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Performance Analysis of Adhoc On Demand Distance Vector routing Protocol and its Enhancement using Sectorized Antenna

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CERTIFICATE

This is to certify that the dissertation titled "**Performance Analysis of Adhoc On Demand Distance Vector Routing Protocol and its Enhancement using Sectorized Antenna**" is a bonafide record of work done at **Delhi Technological University** by **Viomesh Kumar Singh, Roll No. 2K11/CSE/20** for partial fulfilment of the requirements for the degree of Master of Technology in Computer Science & Engineering. This project was carried out under my supervision and has not been submitted elsewhere, either in part or full, for the award of any other degree or diploma to the best of my knowledge and belief.

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ABSTRACT

Mobile Ad hoc Networks (MANET) are collection of autonomous mobile wireless devices (nodes) that form decentralized, self organizing and infrastructure-less wireless network among them. Mobility of nodes causes topological changes in network. MANET rely on dynamic routing protocols such as Adhoc on demand distance vector routing (AODV) with Expanding Ring Search (ERS) to reduce energy consumption and broadcast cost of searching. In AODV, network-wide flooding is initiated whenever any node wants to communicate with some other node to find the route between source and destination whereas in ERS, flooding is performed in successively larger area in network. In this thesis, first we analyze effect of efficient flooding using sectorized antenna applied on AODV and ERS in high density networks. Second, we propose an improved routing algorithm, Efficient AODV using Sectorized Antenna (EAODVSA), which improves flooding using sectorized antenna and reduces redundant flooding using unicasting to improve efficiency of ERS.

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Chapter 1 INTRODUCTION

1.1 Adhoc Networks

Ad hoc networks have recently been the subject of active research because of popularization of mobile devices. Mobile Ad hoc Networks (MANET) are a collection of autonomous mobile wireless devices (nodes) that form decentralized, self organizing and infrastructure-less wireless network among them [1].Each node in the network acts both as a host and a router, that means they (MANETs) do not need any wired infrastructure support or access points. So they are best suited wireless communication system to support various potential applications in mobility environments such as emergency services, disaster recovery situations, sensor networking, military scenarios, conferencing and intelligent transportation systems where fixed infrastructure is not easily acquired or communication infrastructure is damaged or non-existing and rapid deployment of a communication network is required.

In MANET, networking is limited in range by the individual nodes transmission ranges and is typically smaller compared to the range of cellular systems [2]. If two nodes are within the transmission range of each other they communicate directly otherwise communication is performed via intermediate nodes by forwarding messages. In an ad hoc network, nodes can move, join or exit freely. Thus, the choice of intermediate nodes may change that means routes often need to be changed. Traditional routing protocols available for wired networks are not suited for wireless networks as nodes are free to move arbitrarily in different directions with different speeds and also topological changes occur randomly. MANETs require efficient dynamic routing algorithm to respond to the topological changes.

1.2 Problem Description

In MANET, each mobile device has a different mobile characteristic that means they can move arbitrarily in different directions with different speeds. It does not maintain topology information about all other nodes in the network [3]. If the wireless nodes are within the transmission range of each other, the routing is not necessary but in case when the destination node is outside the range of a source node, communication between any two nodes is accomplished via a multihop route in peer-to-peer fashion. Mobility of nodes causes many problems like multipath propagation, path loss and interference, topological changes occur in network which makes routing difficult. Trust relationship among nodes might be disturbed due to dynamic topology [4]. Traditional routing protocols available for wired networks, are not suited for wireless networks, it require dynamic routing to respond to the topological changes as nodes are dynamic in nature.

Various routing algorithms were purposed but none of the proposed protocols for MANET satisfy all desirable properties like on demand operation, multiple routes, power conservation loop free characteristics etc. Adhoc on demand distance vector (AODV) routing algorithm is widely used for route discovery in MANET [5]. AODV is simple and highly scalable routing algorithm, which uses most current routing information and provide loop free most effective path which makes it most suitable for dynamic topology but still it has some limitation such as overhead in terms of wireless node processing, energy consumption and bandwidth which need to be improved. To solve these problems Expanding Ring Search (ERS) concept is applied along with AODV which searches in successively larger area in network to avoid broadcast storm [6]. Even with the controlled manner of flooding, expanding ring search still suffers from high overhead due to redundant broadcasting of RREQ since the route discovery process starts from the source node, each time search fails. Furthermore, the cost drastically increases when a larger area of the network needs to be searched.

1.3 Related Work

To stop network wide broadcast Expanding Ring Search (ERS) is applied to Adhoc on demand distance vector routing algorithm (AODV) where flooding is performed in successively larger area in network to avoid network-wide broadcast. But it suffers the problem of redundant broadcasting. After the introduction of ERS with AODV, many techniques were proposed to reduce redundant rebroadcast of ERS. Jahan Hassan, Sanjay Jha proposed the concept of optimal TTL threshold value, as Network-wide broadcast is initiated only if TTL touches threshold value [28]. Incheon Park, Ida Pu proposed Blocking Expanding Ring Search algorithm which do not start broadcasting from source every time when search fails [29]. Ngoc Duy Pham and HyunseungChoo proposed a method that involves obtaining and utilizing the information of the incoming message before dropping, to reduce redundant rebroadcast. Directional antenna is used for efficient flooding and mitigating broadcast storm in [39], [41], [42]. But none of the technique is proposed to provide efficient broadcasting in AODV using sectorized antenna with combination of efficient ERS.

1.4 Thesis outline

Remaining part of this thesis is organized in the following chapters:

Chapter 2: MANET

In this chapter, we discuss basics of MANET. It starts with definition of MANET then it describes various MANET's characteristics, applications and advantages in detail. At last it discusses the MANET's challenges.

Chapter 3: ROUTING

This chapter starts with the traditional routing algorithms for network, later it highlights the problems with routing in Mobile Ad-hoc Networks, routing desirable properties and also discuss classification of routing protocols for MANET.

Chapter 4: AODV ROUTING PROTOCOL

In this chapter, we discuss AODV working, features and challenges in detail. It also discusses AODV advantages and disadvantages. At the end of this chapter, Expanding Ring Search protocol (ERS) is described in brief.

Chapter 5: ANTENNA

This chapter presents definition and fundamental characteristics of antenna. Later it discusses radiation pattern based classification, omni-directional antenna, directional antenna and sector antenna. Selective flooding using sectorized antenna is described at the end of chapter.

Chapter 6: PROPOSED APPROACH

In this chapter first we discuss various sector antenna used for analysis then we apply concept of selective flooding in AODV and ERS using sectorized antenna. Later in this chapter, we propose our algorithm to reduce routing overhead in two ways, firstly to control flooding using sectorized antenna, and secondly to reduce redundant rebroadcast with the concept of unicasting.

Chapter 7: RESULT and ANALYSIS

To start with, we introduce three standard models based on regular topology to analyze effect of sectorized antenna. Then we discuss the selective flooding using sectorized antenna on AODV and the scenarios in which ERS is applied to these models and then analyze the corresponding results. Later we generate and analyze the results of proposed EAODVSA algorithm.

Chapter 8: CONCLUSION

This is the last chapter of our thesis where we conclude our work.

Chapter 2 MANET

In today's world people wish to use their network terminals (laptops, mobile phones, etc.) anywhere, anytime. Wireless communication provides this facility that's why it is rapidly increasing technology [7]. Wireless networks have become one of the fastest growing technologies. Wireless networks use radio waves to transmit and receive data. The most admiring fact of wireless communication is that it eliminates the use of expensive cables and their maintenance costs. Wireless networks are mainly adapted to enable mobility. They are classified into two main categories. The first one is known as infrastructure based wireless network which is a network with fixed and wired gateways. These kinds of networks use access point as router or as a bridge. Access points contain all the information about the network and responsible for communication between wireless devices/nodes [7]. Wireless devices within these networks connect to, and communicate with nearest base station in their communication range. This type of network is mainly used for wireless local area networks (WLANs). The second one is infrastructure-less mobile network, commonly known as ad-hoc network. Ad-hoc network is a network without any central controller/base station and does not require any kind of infrastructure.They are characterized by multi-hop connectivity, decentralized routing, dynamically changing topology, and the use of wireless links**.** Each node in the network acts both as a host and a router and performs route discovery and route maintenance [1], [8].Each node has limited transmission range. The communication between any two nodes is accomplished via forwarding of messages by other member nodes, called intermediate nodes. The choice of intermediaries will change constantly because the network topology is dynamic with nodes always in movement. Thus efficient forwarding or routing algorithms are required.

