ESAR: Energy Saving Ad Hoc Routing Protocol for Mobile Ad Hoc Networks

Project submitted in partial fulfillment of the requirements for the degree of

Bachelor of Technology

in

Computer Science and Engineering

By

Utkarsh

Mukesh Kumar Mishra

Department of Computer Science and Engineering

National Institute of Technology Rourkela

Rourkela, Orissa, 769008, India

May 2012

ESAR: Energy Saving Ad Hoc Routing Protocol for Mobile Ad Hoc Networks

Project submitted in partial fulfillment of the requirements for the degree of

Bachelor of Technology

in

Computer Science and Engineering

By

Utkarsh

Mukesh Kumar Mishra

Under the guidance of

Prof. Suchismita Chinara

Department of Computer Science and Engineering

National Institute of Technology Rourkela

Rourkela, Orissa, 769008, India

May 2012

Department of Computer Science and Engineering
National Institute of Technology Rourkela
Rourkela-769 008, India. www.nitrkl.ac.in

Dr. Suchismita Chinara
Assistant Professor

May 13, 2012

Certificate

This is to certify that the work in the project entitled *ESAR*: *Energy Saving Ad Hoc Routing Protocol for Mobile Ad Hoc Networks* by Utkarsh and Mukesh Kumar Mishra is a record of an original work carried out by them under my supervision and guidance in partial fulfillment of the requirements for the award of the degree of Bachelor of Technology in Computer Science and Engineering. Neither this project nor any part of it has been submitted for any degree or academic award elsewhere.

Suchismita Chinara

Acknowledgment

This project would not have been possible without the help, support, and cooperation of many. At the outset, we would like to express our sincere thanks to Prof. Suchismita Chinara for her advice during our project work. As our supervisor, she has constantly encouraged us to remain focused on achieving our goal. Her vast knowledge and expertise in the area of networking was immensely helpful. Her observations and comments helped us to establish the overall direction of the research and to move forward with investigation in depth. She has helped us greatly and been a source of knowledge.

We are highly indebted to Prof. Ashok Kumar Turuk, Head-CSE Department, for his continuous encouragement and support, as he has always been eager to help. We are also thankful to Prof. S.K. Rath, Prof. S. K. Jena, Prof. B. Majhi and all the faculty members and staffs of the department for their support.

We are thankful to all our friends. Our sincere thanks to everyone who has provided us with inspirational words, a welcome ear, new ideas, constructive criticism, and their invaluable time, we are truly indebted.

We must acknowledge the academic resources that we have acquired from NIT Rourkela. We would like to thank the administrative and technical staff members of the department who have been kind enough to advise and help in their respective roles.

Last, but not the least, we would like to dedicate this project to our families, for their love, patience, and understanding.

Utkarsh(108CS060)

Mukesh Kumar Mishra(108CS071)

Abstract

Mobile ad hoc networks support multi hop routing where the deployment of central base station is neither economic nor easy. Efficient routing of the packets is a major challenge in the ad hoc networks. There exist several proactive (like DSDV etc.) and reactive (Like AODV etc.) routing algorithms for the dynamic networks. The proactive or the table driven routing algorithms maintain consistent information about the path from each node to every other destination by periodically updating their routing tables. After storing all the possible paths from the source to the destination, ESAR considers the following two parameters to select a suitable path for packet transmission:

(i) The minimum available battery power of a node in the i^{th} path, E_i

(ii) The actual distance between the source and the destination in the i^{th} path, $Dist_i$.

Then the cost of the path is calculated as:

$Cost_i = \alpha * D_{Ei} + \beta * Dist_i$

Where α and β are the weighing factors that decide the priority of the battery power or the distance between the nodes in a network topology. The ESAR algorithm selects the path with minimum cost value indicating that the path has the shortest distance to the destination and has the maximum of the minimum available battery power of the node among the different paths. This selected path is chosen as the best path for packet transmission till any node in the path exhausts battery power beyond a threshold value. At this point of time, a backup path having the next lower cost is selected as an alternate path for packet transmission. The process is repeated till all the paths from the same source to destination are exhausted with their battery power. When this situation occurs, the cost of the paths is re-calculated and the process continues. The simulation result of the proposed algorithm ESAR enhances the network life time over the AODV and EEAODR algorithm.

.

Keywords: Mobile Ad-hoc Networks; Multipath Routing; Routing Protocols; Energy Efficiency; Network Life Time.

Contents

List of Figure

List of Abbreviations

PDA	Personal Digital Assistant
MANET	Mobile Ad hoc Network
DoS	Denial of service
QoS	Quality of service
PAN	Personal Area Networking
MTU	Maximum Transfer Unit
DSDV	Destination Sequenced Distance vector
FSR	Fisheye State Routing
DSR	Dynamic Source Routing
MPDV	Multi-Path Distance Vector
AODV	Ad-hoc On-demand Distance Vector
WRP	Wireless Routing Protocol
LEARAODV	Local Energy-Aware Routing based on AODV
PAR-AODV	Power-Aware Routing based on AODV
LPR-AODV	Lifetime Prediction Routing based on AODV
ZRP	Zone Routing Protocol
ZHLS	Zone Based Hierarchical Link State
HARP	Hybrid Ad-hoc Routing Protocol
RREQ	Route Request
RREP	Route Reply
RERR	Route Error
DLL	Data Link Layer

Chapter 1

Introduction

Chapter 1

Introduction

Mobile Ad Hoc Networks

With the advancement in technologies and relatively low cost, there is a rapid rise in the use of personal communication devices like mobile phones, personal digital assistants (*PDAs*) and mobile computers. These devices easily get access to network through wireless interfaces.

(a) An infrastructured network with two base stations. (b) A mobile ad-hoc network.

Fig 1 Infrastructured and ad-hoc networks

There exist three types of mobile wireless networks: *infrastructured networks*, *ad-hoc networks* and *hybrid networks* which combine infrastructured and ad-hoc aspects.

An infrastructured network (Figure 1(a)) comprises of wireless mobile nodes and one or more connecting bridges (called as *base stations*) to connect the wireless network to the wired network. A mobile node within the network looks for the nearest base station (e.g. the one with the best signal strength), connects to it and communicates with it. In this type of network, all communication takes place between the wireless node and the base station and not between different wireless nodes.

When any mobile node gets out of range of the current base station, a *handover* to a new base station occurs and that will let the mobile node communicate seamlessly with the new base station.

These wireless interfaces also allow the devices to interconnect directly with each other in a decentralized way and *self-organize* into "*Ad Hoc Networks*". An ad-hoc network does not have any infrastructure. It is devoid of base stations, routers and centralized administration. Nodes may move randomly and connect dynamically to one another. Thus all nodes act as routers and must be capable of discovering and maintaining routes to every other node in the network and to forward packets accordingly.

Mobile Ad hoc Networks (MANET) is a communication network formed by the union of autonomous aggregation of mobile nodes (computers, mobiles, PDAs etc.) and connecting wireless links. The network is modeled in the form of an arbitrary communication graph. In a MANET, there is no fixed infrastructure (Base Station) and since nodes are free to move, the network topology may dynamically change in an unpredictable manner. MANET is decentralized and self-organizing network where the functions from discovering the network topology to delivering the message are carried out by the nodes themselves; In this network each node acts as a router along with its job as an ordinary device.

The organization of Ad hoc networks is peer-to-peer multi hop and information packets are relayed in a store-and-forward mode from a source to any arbitrary destination via intermediate nodes. As the nodes are mobile, any change in network topology must be communicated to other nodes so that the topology information can be updated or eliminated. It is not possible for all mobile nodes to be within the range of each other. However, all the nodes are close by within radio range.

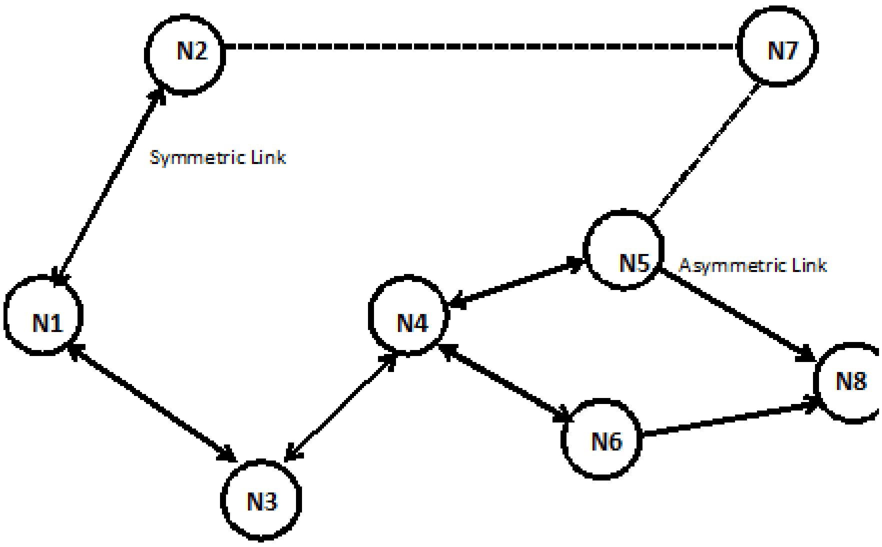


Fig 2 Mobile Ad Hoc Network Topology

1.1 Design Issues/Challenges

MANET raises some issues while designing the network topology. Some of the major considerations include:

- Power Consumption, Battery Life and Spatial Reusability
- Symmetric (bi-directional) and Asymmetric (unidirectional) links
- Mobility pattern of nodes
- Scalability
- Quality of Service (QoS)

1.2 Characteristics of a MANET

MANET is characterized by some specific features as follows:

- **Wireless:** The nodes are connected by wireless links and the communication among nodes is wirelessly.

