate node, so when RREQ from path S_2 will reach at node D later it will be discarded as it is the same RREQ initiated from node A. So here path S_1 with higher energy will be selected over path S_2 with lower energy. And if there will be a node with less than 30% of initial energy then RREQ at that node will be discarded before broadcasting. In this way , our approached is proved to be better over the existing AODV approach leading to paths having higher energy and more network lifetime.

3.2 Performance Evaluation

As mentioned in the previous sections, we implemented ENL-AODV routing protocol in NS_2 network simulator. It is discrete event-driven network simulator, which supports various mobile ad-hoc network routing algorithms. So in NS_2 we have implemented the improved AODV i.e., ENL-AODV routing protocol and compared it with existing AODV routing protocol. In our simulation model, we prototyped MANET networks over a wireless channel with Two-Way Ground reflection propagation model. Drop-Tail/Priority Queue is used as queuing model with 802.11 MAC protocol.

S.No.	Name of Parameter	% Set Values
1.	Channel	wireless channel/wireless physical
2.	Propagation Model	Two way ground Reflection Model ×500
3.	Queuing Model	Drop-Tail/ Priority Queue
4.	MAC Protocol	802.11
5.	Traffic	CBR
6.	e	0.5
7.	l	0.5
8.	Tc	0.01

Table 3.1: ENL-AODV Algorithm Parameters

3.2.1 Simulation Environment

To simulate both routing protocols in NS2 network simulator, we used virtual network field of area 500 × 500 with a dynamic topology where nodes are free to move in any direction. Random waypoint model is used as mobility model with Two-Way ground radio propagation model. Communication range for each node is set as 250 meters and at application layer CBR CBR traffic generator is applied to produce data packets at the rate of 1 Mbps and bandwidth is 2Mbps. The simulation runs for 150 seconds while each node's maximum capacity of buffer queue is taken as 50. With a particular goal to imitate the rule-less development in this present reality, the *setdest* command is used to get rule-less random movement of node creating a random topology. Analysis are made on different velocities of mobile nodes they are: 2 m/s, 5m/s and 10m/s.

3.2.2 Results

In NS2 network simulator[18], we implemented and analyzed both existing AODV and ENL-AODV routing protocols with the simulation environment as described in the previous section. On simulation, we compared both the protocols on the basis of most

S.No.	Name of Parameter	% Assigned value
1.	Number of Mobile Nodes	20, 40, 60, 80
2.	Network field area	500 ×500
3.	Communication Range	250 m
4.	Maximum size of Buffer Queue	50
5.	Mobile Speeds of Nodes	2 m/s, 5 m/s, 10 m/s
6.	Maximum Connections	10

Table 3.2: Parameter values for NS2 Simulation

commonly used performance metrics: Packet Delivery Ratio, Average End-to-End delay, Throughput and Network Lifetime. The comparative analysis is shown in Figure 3.3, Figure 3.4, Figure 3.5, Figure 3.6, Figure 3.7 and Figure 3.8.

Packet Delivery Ratio

It is the ratio of data packets successfully arrived at destinations to that data packets originated at sources. Mathematically, it is represented as P_1/P_2, where P_1 is the sum of data packets successfully arrived at each destination and P_2 is the sum of data packets originated at each source in the network. It is also called packet delivery fraction. PDR(Packet Delivery Ratio) reflects the performance of the routing protocol. Higher PDR means better the network performance. Figure 3.2 shows simulation results of packet delivery ratio of ENL-AODV and AODV with a different number of nodes. If we compare the average growth rate of both the protocols, the delivery ratio of ENL-AODV is an average of 5.5 % higher than AODV's. Which clearly implies that ENL-AODV optimizes the network performance.

Average End-to-End Delay

It is defined as average time consumed by the data packet to successfully arrive at the destination. It also includes delay caused by route discovery process and also the delay due to queuing in a buffer in data packet transmission. It is inversely proportional to network performance, i.e., lower the end-to-end delay better the routing protocol for a network.Figure 3.3 shows simulation results of Average End-to-End Delay of ENL-AODV and AODV with a different number of nodes. According to calculation average reduction rate, in the case of ENL-AODV is an average of 5.8 % lower than AODV's which clearly implies an increase in performance of a network.