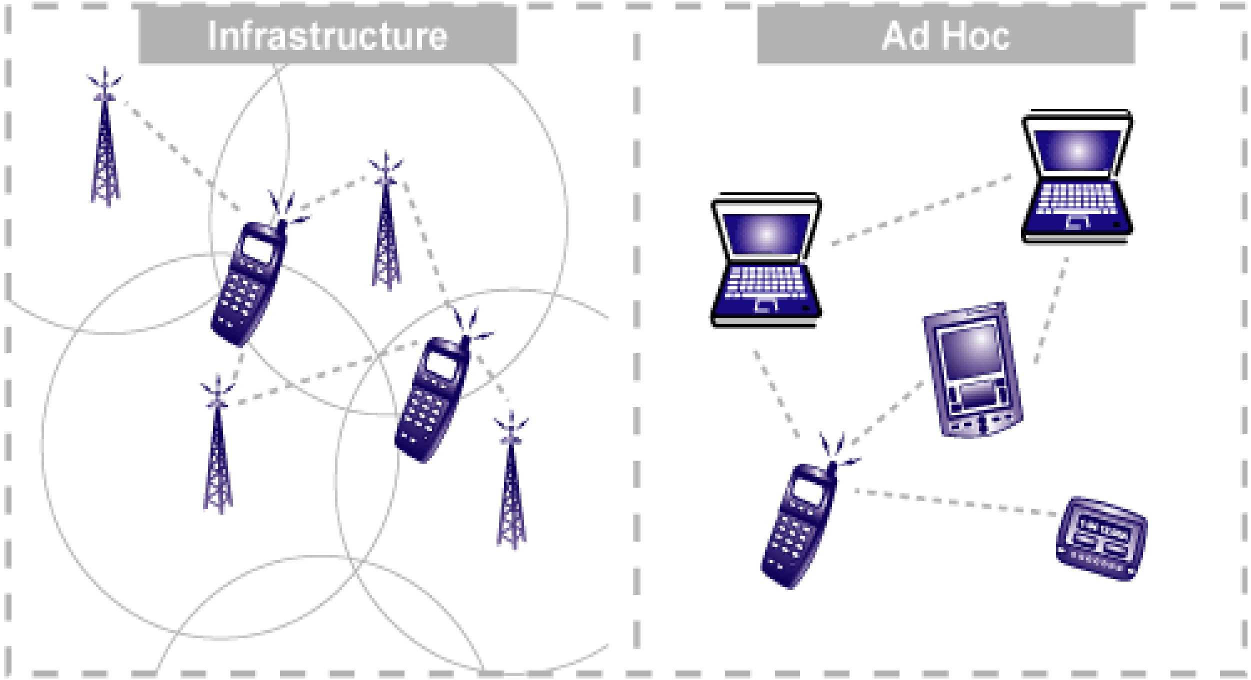


Figure 1 Infrastructure based wireless vs Adhoc network image [9]

Mobile Ad hoc Networks (MANETs) are best suited wireless communication system to support various potential applications in mobility environments. Mobile Ad hoc Network (MANET) is collection of mobile wireless devices that form decentralized, self organizing and infrastructure-less wireless network among themselves [1][2]. In mobile ad-hoc networks a destination node might be outside the range of a source node, in that case communication between any two nodes is accomplished via forwarding of messages by other member nodes known as intermediate nodes.Mobility and limited power, inherent to all MANET nodes, greatly affect the functioning of the system [10].Each mobile device moves randomly with different mobile characteristics such as velocity and movement direction. Due to the mobility of nodes, multipath propagation, path loss and interference topological changes occur in network which makes routing difficult. Dynamic routing is required to respond to the topological changes as nodes are dynamic in nature.

2.1 Salient Features of MANET

1) Distributed operation: There is no need of existing infrastructure in MANET and they do not require any central controller/base station, the control of the network is equally distributed among the nodes. The mobile devices in a MANET should cooperate with each other to built reliable transmission links among themselves.

2) Rapidly deployable: MANETs are rapidly deployable, as they don’t need any centralized control system and any fixed infrastructure. They are self creating, self administrating, self organizing and self configuring in nature.

3) Multi-hop routing: When a node tries to communicate with other nodes which is out of its communication range, in that case communication between any two nodes is accomplished via forwarding of messages by one or more intermediate nodes.

4) Autonomous terminal: Each mobile node in network acts both as a host and a router and independent of each other. These devices could be heterogeneous.

5) Scalability of Network: Nodes in MANETs can move from one autonomous system to another as they are mobile devices so network should be scalable to accommodate the additional nodes.

6) Dynamic topology: Nodes are free to move arbitrarily in different directions with different speeds. Due to the mobility of nodes topological changes occur randomly and at unpredictable time in network.

7) Light-weight terminals: Most of the time, the mobile nodes at MANET are with Limited power resources, small memory size and less CPU capability.

2.2MANET Usage Areas

Some of the typical applications include [2][11]:

A) Military scenarios: Mobile Ad-Hoc networking enables military to take benefit of commonplace networks technology to create and maintain network between the vehicles, soldiers, and military information head quarter to exchange information anytime anywhere.

B) Commercial Use: Some business environments need collaborative computing as it might be important outside office environments than inside and where people do need to have outside meetings to cooperate and exchange information on a given project.

C) Local level: Ad-Hoc networks can autonomously link an instant and temporary multimedia network using mobile devices, notebook computers and laptops for information exchange among them e.g. conference or classroom. MANETS are best suited for local level application like home networks where devices can communicate directly to spread and share information.

D) Personal area network and Bluetooth: A personal area network is a localized network of short range where devices are usually associated with a given person. MANET such as Bluetooth is best suited for short-range environments such as inter communication between various mobile devices such as a laptop, and a mobile phone.

E) Emergency/rescue operations: Ad hoc can be used in emergency/rescue operations for disaster relief efforts, e.g. in fire, flood, or earthquake. Emergency rescue operations require rapid deployment of a communication network as existing communications infrastructure is damaged.

2.3 Advantages of MANET

The advantages of an Ad-Hoc network include the following [10]:

A) The network can be set up at any place and time

B) They do not require any centralized control system which make it robust due to decentralize administration.

C) Easily deployable as they don’t need any fixed infrastructure.

D) They provide access to information and services regardless of geographic position.

E) Independence from central network administration. Self-configuring network, nodes acts both as a host and a router. Less expensive as compared to wired network.

F) Scalable - accommodates the addition of more nodes.

G) Improved Flexibility.

2.4 MANETs Challenges

All the MANETs have certain problem to be resolved which are given below [5], [12]:

1) Limited bandwidth: Wireless links continue to have significantly lower capacity than infrastructured networks. In addition, the realized throughput of wireless communication after accounting for the effect of multiple access, fading, noise, and interference conditions, etc., is often much less than a radio's maximum transmission rate.

2) Node mobility and Dynamic topology: Nodes are free to move arbitrarily in different directions with different speeds. Due to the mobility of nodes topological changes occur randomly and at unpredictable time in network. Trust relationship among nodes might be disturbed due to dynamic topology changes and if some nodes are detected as compromised [13].

3) Routing Overhead: Nodes in MANET often change their location within network as they are dynamic in nature. In table-Driven routing protocols, route table of each node is required to be updated each and every time when nodes changes its location and On Demand routing protocols follow flooding to find the route to destination, which leads to unnecessary routing overhead[13][14].

4) Frequent route changes: Dynamic movement of nodes leads to topological changes in ad hoc wireless network; hence an on-going session suffers frequent path breaks. That means Mobility of nodes induced route changes in network [13].

5) Hidden terminal problem: The hidden terminal problem refers to the collision of packets at a receiving node due to the simultaneous transmission of those nodes that are

not within the direct transmission range of the sender, but are within the transmission range of the receiver [3][15].

6) High packet losses: Much higher packet loss is experienced in mobile ad hoc wireless networks due to factors such as increased collisions due to the presence of uni-directional links, hidden terminals, presence of interference and frequent path breaks(due to mobility of nodes) [4].

7) Tight limitations in energy, processing power and memory: Mobile Devices used in MANETs are battery operated so there is limited power due to which there are tight limitations on energy, processing power and storage in order to maintain portability [3][15].

8) Security challenges: The wireless and dynamic nature of MANETs brings new security threats. These networks are intrinsically exposed to numerous security attacks as the wireless medium is vulnerable to eavesdropping and ad hoc network functionality is established through node cooperation, and trust relationship among nodes disturbed due to the mobility of nodes and if some nodes are detected as compromised.

Chapter 3   ROUTING

Routing is the act of determination the route from a source to a destination in an internetwork. The routing mechanism basically involves two activities:

1. Determining optimal route up to destination

2. Transmitting information between nodes (called packet switching)

Packet switching is simple and straight forward operation, but path determination could be very complex task. To compute the optimal path from source to destination, routing protocols use several metrics. The path length is measured in terms of number of hops encountered in the route. Routing algorithms store total route information of network in routing tables. This route information varies from one routing algorithm to another.

Routing tables contains variety of information which is generated by the routing algorithms. Most common entries in the routing table are ip-address prefix and the next hop. Destination-next hop pair in routing table tells the router how a particular destination can be reached optimally by sending the packet to a router representing the “next hop” on its way to the final destination and ip-address prefix specifies a set of destinations for which the routing entry is valid .