- **Ad hoc based:** A MANET is a need based network formed by the union of nodes and the connecting links in an arbitrary fashion. The network is temporary and dynamic.

- **Autonomous and infrastructure less:** Network is self-organizing and is independent of any fixed infrastructure or centralized control. The operation mode of each node is distributed peer-to-peer capable of acting as an independent router as well as generating independent data.

- **Multi hop Routing:** There is no dedicated router and every node acts as a router to pass packets to other nodes.

- **Dynamic Topologies:** Due to arbitrary movement of nodes at varying speed, the topology of network may change unpredictably and randomly.

- **Energy Constraint:** Energy conservation becomes the major design issue as nodes in the MANET rely on batteries or some other exhaustible source of energy.
- **Limited Bandwidth:** Infrastructure less networks have lower capacity as well as less

throughput than the infrastructure based network.

- **Security Threats:** There are higher chances of physical security threats like eavesdropping, spoofing and denial of service (DoS) in wireless networks as compared to wired networks.

1.3 Applications

Because of their flexibility, MANETS are seen as important components in 4G architecture and ad hoc networking capabilities are believed to form a significant part of overall functionalities of next generation. The application of MANET has become wide and varied from email to ftp to web services. Some common MANET applications are:

- **Personal Area Networking:** Devices like laptops, PDAs, mobile phones create a temporary network of short range to share data among each other called the personal area network (PAN).

- **Military Environments:** Since it is not possible to install base station in the enemy territories or inhospitable terrain MANET provides communication services where soldiers act like nodes. The required coordination among the soldiers and in military objects can be seen as another application of MANET in military services.

- **Civilian Environments:** MANET finds its use in many civilian activities like taxi cab network, meeting rooms, sports stadiums, boats, small aircraft, etc.

- **Emergency Operations:** Because of its easy deployment, the use of MANET in situations like search and rescue, crowd control, disaster recovery and commando operations, the use of mobile ad hoc networks is very much suitable. MANET can also be established when conventional infrastructure based communication is damaged due to any calamities.

1.4 Routing

Routing is the process of choosing a path in a network for moving packets form source to destination. It basically involves two processes like finding an optimal routing path and transfers the packets in the internetwork.

Routing information of a node is maintained in a routing table. The routing table contains only partial information about possible destinations. For the unknown destinations, these are forwarded to the default router. However the potential problem to this mechanism is some destinations might be unreachable.

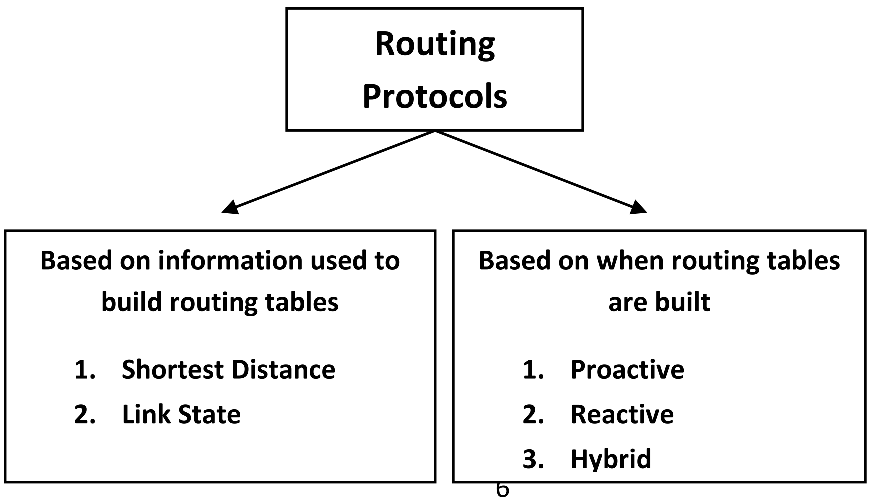
1.4.1 Routing Protocols

A routing protocol is the software or hardware implementation of a routing algorithm. A routing protocol uses metrics to select a path to transmit a packet across an internetwork. The metrics used by routing protocols include:

- Number of network layer devices along the path (hop count)
- Bandwidth
- Delay
- Load
- Maximum Transmission Unit (MTU)
- Cost (in terms of Energy Consumption and Time)

1.4.2 Types of Routing Protocol

Routing protocols are broadly categorized on two bases: based on what information is used to build the routing table and based on when the routing tables are built.



1. Based on the information used to build routing tables:

a. Shortest distance algorithms: algorithms that use distance information to build routing tables.

b. Link state algorithms: algorithms that use connectivity information to build a topology graph that is used to build routing tables.

2. Based on when routing tables are built:

a. Proactive algorithms: even if not needed, routes to destinations are maintained.

Examples:

Shortest Distance Approach: Destination Sequenced Distance vector (DSDV)

Link State Routing Approach: Fisheye State Routing (FSR)

b. Reactive algorithms: routes to destinations are maintained only when they are needed.

Examples:

Dynamic Source Routing (DSR)

Ad-hoc On-demand Distance Vector (AODV)

c. Hybrid algorithms: for nearby nodes, routes are maintained even if they are not needed and for far away nodes routes maintained only when needed.

Examples:

Zone Routing Protocol (ZRP)

1.4.3 Routing Protocols in MANET

Routing is one of the major challenges in MANETs due to their highly dynamic and distributed nature. The routing protocols for MANETs are broadly classified as *table-driven* and *on-demand driven* based on the timing of when the route tables are built / updated.

Table-driven routing protocol is a *proactive approach* for the reason that when a packet is to be forwarded the route is known in priori and can be used immediately. Each node tries to maintain a consistent, up-to-date routing table containing information of every other node in the network.

The routing table contains a list of all the destinations, the next hop, and the number of hops to each destination. Each node updates its routing table in response to the change in network and communicates the updates to all its neighboring nodes. The table is created using either *link-state* or *distance vector* algorithmic approach. Some popular routing protocols like *Destination-Sequenced Distance Vector (DSDV)* and *Fisheye State Routing (FSR)* protocol belong to this category. These protocols differ in the number of routing tables and the procedures used to exchange and maintain routing tables.

In on-demand driven routing, routes are found only when a source node requires them. *Route discovery* and *route maintenance* are two basic procedures for these kind of routing algorithms.

In route discovery route-request packets are sent from a source to all its neighbor nodes. These neighboring nodes forward the request to their neighbors, and so on. On arrival of the route-request to the destination node, it responds back by sending a unicast route-reply packet to the source node through the neighboring nodes through which it first received the route-request. Once the route-request reaches an intermediate node that has sufficiently up-to-date route, it ceases forwarding and sends a route-reply message back to the source.

Route establishment is followed by route maintenance process which maintains internal data structure called a route-cache, of each node till the destination is inaccessible along the path. The nodes along the path from source node to destination node, are aware of the routing paths with passage of time.

As opposed to table-driven routing protocols, not all up-to-date routes are maintained at every node. *Dynamic Source Routing* (DSR) and *Ad-Hoc On-Demand Distance Vector* (AODV) are popular examples of on-demand driven protocols.

1.5 Multipath Routing

Typically, nodes in MANET are characterized by their limited power, limited processing, limited memory resources but high degree of mobility. The wireless mobile nodes, in such networks, may dynamically enter as well as leave the network. These nodes have limited transmission range and therefore, multiple hops are usually required for message exchange among nodes in the network. For this reason, routing becomes a crucial design issue of a MANET.

Routing protocols in MANETs like AODV and DSR, usually intend to find a single path between a source and destination node. Multipath routing is finding multiple routes between source and destination nodes. It comprises of three components: route discovery, route maintenance, and traffic allocation. These multiple routes between a source node and a destination node compensate for the dynamism and unpredictability of ad hoc networks.

There are basically two existing *Multipath Routing Models*: MPDV (Multi-Path Distance Vector) and MPLS (Multi-Path Link State). These models consist of two different routing algorithms based on extensions of the traditional routing algorithms.

The concept of multipath routing came into existence to assist in a variety of applications in MANETs that supports load balancing, fault-tolerance (reliability data transmission), energy conservation, minimization of end-to-end delay and higher aggregate bandwidth. Because of the limited bandwidth between the nodes, load balancing is very important in MANETs and it can be achieved by spreading the traffic along multiple routes. Multipath routing can provide route resilience that aims to solve the fault tolerance problem. When multiple paths are used simultaneously to transmit data, the aggregate bandwidth of the paths may fulfill the application bandwidth requirement. Increased available bandwidth may contribute to a smaller end-to-end delay. Multipath routing also finds its application to support energy-conservation and Quality-of-Service (QoS).

Better throughput is achieved by using multipath routing than using unipath routing in high density ad hoc networks. However, there are some disadvantages of using multi path routing over unipath routing; the primary being complexity and overhead. Maintaining multiple paths to a destination, in multipath protocols, results in greater number of routing tables at intermediate nodes. Also the method by which packets are allocated to the multiple routes has to be considered. It can result in packet reordering. Again traffic allocation is not an issue in unipath routing, since only one path is used. A comparative analysis of both advantages and disadvantages of multipath routing over unipath routing suggests multipath routing is desirable for MANET.