Throughput

Throughput or network throughput is the average rate of successful message delivery over a communication channel i.e. data whether or not data packets correctly delivered

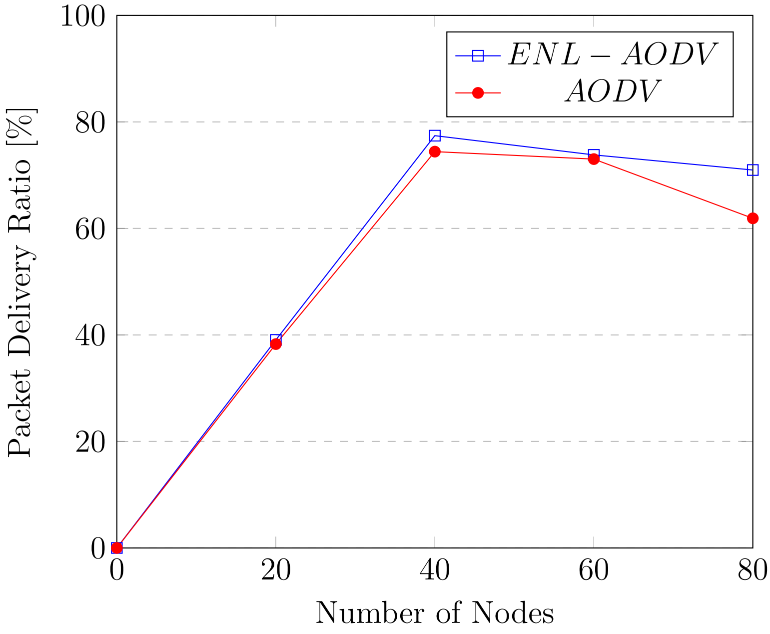

Figure 3.3: Packet Delivery Ratio

to the destinations. Figure 3.4 shows the simulation results of throughput vs number of nodes. If we compare the average growth rate of both the protocols, the throughput of ENL-AODV is an average of 9.48 % higher than AODV's. While increase in number of nodes tends to increase the network throughput.

Network Lifetime

Network lifetimes is a measure of time of network. the number of energy exhausted nodes during simulation. In NS2 we have carried out simulation over 200 seconds and number of exhausted nodes at different time are measured. Figure 3.5, Figure 3.6, Figure 3.7 shows the simulation results of the number of energy exhausted nodes under the maximum speed of 2 m/s, 5 m/s and 10 m/s respectively. It clearly indicates that ENL-AODV performs better and have higher network lifetime than AODV routing protocol.