Switching is relatively simple task in comparison with the path determination (routing).Routing is mainly classified into static routing and dynamic routing. In static routing, routing information is inserted and updated manually or statically in the routing table of routers by a networks administrator. In static routing, routing table does not depend on the state of the network status, i.e., whether the destination is active or not. Dynamic routing refers to the routing strategy that is being learnt by an interior or exterior routing protocol. These kinds of routing consider the state of the network, which means the routing table is affected by the activeness of the nodes in the network. On the basis of what the routers tell each other and how they use the information to form their routing tables, dynamic routing protocols are classified into two categories:

3.1 Link-State Protocols

In link state routing protocols, router doesn't provide the information about the destination instead each router in the network maintains a complete view of the topology of the network with the cost for each link in its routing table. Each node periodically floods routing information throughout the network and then every router in the network creates its own picture of the current state of all the links in the network then updates its view of the network and applies shortest path algorithm to choose the next hope for each destination.

3.2 Distance Vector Protocols

In Distance Vector Protocols, each router maintains the shortest distance to every node in the network. Each router over the internetwork sends the information about destination with cost to each of its neighboring routers instead of broadcasting the information throughout the network. The receiving nodes applies shortest path algorithm and update their routing tables. Using a distance vector protocol, the router simply transmits the information to the neighboring host with the available shortest path in the routing table and assumes that the receiving router will know how to forward the packet beyond that point [9]. The routing information protocol (RIP) is the best example of distance vector protocols.

3.3Ad-hoc Routing Protocols

MANETs use radio waves to transmit and receive data. Like infrastructure based wireless network, MANETs do not have any central controller/base station, each node acts both as a host and a router in the network [16]. Each mobile device moves randomly with different mobile characteristics such as velocity and movement direction. Mobility and limited power, inherent to all MANET nodes, greatly affect the functioning of the system. If the wireless nodes are within the range of each other, the routing is not necessary but in case when the destination node is outside the range of a source node, communication between any two nodes is accomplished via forwarding of messages by other member nodes known as intermediate nodes [17].The choice of intermediaries will change constantly because the network topology is dynamic with nodes always in movement [13]. Due to the mobility of nodes, multipath propagation, path loss and interference topological changes occur in network which makes routing difficult [15]. Dynamic routing is required to respond to the topological changes as nodes are dynamic in nature.

As nodes are free to move arbitrarily in different directions with different speeds, topological changes occur randomly and at unpredictable time in network. Trust relationship among nodes might be disturbed due to dynamic topology and if some nodes are detected as compromised and the choice of intermediaries will change. The routing protocols described above are not directly applicable to ad hoc networks. MANETS require efficient dynamic routing algorithm to respond to the topological changes as nodes are dynamic, network is unstable and no central controller/base station [18][19].

3.4 Problems with Routing in Mobile Ad-hoc Networks

A) Addressing

Currently, there is no mechanism to realize the auto configuration, as for example in the DHCP (Dynamic Host Configuration Protocol) existing in the fixed or infrastructure networks [20].

B) Dynamic topology

Due to the mobility of nodes topological changes occur in the network, routing tables must somehow reflect these changes in topology and routing algorithms have to be adapted [13].

C) Interference

This is the major problem with MANETS as depending on the transmission characteristics links come and go, one transmission might interfere with another one and node might overhear transmissions of other nodes and can corrupt the total transmission [4].

D) Routing Overhead

As each node has different mobile characteristics such as velocity and movement direction, they often change their location. So, some stale routes are generated in the routing table which leads to unnecessary routing overhead [14].

E) Asymmetric links

Most of the wired networks rely on the symmetric links which are always fixed. But this is not a case with ad-hoc networks as the nodes are mobile and constantly changing their position within network [7][20].

3.5 Desirable properties

Due to the problems described above conventional routing protocols are not suited for MANETs, efficient dynamic routing is required. These routing protocols should have some properties to meet MANETs requirements [2][4][21], that are described below:

A) Distributed operation

There is no central controller/base station in MANETs, the control of the network is equally distributed among the nodes. Each node acts both as router and host, so routing protocol should be distributed. It should not be dependent on a centralized controlling node

B) Loop free

To improve the overall performance, we want the routing protocol to guarantee that the routes supplied are loop-free. This avoids any waste of bandwidth or CPU consumption.

C) Power conservation

Mobile Devices used in MANETs are battery operated so there is limited power due to which there are tight limitations on energy, processing power and therefore uses some sort of stand-by mode to save power. Routing protocol should be energy efficient.

D) Demand based operation

Due to the mobility of nodes topological changes occur in the network, thus the protocol should not periodically flood control information, it should only react when needed to minimize the control overhead in the network.

E) Multiple routes

To reduce the number of reactions to topological changes and congestion multiple routes could be used. If one route has become invalid, it is possible that another stored route could still be valid and thus saving the routing protocol from initiating another route discovery procedure.

G) Quality of service support

Some sort of Quality of Service support is probably necessary to incorporate into the routing protocol. This has a lot to do with what these networks will be used for. It could for instance be real-time traffic support.

H) Security

The wireless and dynamic nature of MANETs brings new security threats. These networks are intrinsically exposed to numerous security attacks as the wireless medium is vulnerable to eavesdropping and ad hoc network functionality is established through node cooperation, and trust relationship among nodes disturbed due to the mobility of nodes and if some nodes are detected as compromised, we need some sort of preventive security measures. Routing protocol should ensure the security of information.

None of the proposed protocols from MANET have all these properties, but it is necessary to remember that the protocols are still under development and are probably extended with more functionality. The primary function is still to find a route to the destination, not to find the best/optimal/shortest-path route.

3.6 Classification of Routing Protocols in MANET's:

Routing protocols in MANET are categorized as flat routing, hierarchical routing and geographic position assisted routing. According to routing strategy flat routing is further subdivided into proactive routing and reactive routing [1][18][19]. The proactive routing algorithms (e.g. FSR,OLSR) are table driven that find the routes constantly and maintain routing information for all source-destination pairs in routing table which cause high routing overhead. Reactive routing protocols such as AODV, DSR discover the route between source and destination pair only when needed. These algorithms are also known as on demand routing protocols.

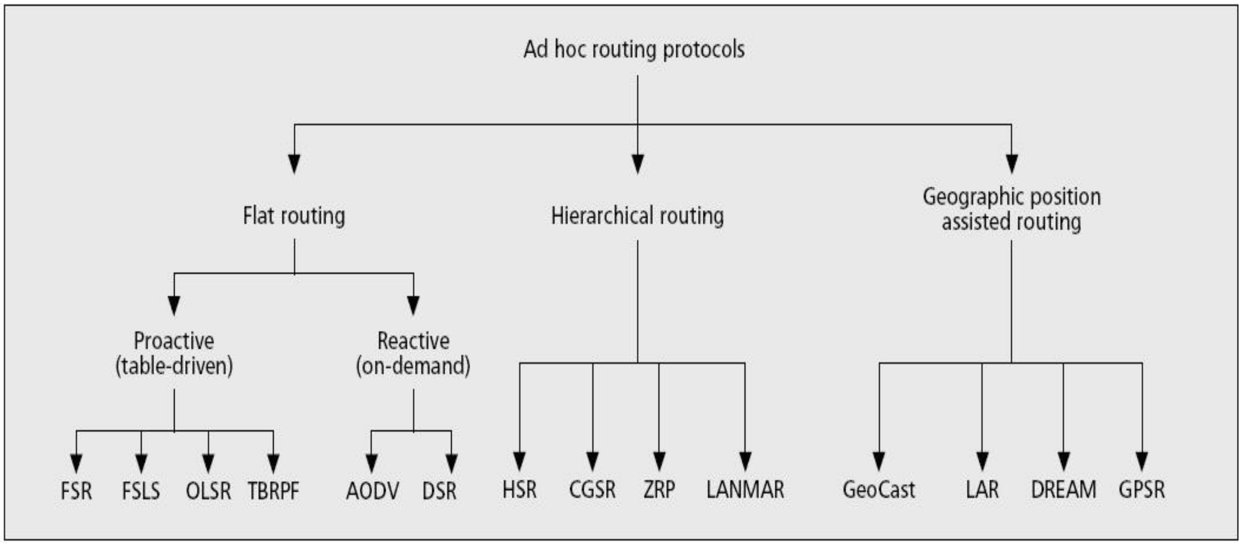


Figure 2 Classification of Routing Protocols in MANET [20]

3.7 Flat Routing

Flat routing is further categorized into proactive routing and reactive routing according to routing strategy. The proactive routing algorithms (e.g. DSDV,OLSR) are table driven that find the routes constantly and maintain routing information for all source-destination pairs in routing table which causes high routing overhead. Reactive routing protocols such as AODV, DSR discover the route between source and destination pair only when it's required.