1.6 Energy Efficient Routing

An ideal network is the one that can function as long as possible. On the other hand, optimal routing requires future knowledge and thus, it is not practically viable to have optimized routing in energy constrained environment. Therefore, instead of having energy optimal scheme, we have a statistically optimal **energy efficient** scheme that considers only past and present and not future knowledge. In order to avoid coverage gap in many surveillance / monitoring applications, **lifetime** of network is defined. Instead of average time or overall scenarios, the worst case (when a first node dies out) is maximized.

Establishing correct and energy efficient routes, in mobile ad hoc networks, is not only an important design issue but also a challenging task. It is because operation time of mobile nodes is the most critical limiting factor. Mobile nodes derive their power from batteries with limited capacity. Power failure of a mobile node affects the node as well as its ability to propagate packets on behalf of others and therefore the overall network lifetime is affected.

Energy efficient routing aims to minimize the energy required to transmit or receive packets i.e., ***active communication energy.*** It also tries to minimize the energy consumed when a mobile node stays idle but listens to the wireless medium for any possible communication requests from other nodes i.e., ***inactive energy***. ***Transmission power control approach*** and ***load distribution approach*** minimizes active communication energy and ***sleep/power-down mode approach*** minimizes inactive energy. Each protocol has definite advantages/disadvantages and is well-suited for certain situations and it is not clear any particular algorithm or a class of algorithms is the best for all scenarios.

Many researches are being carried out to develop energy aware routing protocols. New energy efficient routing algorithms are proposed and designed to enhance the network survivability. This is achieved by maintaining the network connectivity to lead to a longer battery life of the terminals. In contrast to AODV which optimizes routing for lowest delay, the energy efficient protocols ensure the survivability of the network which is to ensure that all nodes equally deplete their battery power.

Some of the proposed energy efficient routing protocol includes ***Local Energy-Aware Routing based on AODV*** (LEARAODV), ***Power-Aware Routing based on AODV*** (PAR-AODV), and ***Lifetime Prediction Routing based on AODV*** (LPR-AODV).

Chapter 2

Literature Survey

Chapter 2

Literature Survey

2.1 Summary of Routing Protocol in Mobile Ad-Hoc Network [13]

In wireless Ad-hoc networks, nodes relay packets using multi-hop links. These lack any fixed infrastructure or base station for communication. Each node is capable of exchanging packets to/from other nodes, thus, acting as a router. Routing in ad-networks is a challenging task and it has been posing challenges from the time the wireless networks came into being. The reason for the constant change in network topology is due to high degree of node mobility. Many protocols have been proposed to accomplish this task.

The various routing protocols are reviewed along the typical characteristics of each protocol. Here, we discuss the major routing protocols in MANET:

2.1.1 Proactive, reactive and hybrid routing

One of the ways to classify MANET routing protocols is based on when and how routing information is gathered and maintained by mobile nodes. On this basis MANET routing protocols are classified into **proactive**, **reactive** and **hybrid** routing protocols.

In *proactive protocols* (also called "*table driven*" approach), nodes in the network regularly evaluate routes to all reachable nodes and tries to keep consistent and up-to-date routing information thereby facilitating a source node to get a routing path easily and immediately when required. All the nodes have to maintain a consistent view of the network topology and respective updates need be communicated throughout the entire network to notify any change in the topology. Most of the proactive routing protocols designed for MANET inherit properties from procedures deployed in wired networks and required amendments is made on conventional wired network routing protocols to incorporate the dynamic features of MANET. In this protocol nodes keep an updated network state and maintain a route when data traffic does not exist. This results in high overhead to maintain up-to-date network topology information. Some of the typical proactive routing protocols for MANET are Wireless Routing Protocol (WRP), Destination Sequence Distance Vector (DSDV) and Fisheye State Routing (FSR).

In *reactive protocols* (also called "*on-demand*" routing approach) routing paths are discovered only on demand. A route discovery task invokes a route-determination procedure and which terminates when either a route is found or there is no possible route available. Because of nodes mobility, active routes may be disconnected and therefore route maintenance is important in reactive routing protocols. A reactive routing protocol has less control overhead as compared to the proactive routing protocol and therefore a reactive routing protocol has better scalability than a proactive routing protocol. However, source nodes may suffer from long delays for route discovery in reactive approach. Dynamic Source Routing (DSR) and Ad hoc On-demand Distance Vector routing (AODV) are popular reactive routing protocols for MANET.

Hybrid routing protocols are the third category of routing protocols in MANET that combine the advantages and remedy the shortcomings of both proactive and reactive routing protocols. Generally, these protocols exploit hierarchical network architectures. Proper proactive and reactive routing approaches are utilized in different hierarchical levels, respectively. Some hybrid routing protocols for MANET are Zone Routing Protocol (ZRP), Zone-based Hierarchical Link State routing (ZHLS) and Hybrid Ad hoc Routing Protocol (HARP).

2.1.2 The Dynamic Source Routing (DSR) Protocol

The DSR is a reactive unicast routing approach that uses source routing algorithm where each data packet consists total routing information to reach its destination. Also, in DSR, each node uses caching method to maintain route information.

DSR involves the route discovery and the route maintenance phase. Before sending a packet, a source node first checks its route cache. If the required path is available, the source node includes the routing information in the data packet before sending and if not, the source node initiates a route discovery task by broadcasting route request (RREQ) packets. This RREQ packet has addresses of the source and the destination and a unique request identifying number. When a node receives a RREQ, it checks its own route cache. If the node doesn't have the routing information for the requested destination, it concatenates its address to the route record field of the RREQ. After that, the request packet is transmitted to its neighbors. A node processes RREQ in both cases when it has not seen earlier and the route record field does not have its address. This helps to limit the communication overhead. On arrival of RREQ to the destination or an intermediate node has route information to the destination, the node generates a route reply packet (RREP).

A RREP generated by the destination contains the addresses of the intermediate nodes that have been traversed by the RREQ. Otherwise, the RREP comprises the addresses of nodes the RREQ has traversed appended with the path in the route cache of the intermediate node.

When any disconnected link is discovered by data link layer (DLL) in DSR, it forwards a ROUTE_ERROR (RERR) packet to the source which then initiates another route discovery procedure. Moreover, when the source node receives the RERR packet, all the paths having the broken link need to be removed from the route caches of the immediate nodes.

Due to complete routing information into each data packet, the DSR has high traffic overhead which results in degraded routing performance. Figure 3 depicts the path discovery from source to destination in the DSR algorithm. As shown in the figure, each route indicates the complete path from the destination to source from which the source can realise the path to the later.

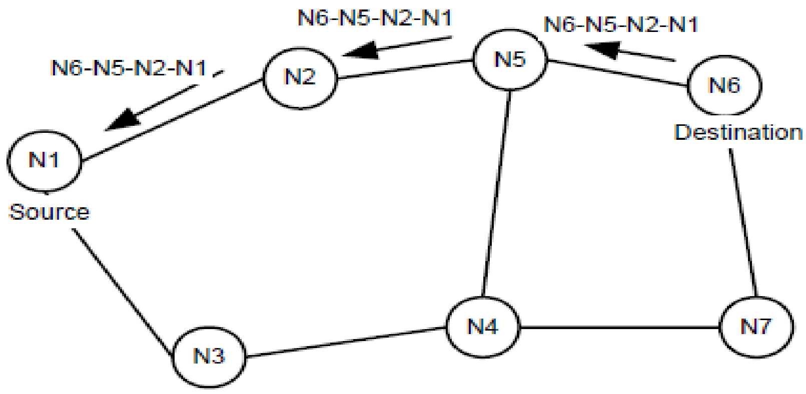


Fig 3 Route Reply with route record in DSR

2.1.3 Ad Hoc On-demand Distance Vector Routing (AODV) protocol

The AODV protocol is a reactive unicast routing approach for mobile ad hoc networks and therefore AODV only has to maintain the routing information about the active routes. Routing information in AODV is maintained in routing tables at nodes. Every node maintains a next-hop routing table that has the destinations to which it has an active route. A routing table entry drop dead if not used or reactivated for a predefined expiration time. Additionally, AODV assumes the destination sequence number mechanism as used in DSDV but in an on-demand way.

In AODV, in absence of available route, a source node initiates a route discovery procedure before sending a packet. The route discovery phase involves broadcasting of route request (RREQ) packets which contain source and destination addresses, broadcast ID, which acts as its identifier, the last visited destination's sequence number as well as the source node's sequence number.

Sequence numbers ensures loop-free and up-to-date paths. Flooding overhead in AODV is reduced by a node discarding RREQs by a node if it has seen before and the route discovery operation is done by expanding ring search algorithm. The RREQ initiates with a small Time-To-Live (TTL) value which is increased in the next RREQ if destination is not found.