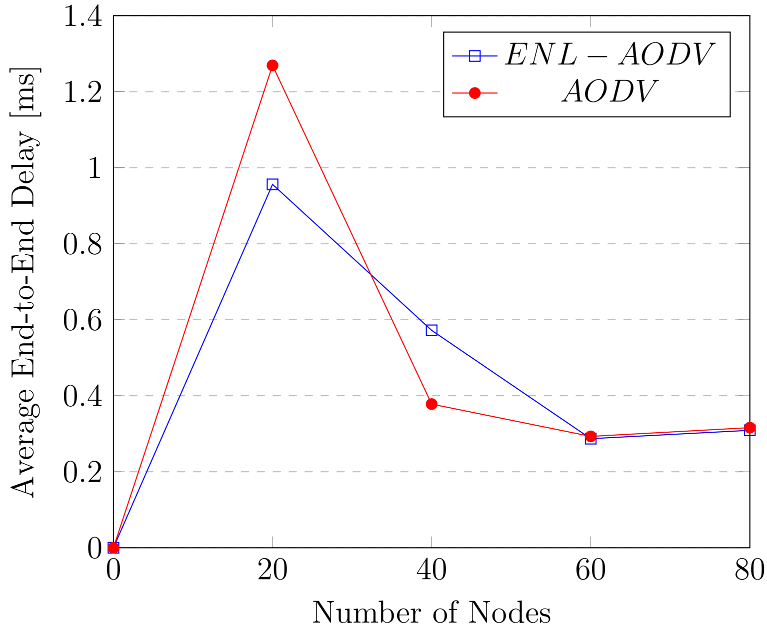

Figure 3.4: Average End-to-End Delay

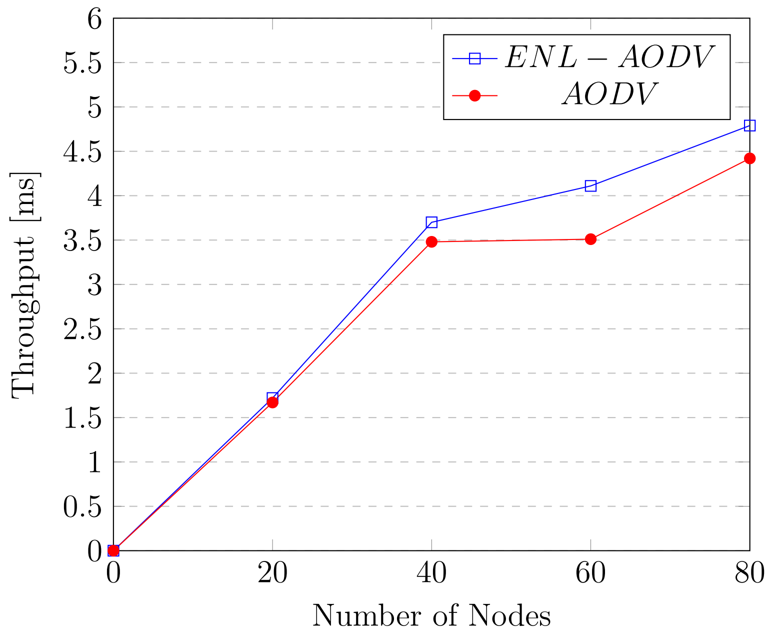

Figure 3.5: Throughput

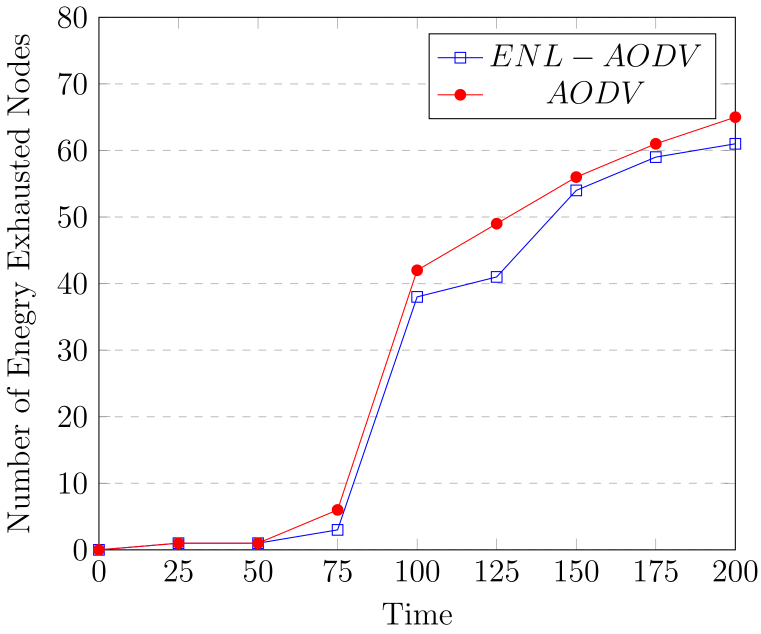

Figure 3.6: Network Lifetime under Max Speed 2 m/s

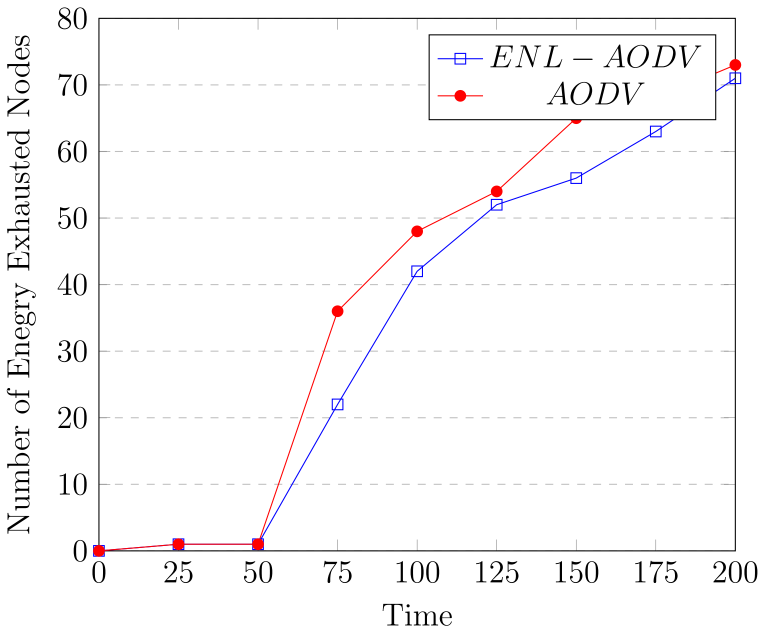

Figure 3.7: Network Lifetime under Max Speed 5 m/s

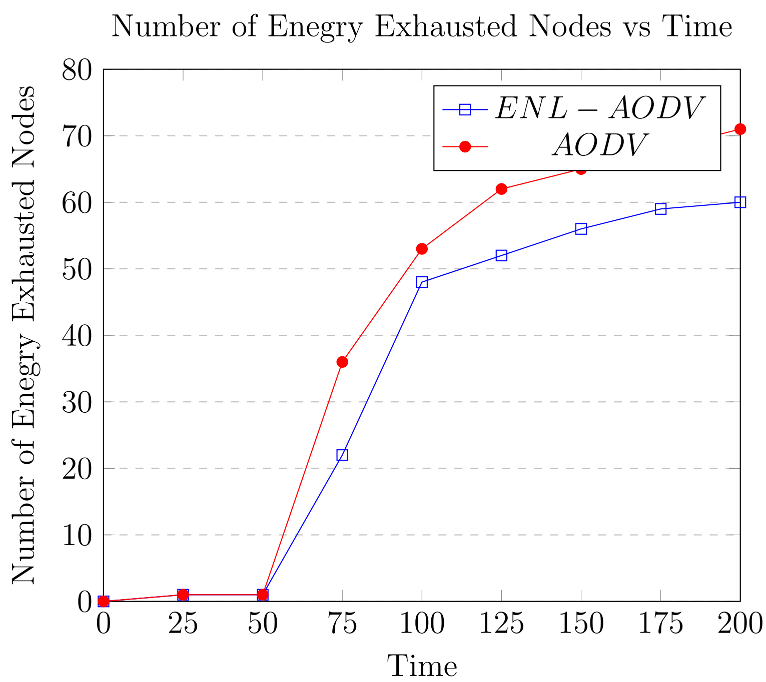

Figure 3.8: Network Lifetime under Max Speed 10 m/s

Chapter 4

Conclusion

We proposed ENL-AODV routing protocol, which is energy and load-based routing protocol. ENL-AODV is a modification of AODV protocol with consideration of residual energy and load level of a node in route discovery stage. In mobile ad-hoc networks, the energy of participating nodes and node's capacity to process the number of packets during data transfer plays a critical role in performance a network. So we have installed energy and load parameters in AODV algorithm and compared ENL-AODV with existing AODV by simulating on NS2 network simulator. To compare both the protocols we used performance metrics such as packet delivery ratio, throughput, average end-to-end delay and network lifetime and found our proposed protocol, ENL-AODV performing better than existing AODV routing protocol. As a result, we improved packet delivery ratio, throughput, and average end-to-end delay. Also, we extended the network lifetime.

Scope for Further Research

In ENL-AODV, we have installed jitter between forwarding RREQ packet in route discovery stage making jitter be dependent on residual energy and load level of the node. But at some cases, our protocol fails to select the optimal path with nodes having highest energy. So while broadcasting RREQ if we are able to get energy information of neighbors then we can forward RREQ to the only neighbor with the highest energy then we can reduce redundant RREQ in the network as well as get the path with highest energy for communication.

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