3.7.1 Proactive Routing

These protocols are also called Table-Driven routing protocols since each and every node maintains fresh routing information for all source-destination pairs (the network topology information) in routing table even before it is needed. Routing table of each node is required to be updated periodically as the network topology changes due to mobility of nodes in MANET. This act is achieved by flooding routing information periodically throughout the network. Huge information is to be transferred throughout the network which causes more routing overhead leading to high bandwidth consumption. That's why proactive protocols are not suitable for larger networks. The examples of this protocol are –

- DSDV (destination sequenced distance vector)
- OLSR (optimized link state routing)

3.7.2 Reactive Routing Protocols

Reactive routing protocols discover the route between source and destination pair only when it's required that's why they are called On Demand routing protocols. Route discovery is performed by flooding the route request (RREQ) and route reply (RREP) packets.The main disadvantage of this approach is that excessive flooding can lead to network clogging and the latency time is high for finding the route. Examples of this protocol are –

- DSR (dynamic source routing)
- AODV (ad-hoc on demand distance vector routing)

3.7.3 Hybrid Routing Protocol

Hybrid routing protocol (both proactive and reactive) combines the advantages of both the strategy. The routing is initially established on some proactively prospected routes and then serves the demand from additionally activated nodes through reactive flooding. Hence it combines both approaches. The main disadvantage of this algorithm is that reaction to traffic demand depends of the gradient of traffic volume. The example of this algorithm is ZRP (zone routing protocol).

3.8 Geographic Position Assisted Routing

Geographic routing relies on geographic position information so it requires that each node can get information about its own location and exact location of its neighbour so each node in MANET should be equipped with GPS (global position system) to know positions. With this geographic location information local decision to route message to the destination can be made, without knowledge of the network topology or a prior route discovery. Although geographic forwarding has the potential to be the foundation for scalable ad hoc networks, it has three main problems: first, geographic forwarding can only send data to network clients with known locations; second, geographic forwarding assumes each computer on the network knows its own position for making forwarding decisions; and third, geographic forwarding performs poorly with some network topology [43].

Chapter 4 AODV ROUTING PROTOCOL

Adhoc On Demand Distance Vector (AODV) routing protocol is widely used routing algorithm for MANET [23]. Whenever any source need to communicate with some other node it starts blind flooding of RREQ (Route request packet, message initiated by the source to find the destination) in whole network to find and establish unicast route between source and destination as it belongs to reactive routing protocols category. Due to network-wide flooding, Each and every nodes of the network have to entertain the Route request packet which causes overhead in terms of wireless node processing, energy consumption and bandwidth [24]. Overhead in bandwidth occurred when an RREQ broadcasted by source in the process of on demand route discovery.

4.1 Routing Table Management

In AODV routing algorithm, each mobile node in the network maintains a route table entry for each destination of interest in its route table [5][23]. Each entry contains the following information:

- Destination IP Address: IP address of the destination node.
- Destination Sequence Number: Sequence number of the destination.
- Next Hop: The next node (neighbor), which has been designated to transmit RREQ to the destination for this route entry.
- Hop Count: Number of intermediate nodes upto the destination.
- Active neighbor list: Neighbor nodes that are actively using this route entry.

- Lifetime: The time for which the route is considered valid.
- Request buffer: Makes sure that a request is only processed once.

4.2 Control Messages:

A) Route Request Packet (RREQ)

Whenever any source need to communicate with some other node and route is not available for the destination, it starts blind flooding of RREQ throughout the network. The RREQ contains the following fields [3]:

Source Address	Request ID	Source sequence No	Destination address	Destination sequence No	Hop count

TABLE I Route Request (RREQ)Packet Format [44]

Each time the source node sends a new RREQ, the request ID is incremented, sothe pair (request ID, source address) identifies a RREQ uniquely. On receiving a RREQ message each node checks the request ID and source address. On receiving RREQ with the same pair (request ID, source address), node discards the received RREQ packet. Otherwise the RREQ will be either replied with a RREP message or forwarded RREQ to its neighbours according to following situations:

If the receiving node has no route entry in its routing table for the destination or its entry is not up-to-date, it rebroadcasts the RREQ with incremented hop count. If the receiving node has a route with a sequence number greater than or equal to that of RREQ, it generates a RREP message back to the source.

B) Routing reply

If RREQ receiving node has a valid route to the destination or itself is the destination, it unicasts a route reply message (RREP) back to the source. RREP has the following format :

Source Address	Destination address	Destination sequence No	Hop count	Lifetime

TABLE II Route Reply (RREP)Packet Format [44]

C) Route Error Message (RERR)

In AODV each and every node monitors its own neighbor node. When any node in the active route moved away from its location or its energy elapsed, it’s neighbor node generate a route error message (RERR) to notify other nodes in the route that link is lost.

D) HELLO Message

In AODV, each node periodically sends HELLO message in its transmission range to tell all it’s neighbor that link is still alive. HELLO messages are never forwarded. After receiving HELLO message node refreshes the corresponding lifetime of the neighbour information in its routing table.

4.3Factors Affecting Route Decisions

A node decides which route to update in the routing table based on the following two values:

A) Destination Sequence Number

Destination sequence numbers are used to ensure, no loops are formed in the network [26].Any node updates its routing table only when it get route that has a higher destination sequence number for the destination. Whenever any node receives an AODV control message, it checks the routing table to determine if an entry exists for the destination ip address or not. If no entry exists for that route, then an entry is created in the routing table. If the sequence numbers are equal but the existing hop count in the routing table is less than the hop count in the control packet plus one or the new sequence number is higher than the destination sequence number in the routing table, entry in the routing table is updated.

B) Hop Count

Hop count is number of intermediate nodes on the route upto destination. The route with the shortest Hop count is selected as the optimal path in AODV [26].If any node receives RREP packet; the route entry to that destination will be updated.

4.4Basic Routing Operation

4.4.1 Route Discovery:

A node broadcasts a RREQ when it needs a route to a destination and does not have one available. This can happen if the route to the destination is unknown, or if a previously valid route expires. After broadcasting a RREQ, the node waits for a RREP. If the reply is not received within a certain time, the node may rebroadcast the RREQ or assume that there is no route to the destination [11][21].

Forwarding of RREQs is done when the node receiving a RREQ does not have a route to the destination. It then rebroadcast the RREQ. The node also creates a temporary reverse route to the Source IP Address in its routing table with next hop equal to the IP address field of the neighboring node that sent the broadcast RREQ. This is done to keep track of a route back to the original node making the request, and might be used for an eventual RREP to find its way back to the requesting node. The route is temporary in the sense that it is valid for a much shorter time, than an actual route entry.

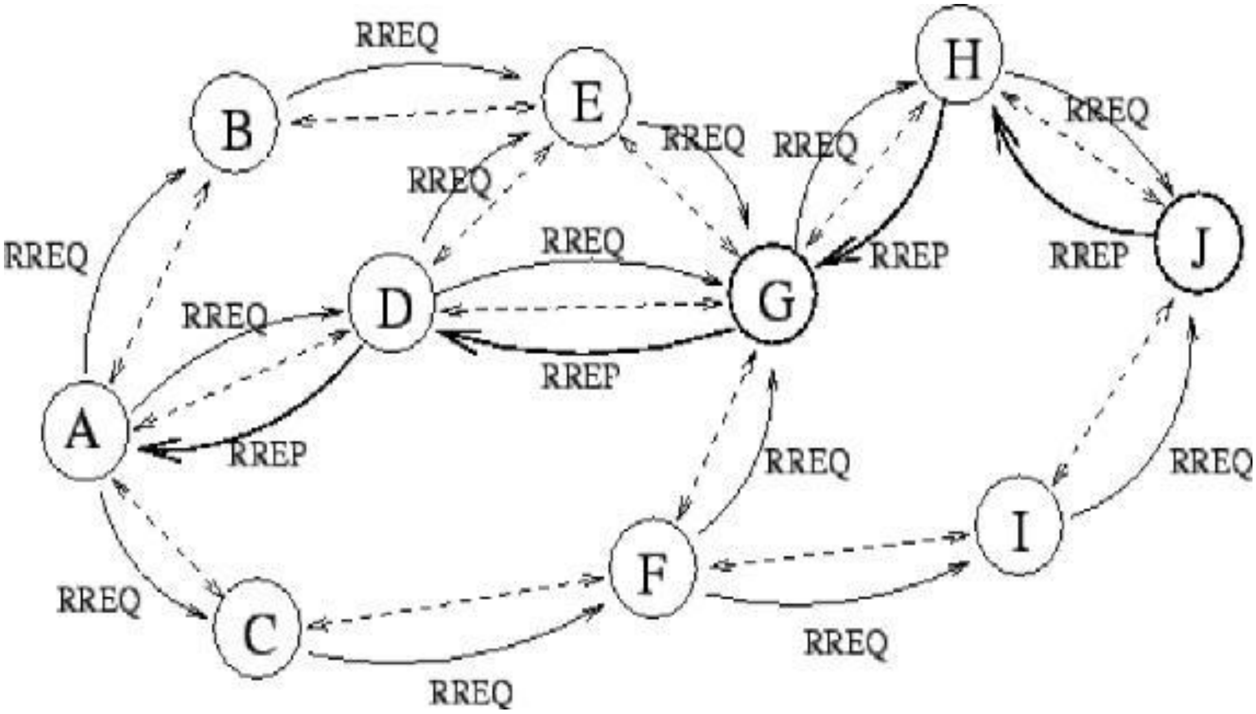


Figure 3 Route Discovery Process in AODV [45]

When the RREQ reaches a node that either is the destination node or a node with a valid route to the destination, a RREP is generated and unicasted back to the requesting node. While this RREP is forwarded, a route is created to the destination and when the RREP reaches the source node, there exists a route from the source to the destination.