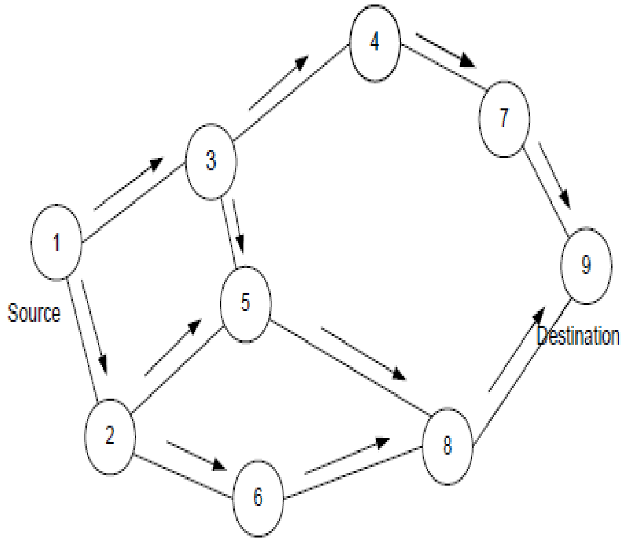


Fig. 4 The Route Request packets flooding in AODV

2.1.4 Temporally Ordered Routing Algorithm (TORA)

The TORA is an on-demand routing approach based on the link reversal concept. It enhances the partial link reversal mechanism by partitions detections and avoiding non-productive link reversals. TORA finds its application for highly dynamic MANET.

The network topology in TORA is represented as a directed graph: a Directional Acyclic Graph (DAG) accomplished for the network by assigning each node (i) a height metric (*hk).* A link direction from *k* to *m* indicates *hk* > *hm*.

Height metric of a node in TORA includes the logical time of a link failure, the unique node ID (defines the new reference level), a reflection indicator bit and a propagation ordering parameter. The former three components collectively represent the reference level and the last two define an offset with respect to the reference level. DAG allows TORA for many nodes to send packets to a given destination and thereby guarantees loop-free routes.

TORA consists of three basic operations: route creation, route maintenance and route erasure: route creation beginning with setting the destination height (propagation ordering parameter) as 0 and heights of all remaining nodes to NULL (i.e., undefined). The source broadcasts a QRY packet containing the ID of the destination. In response to it, a destination node (node with a non-NULL height) broadcasts a UPD packet containing its own height. A node on getting the UPD packet assigns its height to one added to than that of the UPD generator. A node having higher height is regarded as upstream and the as downstream. A directed acyclic graph is thus created from the source node to the destination node and can have multiple routes.

Route maintenance is important as DAG may be disconnected due to nodes mobility. The control messages in TORA are localized into those nodes that are near the occurrence of topology changes. A new reference level is generated and the reference is broadcasted to the neighbors when the last link is lost.

2.1.5 Comparison of DSR, AODV and TORA

AODV has lesser traffic overhead and is more scalable because of the limited size of route record field in DSR data packets.

DSR and TORA and not AODV support asymmetrical links and multiple routes. AODV exercises extra control traffic overhead due to periodic sending of Hello message by nodes.

While AODV and DSR use flooding to inform the affected nodes about a link failure TORA localizes the effect in a set of node near the periphery of the link failure.

To avoid formation of route loops AODV uses sequence numbers and DSR checks addresses in route record field of data packets. A loop-free property can be guaranteed in TORA because each node in a currently participating route has a unique height and packets are transmitted from a node with higher height to a lower one. But to achieve this all nodes in TORA must have synchronized clocks and oscillations may occur when coordinating nodes currently execute the same operation.

2.1.6 Destination Sequenced Distance Vector Routing Protocol

Destination Sequence Distance Vector (DSDV) is a table driven unicast MANET routing protocol.

The routing tables of DSDV stores the next hop towards a destination, the cost parameter for the path to the destination and a destination sequence number created by the destination to distinguish current routes from previous ones and avoid formation of route loops.

The updation of route table of DSDV is time-driven. Each node after certain time interval sends updates routing information to its immediate neighbors. The other method is to send the updates when there is a significant change from the last update in an event-triggered style.

Also, the DSDV sends routing table updates in two ways: "full dump" update type and the “incremental dump”. A full dump update contains full routing table inside the update and it could carry many packets while an incremental update includes only changes since the last update is sent and it fits in one packet.

2.2 A Performance Comparison of Energy Consumption for Mobile Ad Hoc Networks Routing Protocols [15]

A comparison of performances of DSDV, TORA, DSR and AODV based on simulation (ns2) shows that DSDV performs well at low node mobility rates and low speed of movements. For large number of source nodes the TORA’s performance decreases. AODV and DSR both perform well in different simulation conditions. DSR performs better than AODV because routing overhead in DSR is low when nodes are highly mobile. DSR outperforms AODV when number of nodes is small, lower load and /or mobility, and AODV performs better than DSR in more demanding situations.

Fig 5 Percentage energy consumption per packet type (CBR, MAC and routing)

Considering energy consumption due to routing protocol packets only, the DSR outperforms performs AODV and DSDV. It could be due to promiscuous overhearing and caching mechanisms used in DSR to reduce the discovery routes overhead. TORA high-energy consumption is mainly due to the aggregation of IMEP discovery routes packets and TORA maintenance packets.

Normally on-demand protocols such as DSR and AODV outperforms DSDV, and clearly better than TORA. The performance index of TORA is worst for all scenarios explored. The performance of DSR is generally better than AODV with an exception in static networks where they have similar behavior. There are several situations in which the performance of AODV is worse than DSDV, typically when longer paths are allowed. By combining (a) byte packet overhead (greater in DSR) and (b) number of routing packets (greater in AODV) outcome in general energy consumption favorable to DSR in all simulated execution. So, byte overhead in DSR due to source routing headers is not significant.

2.3 Performance evaluation and simulations of routing protocols in ad hoc networks [16]

Metrics	Protocols			
	AODV	DSR	TORA	DSDV
Delay	2	4	3	1
Jitter	1	4	3	2
Loss ratio	1	3	4	2
Throughput	1	3	4	2
Routing load	3	2	1	4
Scalability	3	2	1	4
Connectivity	1	2	4	3
Supporting multicast	YES	NO	NO*	NO

Note: NO* denotes TORA itself does not support broadcasts, but LAM which moves above the TORA, supports broadcasts.

1-4 denotes the decreasing performance; 1 being the best and 4 being the worst

Fig 6 Performance comparison of ad hoc routing protocols: AODV, DSR, TORA and DSDV

TORA has the lowest routing load and a good scalability; it functions as the fundamental protocol for the routing algorithms and supports multicast property. Among these four protocols, DSR has moderate routing load, a less loss ratio, a large throughput and a long delay for the moderate topology.

These properties make it suitable for medium scale network that does not have higher delay demand. DSDV is not suitable for large-scale and high-speed mobile wireless scenario because it needs to maintain the entire situation information. When network topology changes frequently and network size increases, there is quick increment of routing load. In all conditions, AODV exhibits the least delay and loss ratio and the highest throughput scalability. Also connectivity and the adaptive ability are of relative strength.

2.4 EEAODR: An Energy Efficient Ad-hoc On demand Routing Protocol for Mobile Ad-hoc Network [17]

EAODR is an improvisation on *Ad hoc On demand Destination Vector* protocol that calculates the routing path by considering power level of all the nodes in the network. This protocol is proposed to increase the life time of the network.

EEAODR makes use of the alternate paths to increase the network life. Here different paths are used depending on the optimality function of the routing path. Every time we use a different path for sending a packet which is not the case with AODV which always uses the same path every time for sending a packet.

A node in the network loses energy in transmitting, receiving, processing as well as when it is in idle state. The amount of energy that a node spends in any transaction depends on the nature and size of packets, and the distance from the source node to destination node. EEAODR uses an optimization equation that considers all the optimality factors to decide the best path (in terms of communication cost) among all the discovered paths.

Cost = σ × time + μ × 1/minimum battery power of node in route + τ× 1/ number of hops

The path that has minimum of the communication cost among all the possible paths between a source and destination node pair is chosen as the best path. This equation allows the network administrator to prioritize the optimality factors (time, battery power and no. of hops) based on network requirement.

Merits of EEAODR

The advantage of EEAODR over AODV is that EEAODR increases the network life as it considers the alternate paths rather than just considering the minimum hop path. It takes into account the energy of every node for selecting the best route. Apart from this EEAODR is flexible in its approach as it allows the network administrator to vary the priority of optimality functions: time, number of hops and power consumption in path, based on network requirement. Also, this approach keeps track of backup path and allows the nodes to sleep and wake up on need, thereby avoiding the path rediscovery saving energy.

Demerits of EEAODR

In spite of increasing network life time and providing energy load balancing EEAODR has some limitations. First and foremost limitation is since the destination nodes need to wait for δt time before calculating the best route, the network delay increases. Moreover, EEAODR finds a more optimized path, but at the cost of large control packet size even though the packet size is not very large. Also, deciding δt needs computing the density, that slightly increases the complexity and setting the values of μ, σ and τ in the cost equation requires expertise to analyze the network demand.

Chapter 3

Proposed Work

Chapter 3

Proposed Work

3.1 Basics of the Algorithm

The mobile ad hoc network can be modeled as a unidirectional graph G= (V, E), where V is the set of mobile nodes and E is the set of links that exist between the nodes in the network. By the virtue of mobility of the nodes they change their position and the connectivity is also changed. Thus, the cardinality of the nodes V remains same throughout where as the cardinality of the edges E changes with the mobility of the nodes. The link between two nodes exists when the distance between nodes i and j is less than their transmission range, i.e. $dist_{ij} < t_{range}$. Calculation of distance between the two nodes is done using the distance formulae as we know the coordinate position of each node as we are using GPS.