4.4.2 Route maintenance:

When a node detects that a route to a neighbor no longer is valid, it will remove the routing entry and send a link failure message, a triggered route reply message to the neighbors that are actively using the route, informing them that this route no longer is valid. For this purpose AODV uses a active neighbor list to keep track of the neighbors that are using a particular route [21]. The nodes that receive this message will repeat this procedure. The message will eventually be received by the affected sources that can chose to either stop sending data or requesting a new route by sending out a new RREQ.

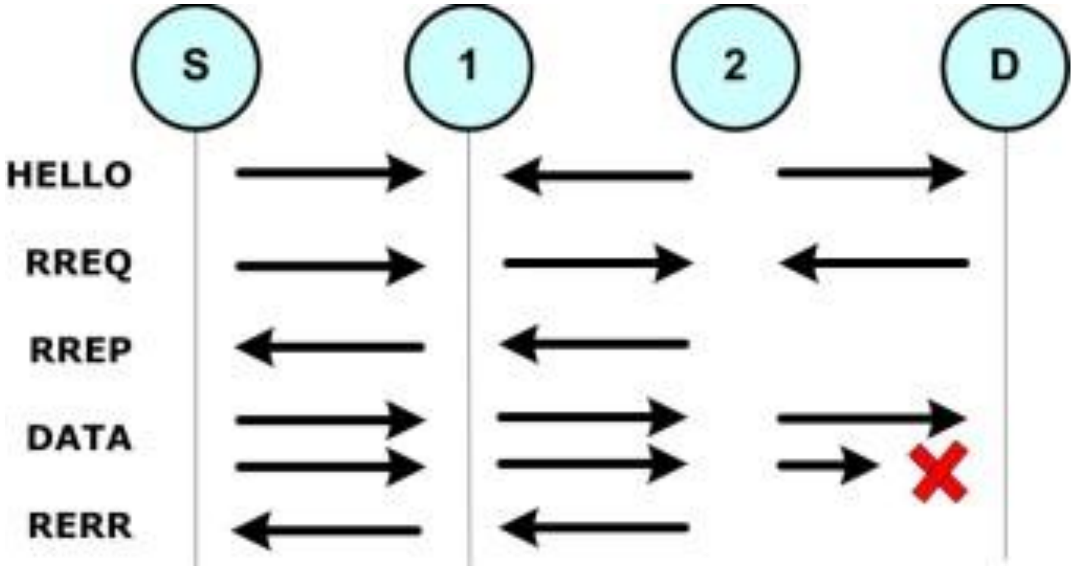


Figure 4 AODV Protocol messages [45]

4.5 Working of AODV

AODV performed following task to provide optimal route for destination and for route maintenance [12][20]:

- Being a routing protocol, AODV involves route table management and is run based on the following route-request/route-reply cycle:
- When a source node transmits data to a node, the route of which is unknown, it broadcasts a route request (RREQ) packet. This request packet will contain the last known sequence number for that route. The sequence number ensures loop-free networks.
- Nodes that receive this packet update the route table for the source node address for a period of time: REV_ROUTE_TIMEOUT. This request will then be flooded throughout the network until it reaches the destination or it reaches a node that has a route to the destination. Every node that forwards the request maintains backward pointers indicating the reverse route back to the source node.
- The RREQ packet will contain the Internet protocol (IP) address of the source node, the broadcast identification, the IP address of the destination node, the destination sequence number, and the latest sequence number for the destination on the source node.
- When a node receives a RREQ, if the node either has a route to the destination with a sequence number greater than or equal to the sequence number in the

RREQ or the node is the destination itself, then a route reply (RREP) message is generated.

- The RREP packet is sent as a unicast transmission to the source. As the RREP traverses toward the source, the routing tables of all nodes will be updated for that destination IP address.
- If the node that receives the RREQ does not have a route or is not the destination, then it will rebroadcast the RREQ.
- Nodes maintain a visible table to keep track of the RREQ's received and their broadcast identifications. If an already-processed RREQ is received, then it will be dropped.
- As soon as the source receives the RREP, it begins to forward traffic to the destination.
- AODV begins to use the route that is first available to the node. If an RREP received by a node has a greater sequence number or an equal sequence number with lesser number of hops then, the node will update its routing table with that route.
- As long as a route is in use, it will remain active. A route will be considered to be active as long as there are data packets requesting the use of the route.
- If a link breaks while a route using that link is active, a route error (RERR) message will be generated by the node upstream. This message will propagate through until the source node and inform it of the now-unreachable destinations. Route discovery will be reinitiated for the destination for the nodes that require the use of that route.

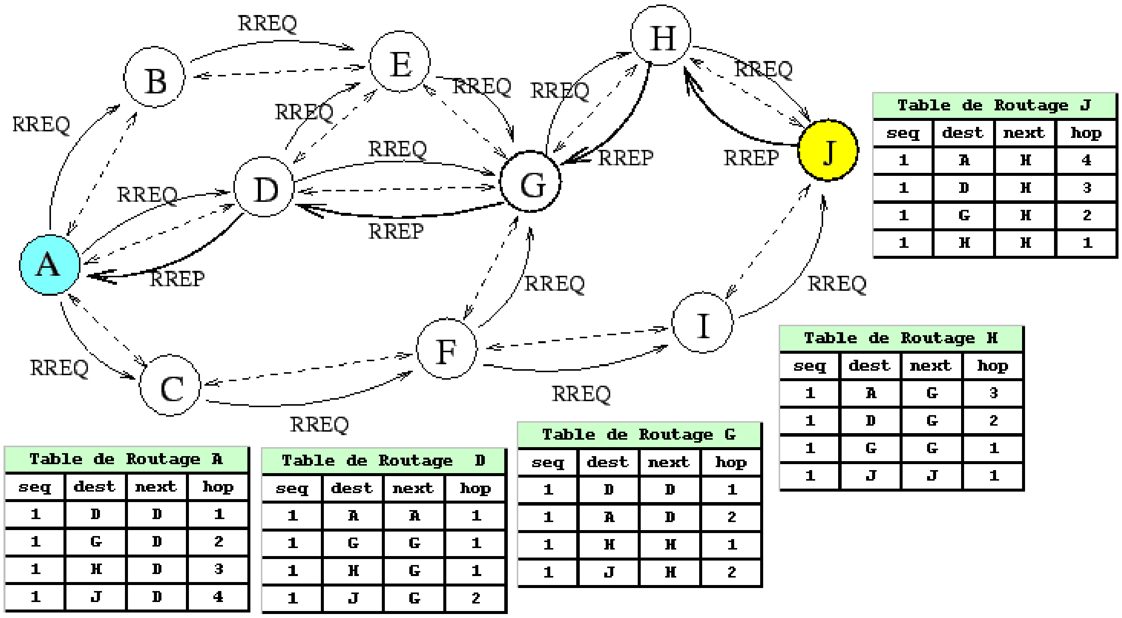


Table de Routage J

seq	dest	next	hop
1	A	H	4
1	D	H	3
1	G	H	2
1	H	H	1

Table de Routage H

seq	dest	next	hop
1	A	G	3
1	D	G	2
1	G	G	1
1	J	J	1

Table de Routage A

seq	dest	next	hop
1	D	D	1
1	G	D	2
1	H	D	3
1	J	D	4

Table de Routage D

seq	dest	next	hop
1	A	A	1
1	G	G	1
1	H	G	1
1	J	G	2

Table de Routage G

seq	dest	next	hop
1	D	D	1
1	A	D	2
1	H	H	1
1	J	H	2

Figure 5 Route Discovery process with Route Table management [46]

- When a route is not used for a period of time, the route times out and is deleted from the route table. This time period is called the route expiry time (RET) or the lifetime of the route.

4.6 Interesting concepts of AODV

The concepts of AODV that make it desirable for MANETs with limited bandwidth include the following [5][20][23]:

A) Minimal space complexity

The algorithm makes sure that the nodes that are not in the active path do not maintain information about this route. After a node receives the RREQ and sets a reverse path in its routing table and propagates the RREQ to its neighbors, if it does not receive any RREP from its neighbors for this request, it deletes the routing info that it has recorded.

B) Maximum utilization of the bandwidth:

This can be considered the major achievement of the algorithm. As the protocol does not require periodic global advertisements, the demand on the available bandwidth is less. And a monotonically increased sequence number counter is maintained by each node in order to supersede any stale cached routes. All the intermediate nodes in an active path updating their routing tables also make sure of maximum utilization of the bandwidth. Since, these routing tables will be used repeatedly if that intermediate node receives any RREQ from another source for same destination. Also, any RREPs that are received by the nodes are compared with the RREP that was propagated last using the destination sequence numbers and are discarded if they are not better than the already propagated RREPs.