In such a multi hop network, packet routing takes place by the intermediate nodes that play the role of the routers. Every node maintains a routing table that gets updated periodically or with the occurrence of a specific event. The current work basically focuses on the event driven updation of the routing table. Energy Saving Ad Hoc Routing (ESAR) is an on demand routing algorithm where distance is the main factor for selecting the route between the source and destination and it is determined and maintained when they require sending data among each other. It is a hop-by-hop routing algorithm where each data packet carries the destination address as well as the next hop address. The routes are adaptable to the dynamic topology of the network as they update their routing table when receive any fresh information about the routes.

The nodes in the network may operate as a transmitter or as a receiver or even as an idle node that only listens to the packets and forward them to the next hop. The idle nodes consume the least energy [15], as idle node or we can say them as intermediate node between the source and destination only listens to the packet and forward them to the next hop, no processing is done here, only physical layer is involved here. As proper processing has to be done by the receiver (destination) and sender (source) there energy consumption will be higher than the intermediate nodes. The node that operates as the transmitter consumes maximum energy than that of the node that operates as the receiver. The formulae used for calculating the energy consumption is given by:

$$E=m*pkt\_size + \alpha,$$

Where,

E=Energy consumed by the node.

m=Incremental cost for energy consumption.

pkt_size=size of the packet in terms of bytes.

α=Fixed constant.

Here m, α is taken from [15], which is different depending on the type of node i.e. whether it is an intermediate node, a sender or a receiver. The node that operates as the transmitter consumes maximum energy than that of the node that operates as the receiver.

The energy dissipation by the nodes is different as per their mode of operation in the network.

$$E\ (total) = \sum E + m * tot\_distance$$

The total energy consumption of the route from source to destination is the sum up of the energy consumption of each node and the total distance between the source and destination.

3.2 Motivation for the work

In the well known AODV routing algorithm, the source node sends RREQ and waits for RREP from the destination. As the destination gets the first RREQ, it sends back the RREP through that path as that path is considered as the shortest path. Then after any RREQ message received by the destination is discarded. Considering the energy impact on the routing path, it is understood that as the same path is used for packet transmission by the source and destination, the energy consumed by the nodes in that path is very high [AODV].

This energy consumption issue was well addressed by Dhurandher et. al. author of EEAODR [17]. The authors in this work have considered alternate paths for packet routing so that specific nodes are not prone to energy consumption throughout and helps in even enhancing the network life time. Unlike AODV, when the destination receives the first RREQ, it waits for a δt time period to collect any other RREQ during that period. These paths are stored as the alternate paths for packet routing in order to save the energy consumption by the nodes of a fixed path selected as in the AODV algorithm. After the expiry of the δt time period, a best path is selected by computing the cost of each path stored for packet routing. The cost of the path is calculated by considering the maximum of the minimum battery power available with a node in all the alternate paths, the number of hops present between the source and the destination and the time required to cover the distance between the source and the destination. The path having the minimum cost among all the paths is selected as the path for packet routing. The objective of the work is to use alternate paths for packet routing so that the nodes in a single path are not dead because of battery drainage which ultimately results in the increasing of the network life. The simulation result of the work indicates that the energy consumed by the nodes selected in the path of AODV is reduced in EEAODR as alternate paths were selected for packet routing at times, thus the overall energy consumption in the AODV path i.e. minimum hop path by AODV is more than EEAODR. This also results in increasing the network life time because the battery power of certain nodes is saved. But in actual it is seen that the total energy consumed per packet by the nodes in the path of EEAODR is more than that of the total energy consumed by the nodes in the path of AODV. This is because the AODV always provides the minimum hops path i.e. intermediate nodes in EEAODR may be more or equal to that of AODV but never less than that and as the total energy consumption is the sum up of the energy consumption by the sender, receiver and the intermediate nodes and as the intermediate nodes will always be more or equal in EEAODR than in AODV thus the total energy consumption of EEAODR is more than that of AODV. Fig. 1 compares the energy consumed by the nodes in the actual path of routing for both AODV and EEAODR. This novel concept of EEAODR provides a motivation for choosing alternate paths for packet forwarding that can save the battery power of the nodes as well as the network life time could be improved.

As we discussed EEAODR increases the network life but compromises with the average energy consumption.

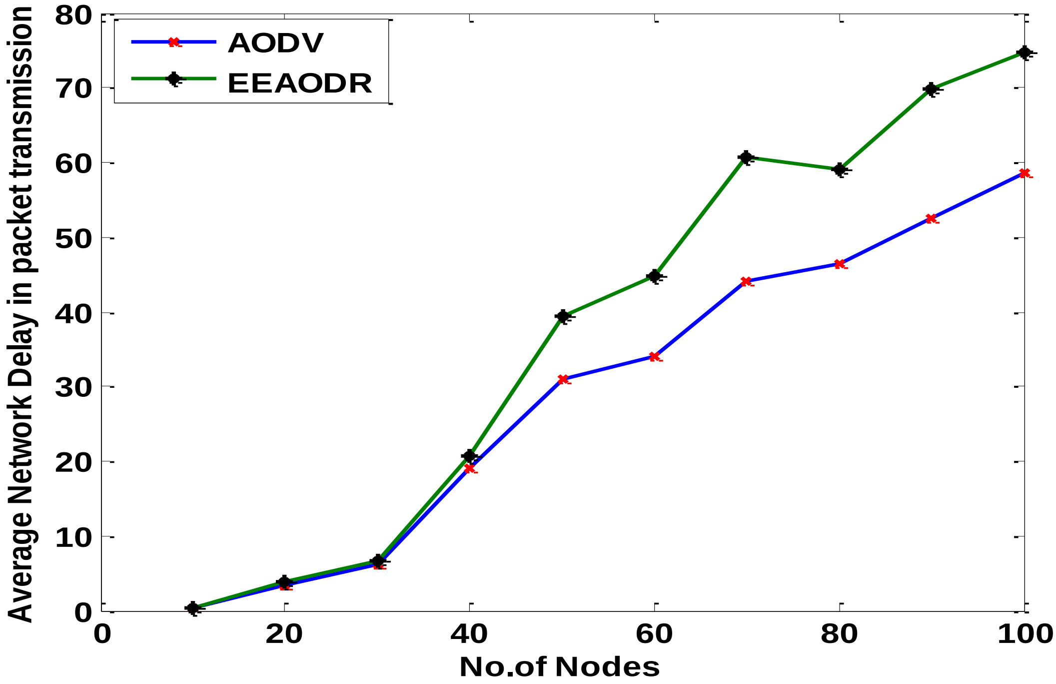


Fig 7 EEAODR fault with energy comparison.

The average network delay of EEAODR is more than AODV.

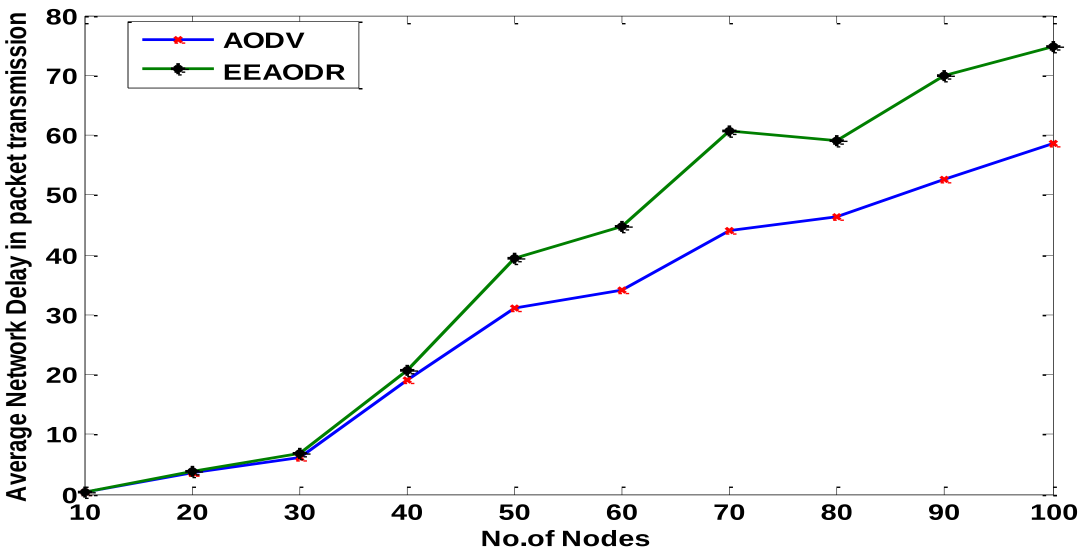


Fig 8 EEAODR Delay comparison with Aodv

3.3 Proposed Algorithm ESAR

The target of the proposed work is to achieve a better energy efficient routing algorithm that increases the network life time by using the strengths of both the AODV algorithm and EEAODR algorithms. The shortest path in terms of minimum hop counts is chosen by AODV for packet routing ensures that the transmission delay is reduced whereas the network life time is compromised. At the same time EEAODR chooses an alternate path for packet transmission to save the energy of the shortest path while compromising the delay in transmission. The current work selects a path for routing by considering the actual distance between the source and destination along with the minimum available energy of a node in the path. When a source does not find a path to the destination in its routing table, it broadcast the route request RREQ message. The receiver upon receiving the first RREQ waits for δt time period to collect more RREQ messages through other paths. All these RREQ message paths are stored for the selection of actual routing paths as and when required.