C) Simple

It is simple with each node behaving as a router, maintaining a simple routing table, and the source node initiating path discovery request, making the network self-starting [27].

D) Most effective routing info

After propagating an RREP, if a node finds receives an RREP with smaller hop-count, it updates its routing info with this better path and propagates it.

E) Most current routing info

The route info is obtained on demand. Also, after propagating an RREP, if a node finds receives an RREP with greater destination sequence number, it updates its routing info with this latest path and propagates it.

F) Loop-free routes

The algorithm maintains loop free routes by using the simple logic of nodes discarding non better packets for same broadcast-id.

G) Coping up with dynamic topology and broken links

When the nodes in the network move from their places and the topology is changed or the links in the active path are broken, the intermediate node that discovers this link breakage propagates an RERR packet. And the source node re-initializes the path discovery if it still desires the route. This ensures quick response to broken links.

H) Highly Scalable

The algorithm is highly scalable because of the minimum space complexity and broadcasts avoided.

4.7 Limitations/Disadvantages of AODV

A) Requirement on broadcast medium

The algorithm expects/requires that the nodes in the broadcast medium can detect each others' broadcasts.

B) Overhead on the bandwidth

Overhead on bandwidth will be occurred compared to DSR, when an RREQ travels from node to node in the process of discovering the route info on demand, it sets up the reverse path in itself with the addresses of all the nodes through which it is passing and it carries all this info all its way [12][20].

C) No reuse of routing info

AODV lacks an efficient route maintenance technique. The routing info is always obtained on demand, including for common case traffic [12][26].

D) It is vulnerable to misuse

The messages can be misused for insider attacks including route disruption, route invasion, node isolation, and resource consumption.

E) AODV lacks support for high throughput routing metrics

AODV is designed to support the shortest hop count metric. This metric favors long, low bandwidth links over short, high-bandwidth links [20].

F) High route discovery latency

AODV is a reactive routing protocol. This means that AODV does not discover a route until a flow is initiated. This route discovery latency result can be high in large-scale mesh networks.

4.8Expanding Ring Search Protocol (ERS)

In AODV, network-wide flooding causes overhead in terms of bandwidth, node processing and energy consumption. To solve this problem Expanding Ring Search (ERS) concept is applied along with AODV [28][29][30]. In ERS based on AODV, flooding of RREQ starts with small TTL (time to live) counter value for route discovery. Time-To-Live (TTL) counter is used to count the number of hops to end of the current ring. Each node decrement the TTL value by 1 before rebroadcasting RREQ. Nodes encounter RREQ with TTL zero; do not forward RREQ any further and flooding halts. Using TTL value, source node can control flooding radius. If source does not receive any RREP within the predefined time-out period, it modify old TTL value to a new value by adding some appropriate pre-decided TTL_increment (to increase the search radius) and the flooding is repeated up to new TTL. A TTL_increment variable is used to gradually increase the size of successive rings. This repetitive process is continues until TTL threshold value encounters or destination found. Whenever source receives RREP, source records the route and won’t modify TTL again and flooding stops. If TTL reaches to threshold value the RREQ is broadcast throughout the entire network like AODV. Using TTL value, source node can control flooding.

Chapter 5 ANTENNA

5.1 Definition

In wireless communication systems, antennas are a very important device as it redirects the radio waves in wireless medium. Antenna is used to convert electric power into radio waves and vice versa or we can say antenna transforms RF signals into an electromagnetic wave in free space. It is used with radio transmitter or receivers, to transmit electromagnetic waves produced by a transmitter or receive electromagnetic waves and pass them onto a receiver. For good results, an antenna should be tuned to the same frequency band of the radio system of attached device. An antenna does not add any power to the signal (as it is passive device) instead simply redirects the energy it receives from the transmitter [32][33][34][35][36][37]. The redirection energy means providing more energy in one particular direction, and less energy in all other directions.

5.2 Fundamentals of Antenna

- **Bandwidth:** The bandwidth of an antenna specifies the range of frequencies over which the antenna can operate correctly and its performance does not suffer due to a poor impedance match.
- **Radiation pattern:** Antenna can be used to redirect energy in perfect 3-D plane (by using theoretical isotropic antenna), in 2-D plane(in Omnidirectional antenna)

or some specific direction(in case of directional antenna) which is known radiation pattern of that antenna. It can be represented by 2-D polar plots of the vertical and horizontal cross section or by 3-D graph. Theoretical isotropic antenna has perfect 3-D spherical radiation pattern (a perfect 360 degree vertical and horizontal beamwidth). Omnidirectional antenna provides uniform two-dimensional radiation pattern. In other words, Omnidirectional antenna has perfect 360 degree horizontal beamwidth radiation pattern.

- **Directivity:** An antenna can focus energy in some particular direction while transmitting, or to receive energy, this ability of an antenna is known as directivity. When the transceiver is not fixed, we use omni-directional antenna which radiates equally in all directions whereas during transmission one may want to transmit in some specific direction so antenna directivity is used to concentrate the radiation beam in the desired direction.

- **Gain:** Gain measures the amount of energy added to radio frequency by any antenna. The gain of an antenna is defined as the ratio of the intensity radiated in the direction of its maximum output to the intensity radiated at the same distance by a hypothetical isotropic antenna. In other words, the gain of an antenna in a given direction, is the amount of radiated energy in that direction by that antenna divided by the energy radiated by isotropic antenna in the same direction when driven with the same input power.

- **Effective area or aperture:** On receiving energy antenna delivers the portion of the power of a passing electromagnetic wave to its terminals which is known as effective area of that antenna. No antenna provides 100% efficiency; the effective area of any antenna is directly proportional to gain of that antenna.

- **Beamwidth:** Directional antenna is used to redirect the energy in some specific direction as it decreases angle of radiation. The radiation pattern or reduced coverage angle of directional antenna is measured in degrees and called is beamwidth (half-power beamwidth). Directional antenna focus on reduced coverage angle but increased coverage distance in one direction. Therefore, we can transmit RF energy to farther distances in particular direction as effective beamwidh decreases. The directive gain of any antenna is inversely proportional to the beamwidth of the same: as the beamwidth decreases, the directive gains increases. In this system, antenna should face in the direction where the coverage is desired (should come before).

- **Sidelobes:** Directional antenna is used to redirect the energy in some specific direction in the pattern of lobe in that direction is known as main lobe but directional antenna is not able to radiate all the energy in desired direction. Unwanted radiation occurs in other directions, which is referred as sidelobes.

- **Null:** Antenna redirects the energy in the pattern of lobe; a null is a zone where the effective radiated power falls to zero or minimum. A null often has a narrow directivity angle compared to that of the main beam. We can say the null is useful for several purposes like suppression of interfering signals in a given direction.

- **Field regions:** The space surrounding an antenna can be divided into three concentric regions: far-field, reactive near-field and Fresnell region (radiating near-field). The field structure can be identified by these three regions, although there are no precise boundaries.

- **Front to back ratio:** The front-to-back ratio of an antenna is the ratio of energy directing in particular direction to its directivity in the rearward direction. The gain of any antenna is directly proportional to the front-to-back ratio of that antenna. A good antenna front-to-back ratio is normally 20 dB.

- **Input Impedance:** At any given point ratio of voltage to current in the antenna system is termed as antenna impedance. During the communication between antennas, electro-magnetic waves travel through the different parts of the antenna system like feed line, free space, radio which may cause differences in impedance. Depending upon the influence of surrounding objects, height above ground, and other factors, quarter wave antenna with a near perfect ground may have input impedance of around 36 ohms.

- **Return Loss:** The return loss is another way of expressing mismatch. It compares the power reflected by the antenna to the power that is fed into the antenna from the transmission line and measures their logarithmic ratio in dB.

- **Efficiency:** The ratio of power actually radiated to the power absorbed by the antenna terminals is known as efficiency of a transmitting antenna. The power which is not radiated is converted into heat at the antenna terminals.

- **Polarization:** The direction of orientation of the electrical field vector with respect to the Earth's surface is known as Polarization. It is categorized into two types of polarization that are

- Linear polarization
- Circular polarization.

The electric field vector stays in the same plane in linear polarization, either vertically or horizontally. So, linear polarization is further subdivided into vertical polarization and horizontal polarization.. The most widely used, Omnidirectional antennas always work with the issue of vertical polarization. But it does not pose a major threat to the communication process. Horizontal polarization causes variations in received signal strength.

The electric field vector rotates about the direction of propagation with circular motion, makes one full turn for each RF cycle which is known as circular polarization. Designer can choose polarization either right hand or left hand in RF system.

- **Polarization Mismatch:** Both the transmitting and receiving antennas must have the same polarization sense, the same spatial orientation and the same axial ratio in order to transfer maximum power.