After storing all the possible paths from the source to the destination, the current algorithm considers the following two parameters to select a suitable path for packet transmission:

(iii) The minimum available battery power of a node in the i^{th} path, E_i

(iv) The actual distance between the source and the destination in the i^{th} path, $Dist_i$.

Then the cost of the path is calculated as:

$$Cost_i = \alpha * D_{Ei} + \beta * Dist_i$$

Where α and β are the weighing factors that decide the priority of the battery power or the distance between the nodes in a network topology. α and β are normalized weighing factors i.e. there sum equal to 1 and we can decide their values depending on the requirement i.e. for calculating the delay actual distance plays a prominent role so β is given more weightage over α and in case of total energy consumption reverse is the case. Dhurandher et. al., the authors of EEAODR [17] have indicated that, in a network topology, if the number of hops is higher, then the distance between two hops will be more likely lesser. But the same is not true for all the time. For example in figure 9, the total actual distance of the path 1-3- 2 is lesser than that of the path 1-3-4-2. So the current work proposes to find the actual distances between the hops from the source to the destination rather than to find the number of hops between the two ends. Similarly, D_{Ei} is the difference of the minimum available battery power of a node in any path i from a threshold value δ. The value of δ is kept constant for all the paths in the simulation.

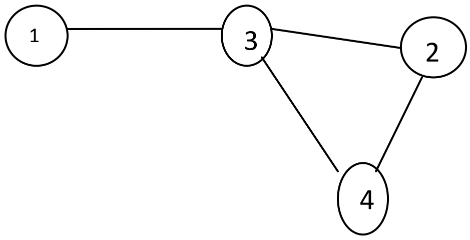


Fig 9 Special Case of EEAODR

3.4 Pseudo Code

The pseudo code for the proposed routing algorithm ESAR is as:

```
Begin
For all v є V
        If (active path to destination is found in route table) then
                Goto Label 3.
        Else
        // Find the path
                Label 1:
                For (every v є V_source)
                        Broadcast RREQ to u є Γ (v)       // Broadcast to neighbor nodes
                For (every v є V_receiver)
                        Receive valid RREQ sent
                        If (v == destination) then
                                If RREP has been sent then
                                        Reject the duplicate RREQ
                                Else
                                        If (RREQ.counter = = 1) then // the first RREQ
                                                Set timer= 1
                                Endif
                        Else
```

Node is intermediate node

Entry in seen table <- node

Jump to label 1

Endif

For (every v ϵ $V_{destination}$)

If timer > δT then

For I = 1 to total no. of paths

Compute E_i= the minimum available battery power of node in i^{th} path

Compute $Dist_i$= Actual distance between the source and destination in the i^{th} path

Compute $D_{Ei} = \Delta - E_i$

Compute $cost_i = \alpha * D_{Ei} + \beta * Dist_i$

Calculate the best path with the minimum cost.

Store the backup paths.

Send RREP through the selected path

Endif

For (every v ϵ V_{source})

If RREP is received within time out interval,

Source node updates its routing table with selected paths

Label 4:

Source sends data through the selected path

Else

If (some active valid backup path exists) then

Select that path and jump to label4

Else

Send RREQ again

Endif

Endif

End

The algorithm selects the path with minimum cost value indicating that the path has the shortest distance from the source to the destination and has the maximum of the minimum available battery power of the node among the different paths. This selected path is chosen as the best path for packet transmission till any node in the path exhausts battery power beyond a threshold value. At this point of time, a backup path having the next lower cost is selected as an alternate path for packet transmission. The process is repeated till all the paths from the same source to destination are exhausted with their battery power. When the situation with all the paths having the minimum battery power below the threshold value occurs, the costs of the paths are re-calculated and the process continues.

EXAMPLE:

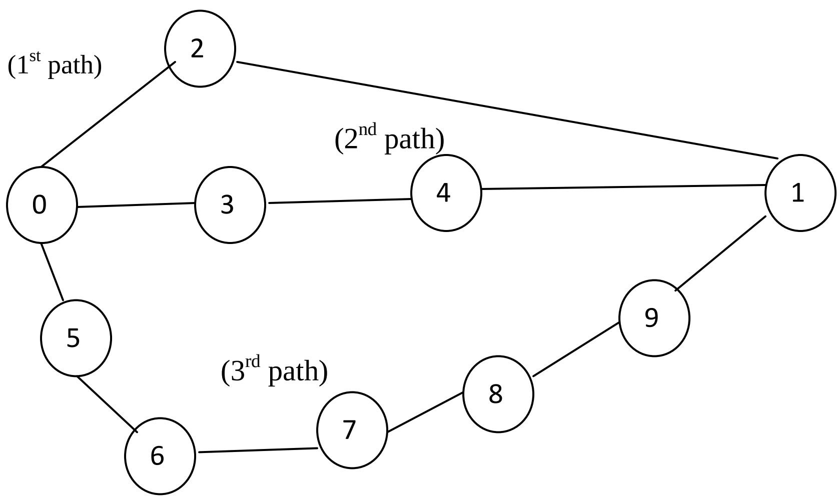


Fig 10 Topology of a Network

In the above topology, source is 0 and destination is 1. Now we will see how AODV, EEAODR and ESAR (proposed algorithm) work. We have three different paths from source to destination; we will see which path is selected when for each algorithm.

AODV:

Every time the 1st path is selected for packet transmission from source to destination i.e. the path selected will be 0-2-1 for every packet transmission till any of the node dies out. The criteria for selecting 0-2-1 as the path for packet transmission from 0(source) to 1(destination) is it will select the path with minimum hops and the 1st path is having minimum number of hops i.e. 2.

EEAODR:

Here for each packet transmission from 0(source) to 1(destination) the same path may or may not be selected depending on the cost value of each path. Minimum cost value path is always selected, cost depends on three factors i.e. no. of hops, time taken and minimum battery power. Suppose 5 packets have to be sent between 0 and 1 and the topology remains the same for 5 packets. When the 1st packet is sent, we calculate the cost value of the 3 paths and select the path with minimum cost value. Suppose 2nd path is selected so the path for sending the packet will be 0-3-4-1.Now when the 2nd packet is sent we again calculate the cost value and the path with minimum cost value is again selected. It may be that again the 2nd path may be selected for packet transmission but not necessary, suppose 3rd path is selected this time so the route for sending the packet this time will be 0-5-6-7-8-9-1.Thus every time whenever a packet has to be transmitted, the cost value for each path is calculated and the path with minimum cost value will be selected.

ESAR:

In ESAR also the same path may or may not be selected every time when a packet is sent, path selection depends on the cost value. The minimum cost value path is always selected, cost depend on the actual distance for each path and minimum energy node of the path. Suppose 5 packets are to be sent for transmission between 0(source) and 1(destination) topology remains the same for every packet. Now when the 1st packet is send that path will be selected which has the minimum actual distance between source and the destination, with a condition that the minimum battery node power is not below the threshold value which is constant throughout the simulation, if the battery power is below the threshold then the path with next minimum distance is calculated and so on. Now, if all the path's minimum battery node power value goes below the threshold, then again the cost will be calculated for each path using the formulae

$Cost_i = \alpha * D_{Ei} + \beta * Dist_i$

Where $Dist_i$ is the actual distance of the i^{th} path, For example in the above figure we will calculate the actual distance between 0(source) and 1(destination) going through each path i.e. 1st path, 2nd path and 3rd path.

D_{Ei} , it is the difference in energy between the threshold and the energy of the minimum energy node of the path i.e. i^{th} path .For example, in the above figure we calculate D_E for the 1^{st} path, 2^{nd} path and 3^{rd} path.

α and β they are weighted factors and thus we calculate the cost value for each path.

Now, suppose 2^{nd} path has the minimum actual distance and the minimum battery node power is not below the threshold value, then the 2^{nd} path will be selected for the transmission of the 1^{st} packet. The first packet route will be 0-3-4-1. In the same fashion other packets are transmitted, by calculating the cost value of each path every time a packet has to be sent.

Chapter 4

Simulation and Results

Chapter 4

4.1 Simulation and Results

We have chosen a 100m × 100m dimension terrain with 20, 30, 40, 50, 60, 70, 80, 90 and 100 nodes. Here the locations of nodes are random with a random velocity between 0 to 5m/s. Nodes in the network follow Random Walk mobility model. Packets of different sizes are used in during the simulation which varies from 256 bytes to 4098 bytes. ESAR is compared with EEAODR and AODV, which are also very popular on-demand routing protocol proposed for ad hoc networks.