There will be a reduction in power transfer between the transmitting and receiving antennas, if they do not have the same polarization or are not aligned which will in turn reduce efficiency and performance of the overall system in terms of power transfer.

5.3 Classification of Antenna

Antenna can be classified on the basis of their physical construction, frequency and size radiation pattern and application [34][37]. But in our thesis we have used antenna for selective flooding so here we consider only the radiation pattern based classification of antenna. Antennas are classified into isotropic and dipole antennas based on 3-D and 2-D radiation [32][33].

Isotropic antenna has uniform three-dimensional spherical radiation pattern. In other words an isotropic antenna has perfect 360 degree vertical as well as horizontal beamwidth radiation pattern like spherical shape. But in real world no such antenna exists, it is an only ideal theoretical antenna with zero gain and zero loss.

Dipole antennas are real antennas those have radiation pattern of 360 degrees in the horizontal plane and approximately 75 degrees in the vertical plane. In dipole antennas, beamwidth is concentrated (as they have smaller vertical beamwidth) in comparison with isotropic antenna so they have some gain.

As Dipole antennas are real world antennas our main interest in that which are further subdivided into omnidirectional antennas and directional antennas.

5.4 Omni Directional Antenna

Omnidirectional antenna provides uniform two-dimensional radiation pattern. In other words, Omnidirectional antenna has perfect 360 degree horizontal beamwidth radiation pattern. As omnidirectional antenna is dipole antenna, it is usually vertical polarized [32]. Due to this concentrated beamwidth it has some gain. Omni antenna increases the probability of receiving signal in a multipath environment. Omnidirectional antennas such as Cisco Aironet Antennas (HGA9N and HGA7S) are used for small office environments.

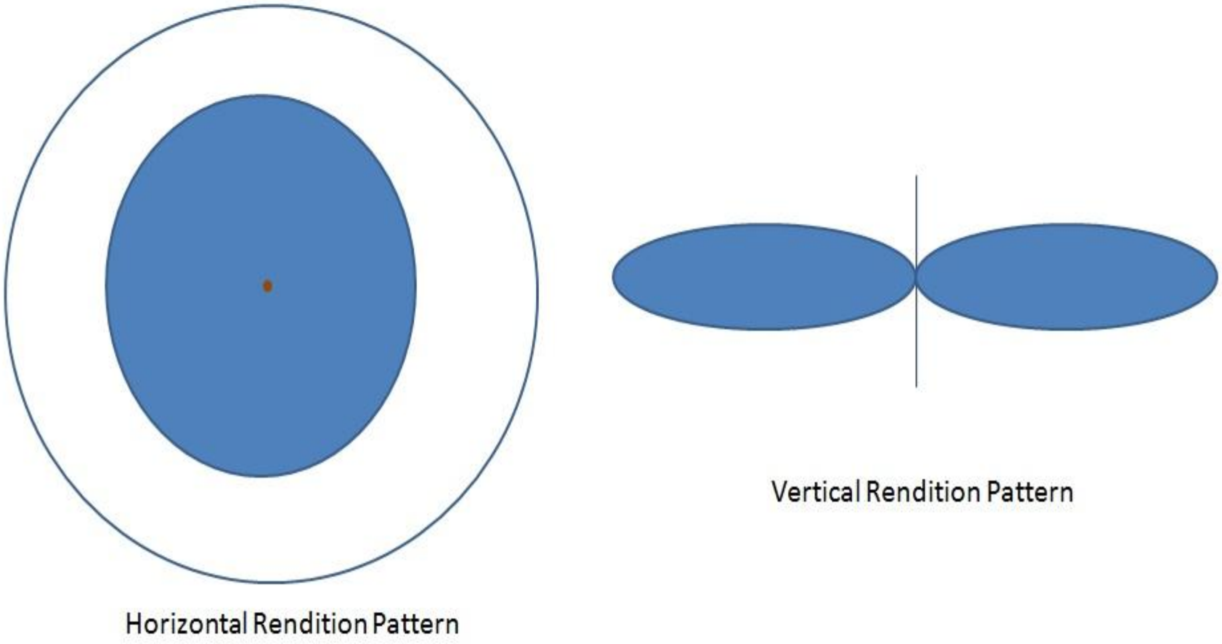


Figure 6 Omnidirectional antenna Radiation Pattern

Pros and cons: Omnidirectional antenna has perfect 360 degree horizontal radiation pattern, they can be mounted upside down from a ceiling in the indoor environment, which is very easy to install. It is very convenient to attach Omnidirectional antennas with the product because of its shape. They are vertical polarized that means radiate energy in concentrated beamwidth, do it has some gain and can transmit long distances, but they have poor coverage below the antenna**.**

5.5 Directional Antennas

Directional antennas are used to redirect the energy in some specific direction as it decreases angle of radiation. The coverage angle is measured in degrees and called beamwidths [32][38][39]. Directional antenna focus reduced coverage angle but increase the coverage distance in one direction. Therefore, we can transmit RF energy to farther distances in particular direction as effective beamwidh decreases.

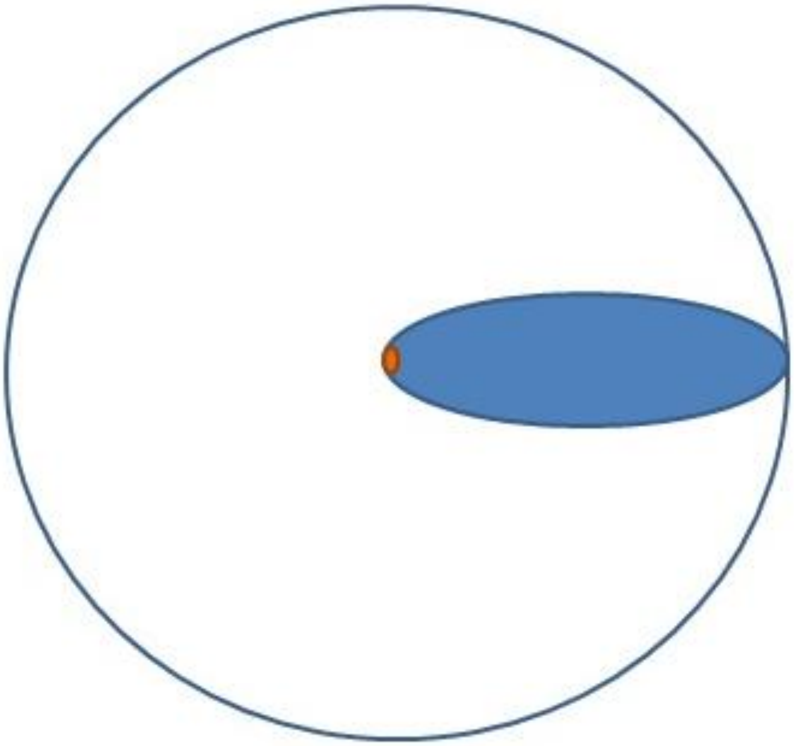


Figure 7 Directional antenna Horizontal Radiation Pattern

Pros and Cons: Directional antenna transmits energy in particular direction as it decreases angle of radiation. It enables transition of RF energy to farther distance in particular direction as effective coverage angle (beamwidh) decreases. So, these antennas are not suitable for indoor environment which require wider angular area around AP as it has less angular coverage. In this system, antenna array should face in the direction where the coverage is desired so the mounting of directional antennas is challenging some times.

5.6 SectorizedAntenna

Sectorized antenna is made of multiple identical directional antennas radiating at equal size coverage angle in non-overlapping manner that makes angularly-separated sector-shaped radiation pattern which divides transmission range into equal size sectors [38][40][41]. It is built by mounting multiple directional antennas radially around common center. In real world 3 to 8 sector antennas are commonly used for propagation of energy built by 45 degree to 120 degree angular azimuth beamwidth directional antennas.

Sectorized antenna systems are mainly used to reduce interference. If any sectorized system built up of k directional antennas aimed in different direction then each node in this system is assigned different channels to different interfaces is assigned to reduce interface. In the proposed work, we are applying sectorized antenna system for efficient broadcasting to reduce routing over head by selective transmission of RREQ. Sectorized antenna system can be used to transmit in one or more selective sectors as well as in whole 360° omnidirectional transmission range. This configuration provides good data rates and good signal consistency within the coverage area.

5.7 Selective Flooding using Sectorized Antenna

Nodes equipped with single omnidirectional antenna is replaced with k directional antennas that equally divide the omnidirectional transmission range into k non-overlapping sectors where one or more such sectors can be switched on for selective transmission. Each antenna supports communication with multiple nodes using different channels.

In sectorized antenna system, each node is capable of selective transmission over multiple sectors. At each node efficient broadcasting is performed by switching on some of the sectors for transmission using directional antennas to avoid broadcast storm problem caused by blind flooding. Each node can control RREQ broadcast which follows blind flooding. In this technique, routing overhead can be reduced and channel capacity can be improved by switching on some of the sectors for transmission using directional antennas while restricting the transmission in others sectors by switching them off [40][42].