4.2 Energy Consumed in data transmission

The motivation of ESAR comes from EEAODR which was designed to increase the network life by distributing the network load and selecting the paths containing nodes with higher power levels i.e. the power of the minimum battery node, but the primary objective of ESAR is to make use of all the available alternate paths (if available) with the help of a threshold power made constant throughout the simulation which helps in increasing the network life. After each packet transmission, newer paths are calculated. AODV selects the same path, as the mobility does not change the location of the node substantially and thus the same path will be shortest path used for the first packet transmission (minimum hop path), EEAODR selects the optimized path with the help of an optimality function (minimum cost value path), ESAR also selects the minimum distance path till a threshold value then we use an optimality function to further get an optimized path. So, newer paths are calculated every time in case of ESAR as well as EEAODR (if available) as compared to AODV but in case of ESAR all the alternate paths will be taken into consideration which ultimately results in increasing the network life time. In this experiment we are sending six packets each of size 512 bytes and perform random data transmission, by selecting different sender and receiver and thus repeating the experiment with different number of nodes (20-100) in the network.

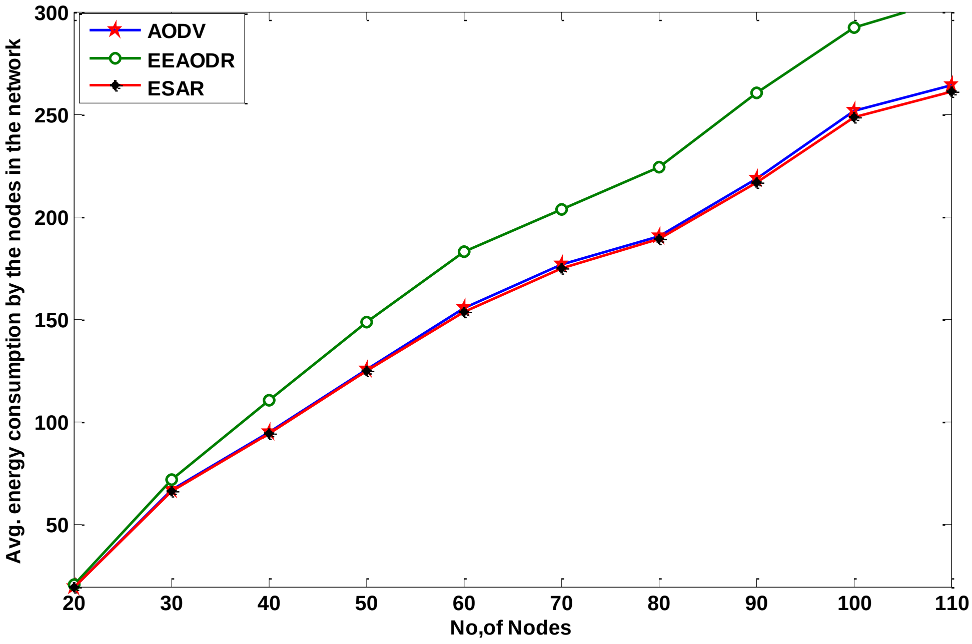


Fig 11 Comparison Graph for Avg. Energy comparison vs No. of Nodes

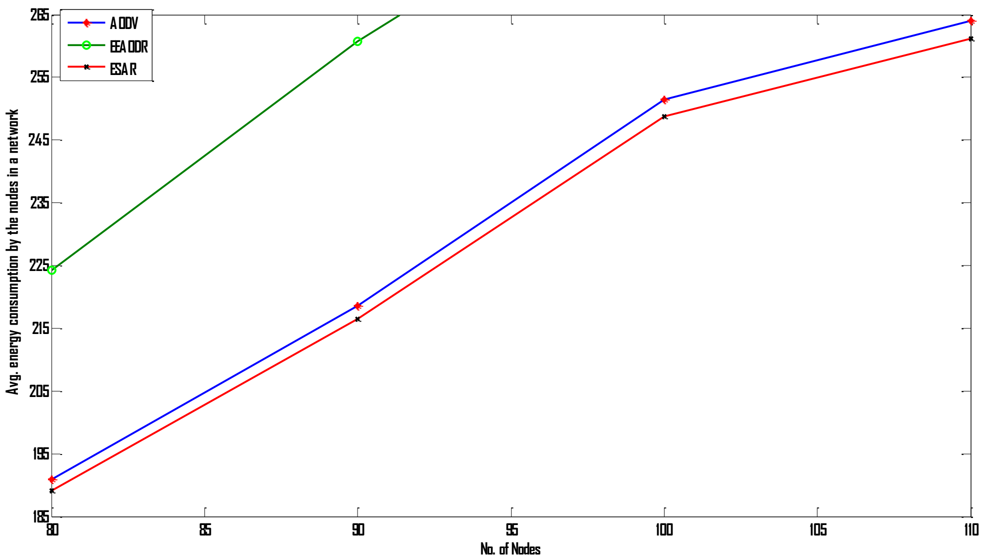


Fig 12 Microscopic view for Avg. energy comparison vs No. of Nodes

We reach to a conclusion that ESAR has lesser energy consumed than EEAODR as well as AODV and thus we conclude the energy is saved as the minimum distance path is selected every time.

4.3 Network Life

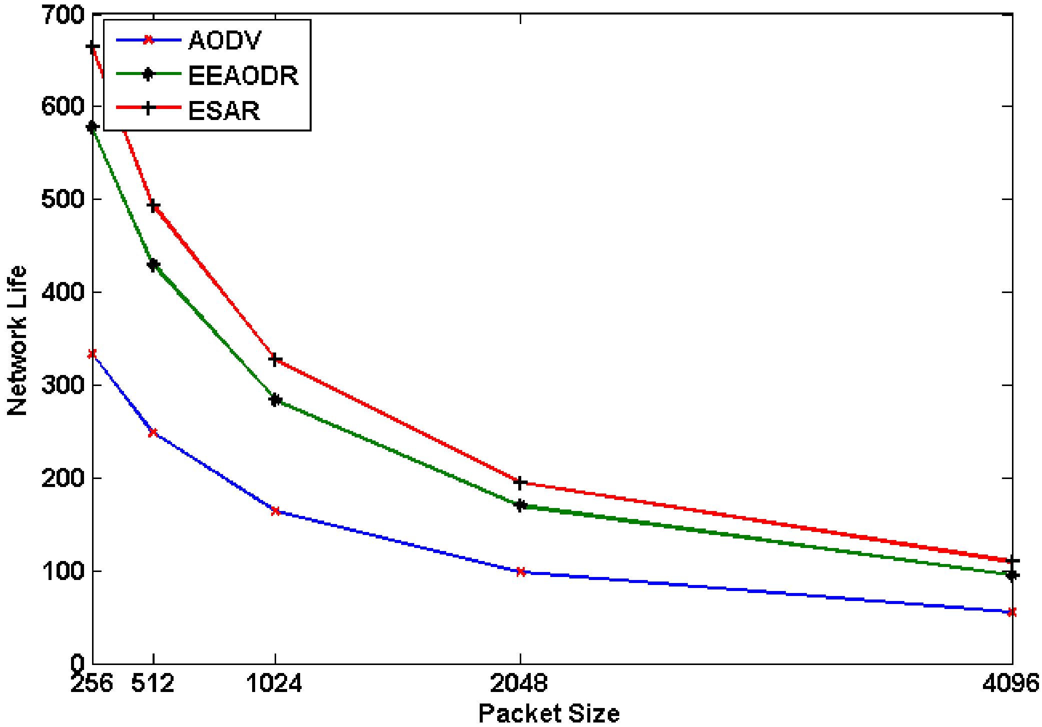
The network life time is defined as the period since the network is started till the first node in the network dies out. In the current work the network dies out when the power of the node becomes zero or below some threshold so that it can’t be used as in intermediate node. When the network fails the performance degrades, as the node that has died out can’t be further used for any packet transmission. The energy consumption by any node is proportional to the packet size, so as the packet size increases, the nodes drain out the battery faster and dies out. ESAR increases the network life by using alternate paths thus avoiding the repeated use of a particular node.

In this experiment we are sending data packets of different sizes for the same source and destination pairs and as the energy consumption is directly proportional to the packet size so the residual energy decreases as the packet size increases and thus the network life increases. Now from the figure we can see that network life of ESAR is higher than EEAODR as well as AODV.

The following observations can be made:

- As network life is inversely proportional to the consumed energy which in turn is proportional to the packet size so as the packet size increases the network life decreases.

- The network life of ESAR is higher than AODV because ESAR makes use of the alternate paths thus avoiding the repeated usage of nodes, but it is more than EEAODR because in ESAR we make use of all the available alternate paths and thus the energy consumption among the nodes is more distributed in ESAR than EEAODR, while in case of EEAODR the choice of alternate paths depends on the optimality function.



•

Fig 13 Comparison Graph for Network Life vs Packet Size

4.4 Average network delay in packet transmission

Delay as defined as the time taken by a packet to reach to a destination, i.e. the time for which destination has to wait before processing a packet. The time taken by a packet to reach to a destination depends on the actual distance between the source and destination i.e. time is directly proportional to the actual distance. The average network delay of ESAR is minimum because every time we search for a path having minimum actual distance between the source and the destination among the different available alternate path.

In this experiment we are sending a packet of size 512 bytes and perform random data transmission, by selecting different source and destination and thus repeating the experiment with different number of nodes (10-100) in the network. Now from the figure 14 we can see the average network delay of ESAR is less than EEAODR as well as AODV.

The following observations can be made:

- As the delay is directly proportional to the actual distance between the source and the destination so as the actual distance increases delay increases.
- The delay of ESAR is less than AODV as well as EEAODR because ESAR every time selects that path which has the minimum distance among the alternate paths so it is minimum, as selection of path for EEAODR depends on the optimality function so EEAODR may not select a path with minimum distance because the optimality function depends also on other factors, while AODV always selects a path with minimum number of hops but not the shortest distance path.

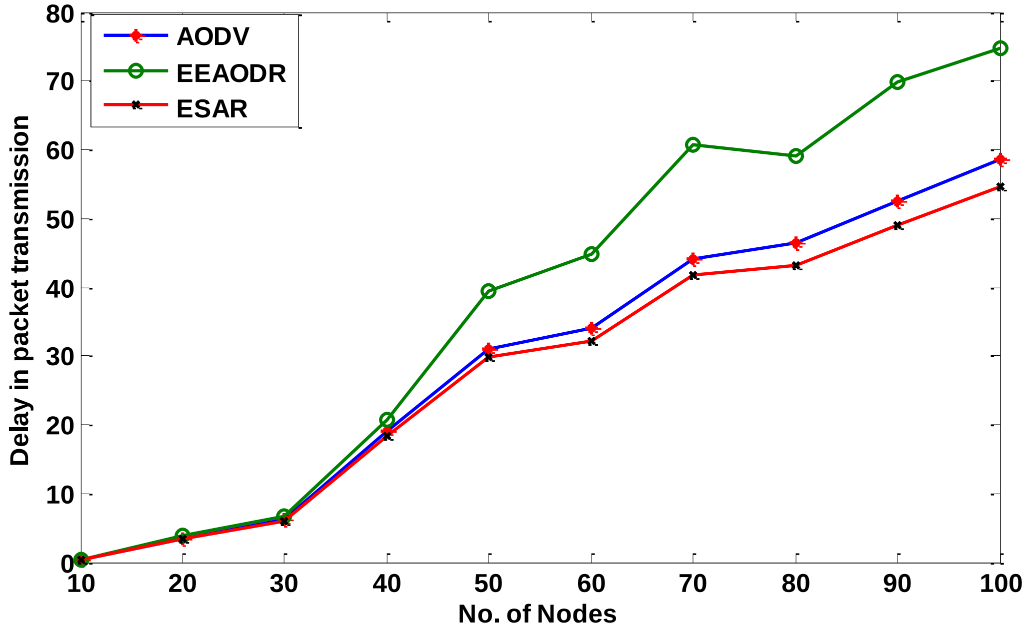


Fig 14 Comparison Graph for Delay vs. No. of Nodes

4.5 Delay with No. of packets

In this experiment we perform data transmission between the selected source and destination throughout the simulation. Here each session consists of 5 packets where each packet size is 512 bytes. The no. of nodes is fixed at the starting of the simulation and continues till eight sessions. We calculate the delay after the end of each session.

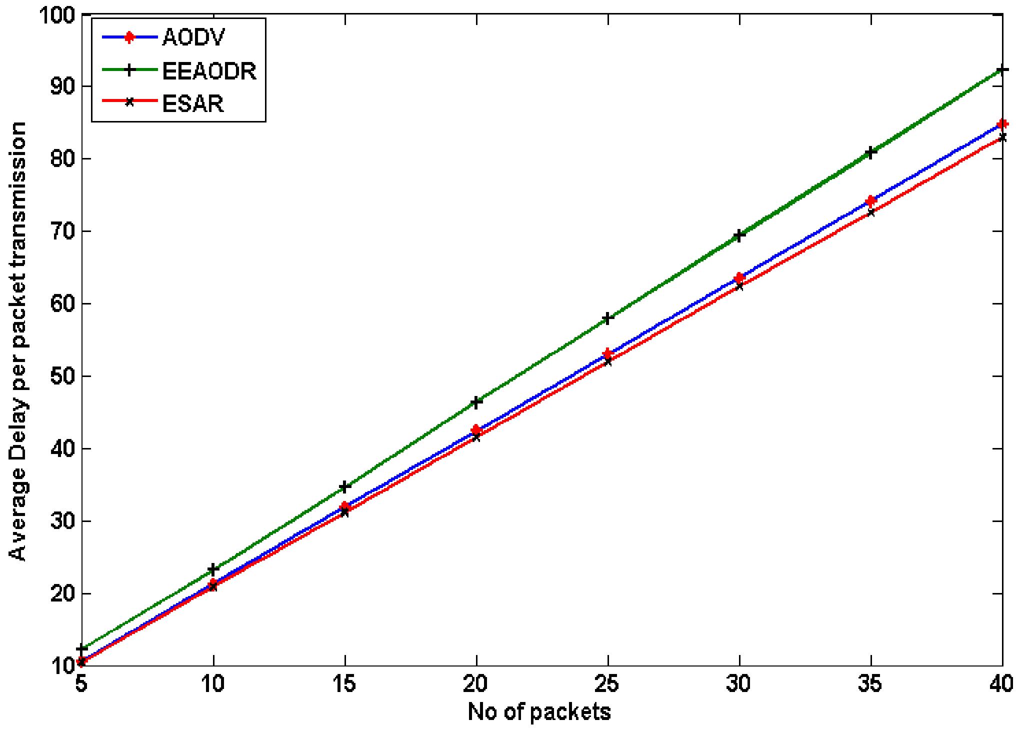


Fig 15 Comparison Graph for Delay vs. No. of Packets

From the figure 15, we come to a conclusion that ESAR delay minimum i.e. less than AODV as well as EEAODR. In ESAR every time we select the minimum actual distance path and thus the delay is minimum.

Chapter 5

Conclusion

Chapter 5

Conclusion

An energy efficient routing protocol was designed as per the problem statement which successfully made runs and achieved the objective. EEAODR overcomes the limitation of AODV i.e. the network life is increased but energy consumption has to be compromised as well as delay also increases in the case of EEAODR, our proposed algorithm ESAR overcomes the limitations of AODV i.e. increases the network life as well as energy is not compromised so it also overcomes the limitation of EEAODR, delay is also minimum in case of ESAR. Delay is minimum as that path is always selected having the minimum actual distance between the source and destination always. Network Life is significantly more than AODV as well as EEAODR because in case of ESAR all the alternate paths are always taken into account so proper load balancing is done and thus all the nodes involved in the alternate paths are used up and thus no node is overused.

Future work may include hardware and software implementation of the proposed algorithm to get results in real world scenario. The mobile network when deployed with each node having Global Positioning System (GPS) is expected give the desires result in real time application.

Bibliography

[1] C. E. Perkins. *Ad Hoc Networking*. Addison Wesley, 2000.

[2] Stefano Basagni, Macro Conti, Silvia Giordano and Ivan Stojmenovic, “Mobile Ad Hoc Networks” , IEEE press, A john Wily & Sons, INC. publication, 2003

[3] C Siva Ram Murthy and B S Manoj. *Ad Hoc Wireless Networks*. Pearson Education, 2005.

[4] C K Toh. *Ad Hoc Mobile Wireless Networks: Protocols and Systems*. Prentice Hall PTR, 2002.

[5] Chinara S., Analysis and Design of Protocols for Clustering in Mobile Ad Hoc Networks., Ph. D thesis, National Institute of Technology, March 2011.

[6] http://w3.antd.nist.gov/wahn_mahn.shtml

[7] Liu C., Kaiser J., A Survey of Mobile Ad Hoc network Routing Protocols, University of Ulm Tech. Report Series, Nr. 2003-08

[8] E.M. Belding-Royer and C. K. Toh, “A review of current routing protocols for ad hoc mobile wireless networks”, IEEE Personal Communications Magazine, pages 46–55, April 1999.

[9] http://www.ietf.org/rfc/rfc2501.txt

[10] http://www.cse.wustl.edu/~jain/cse574-06/ftp/energy_routing/index.html

[11] L.M. Feeney, “Taxonomy for Routing Protocols in Mobile Ad Hoc Networks”, SICS Technical Report T99/07, October 1999.
http://www.sics.se/~lmfeeney/research.html

[12] I. D. Chakeres and E. M. Belding-Royer, “AODV Routing Protocol Implementation Design,” in *Proceedings of the International Workshop on Wireless Ad hoc Networking (WWAN)*, Tokyo, Japan, March 2004.

[13] Y I Jiazi, Summary of Routing Protocols in Mobile Ad Hoc Networks, Polytechnic School of University of Nantes, March 2007

[14] Perkins CE, Belding-Royer E, Das S. Ad hoc on-demand distance vector (AODV) routing. Internet draft. http:// www.ietf.org/internet-frafts/draft-ietf-manet-aodv-13.txt

[15] Cano Juan Carlos, Manzoni Pietro, “A performance Comparison of Energy Consumption for Mobile Ad Hoc Networks Routing Protocols”, *Programa de Incetivo a la Investigacion de La UPV*, Valencia Spain

[16] Li Layuan, Li Chunlin, Yaun Peiyan, “Performance evaluation and simulations of routing protocols in ad hoc networks” Computer Communications 30 (2007) 1890–1898

[17] Dhurandher S.K., Misra S., Obaidat Mohammad S., Bansal V., Singh P. V., Punia V. “An energy efficient ad hoc on demand routing protocol for mobile ad hoc network” , International Journal of Communication Systems 2009; vol. 22: pp. 789-817

Dissemination of the work

Utkarsh , Mishra Mukesh , Chinara Suchismita, “ESAR: An Energy Saving Ad Hoc Routing Algorithm” , communicated to INDICON-2012 .