Chapter 6 PROPOSED AAROACH

Dynamic routing protocol such as Adhoc on demand distance vector routing (AODV) with Expanding Ring Search (ERS) is widely used technique to reduce energy consumption and broadcast cost of searching in MANET. In AODV, network-wide flooding is initiated whenever any node wants to communicate with some other node to find the route between source and destination whereas in ERS, flooding performed in successively larger area in network. We reduce number of transmission links at each forwarding node using sectorized antenna and we propose an improved AODV routing algorithm which utilizes a sectorized antenna at each mobile node in high density networks.

6.1 Selective Flooding Applied on AODV and ERS

In this proposed scheme using sectorized antenna, each node is capable of selective transmission over multiple sectors. Nodes equipped with single omnidirectional antenna is replaced with k identical directional antennas that equally divide the omnidirectional transmission range into k non-overlapping sectors where one or more such sectors can be switched on for selective transmission. At each node efficient broadcasting is performed by switching on some of the sectors for transmission using directional antennas to avoid broadcast storm problem caused by blind flooding.

We analyze selective flooding in AODV and ERS routing protocols using sectorized antenna. In sectorized antenna system, each node can control RREQ broadcast in AODV and ERS, which follows blind flooding. In this technique, routing overhead can be reduced and channel capacity

can be improved by transmitting RREQ in some particular sectors. In this configuration, each node is capable of selective transmission in specific direction with its neighbours. In conventional flooding mechanism, each node sends the RREQ to all its neighbours by following uniform two-dimensional radiation pattern. The improved flooding technique uses sectorized antenna to greatly reduce number of transmission links in route discovery process to reduce routing overhead. We used three different sectorized antenna systems.

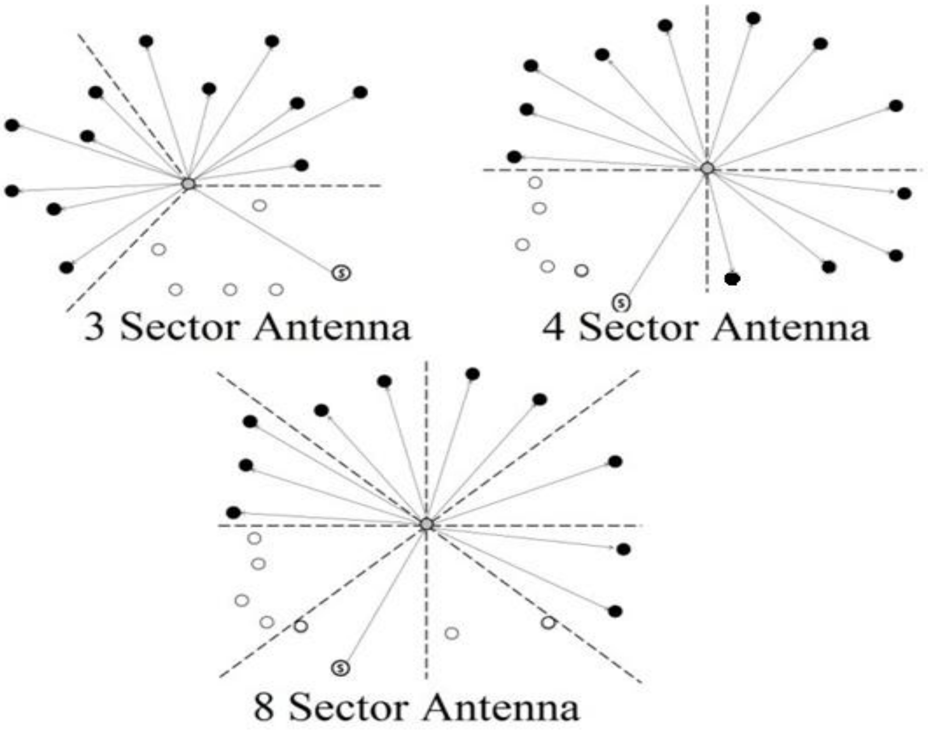


Figure 8 Sectorized Antenna

- Three sector antenna – built by eight directional antennas radiating at an angle of 120 degree each..
- Four sector antenna – built by eight directional antennas radiating at an angle of 90 degree each.
- Eight sector antenna – built by eight directional antennas radiating at an angle of 45 degree each.

As shown in the figure 8, in case of three sector antenna and four sector antenna, the white nodes in the sector of the source node do not receive the flooded packet, whereas all other nodes (black) in the remaining sectors receive the flooded packet, whereas in eight sector antenna none of the node transmits RREQ in the sector of the source node and its adjacent sectors, but broadcasts in the remaining 5 sectors. Node A transmits the RREQ packet only to the sectors with black nodes, not to the sectors with white nodes. This mechanism provides increased efficiency by reducing redundant transmission. In three sector antenna and four sector antenna, no node transmits RREQ in the sector of the source node.

In three sector antenna, each sector is of 120 degree so it restricts flooding in huge area but the only problem is if source node is at the border of that sector then the nodes at the other border of that sector may not be able to receive RREQ, as maximum angular distance can be 120 degree (much high) between two nodes within a sector. In four sector antenna, each sector is of 90 degree which is relatively small in comparison with three sector antenna so there is less chance of any node doesn't get RREQ as maximum angular distance is just 90 degree but selective broadcasting is not as efficient as in case of three sector antenna. In case of eight sector antenna, the nodes in the sector of the source node and its adjacent sectors do not receive the flooded packet, whereas all other nodes (black) in the remaining 5 sectors receive the RREQ. By restricting flooding in sector of the source node and its adjacent sectors we restrict flooding in 135 degree angular area which is higher than both the antenna described earlier and maximum angular distance between any two nodes cannot be more than 90 degree which is similar to the case as in four sector antenna. That means selective flooding in eight sector antenna system, has the advantage of both three sector as well as of four sector antenna.

6.2 Efficient AODV using Sectorized Antenna (EAODVSA)

The proposed algorithm operates in an Adhoc system where all mobile nodes consist of identical sectorized antenna. EAODVSA can be used for on demand routing of messages from a sender to a receiver whose location is unknown. The algorithm improves on the standard AODV and ERS combination in two ways, improved flooding using sectorized antenna and reduced redundant flooding using unicasting.

The improved flooding technique uses sectorized antenna, to greatly reduce unnecessary flooding in all directions of each node. EAODVSA uses eight sector antennas on each node to transmit messages along only five sectors.

The well known Expanding Ring Search (ERS) algorithm uses successive floods of increasing ring size to locate the position of the destination node. It uses a Time-To-Live (TTL) counter to count the number of hops to end of the current ring. A TTL_increment variable is used to gradually increase the size of successive rings. Thus, TTL describes the initial ring size and TTL+TTL_increment describes the size of all further rings.

Sender starts search for the destination node by flooding Route Request (RREQ) packet up to an initial TTL value. At TTL=0 the flooding halts at border of the current ring, all such nodes are known as border nodes. If the destination node is found, then a Route Reply (RREP) packet is sent back to the sender. Otherwise, TTL is increment by TTL_increment and the flooding is repeated up to new TTL value. The proposed EAODVSA algorithm avoids the redundant rebroadcast of RREQ packet in each iteration. In the improved algorithm, all border nodes respond back with RREP packets to the sender to describe the unicast path to themselves, and all successive iterations involve unicasting of RREQ up to border nodes of the previous ring and improved flooding for remaining nodes up to the increased TTL value.

EAODVSA also includes fault tolerance during unicast of RREQ packets. In case of failure of transmission of packet to next node along the unicast path, the current node initiates a directed flood of RREQ in search for the next to next node along the unicast path. Once the next to next node is found, the RREQ packet proceeds along the unicast path up to the border node of previous ring.

Two types of packets, namely, Route Request (RREQ) packet and Route Reply (RREP) packet are used to setup the path between source and destination while using the standard AODV. The proposed algorithm uses conventional RREQ packet [3] [10], as shown in table 1, and the RREP packet is modified (shown in table 3) for two purposes. Firstly, to identify the path to destination node or border node, a Boolean parameter, D-flag, is used. And secondly, to facilitate fault tolerance, the address of immediate sender of RREP (S-address) and the address of the node which sent RREP to immediate sender (PS-address) are also added to the original packet.

Source address	Destination address	Destination sequence No	S-address	PS-Address	D-flag	Hop count	Lifetime

TABLE III Modified Route Reply(RREP) Packet Format

6.2.1 EAODVSA without Fault

1. Initially Source will broadcast the RREQ to all its neighbors with some Initial TTL.
2. RREQ will be broadcasted from all antennas except the receiving sector until TTL=0 or Destination encountered.
3. All Border Nodes (the nodes who encountered TTL=0), RREP with D-Flag=0 will be sent back to the Source.
4. If source receive any RREP with D-flag=1
5. Then discard all other RREP because path to destination is found and start sending unicast data along the path.
6. Else, TTL=TTL + TTL_Increment, send unicast RREQ to all border nodes (RREP source nodes with D-flag=0) along their respective path.
7. Now repeat step 2 to 6 for all current border nodes.

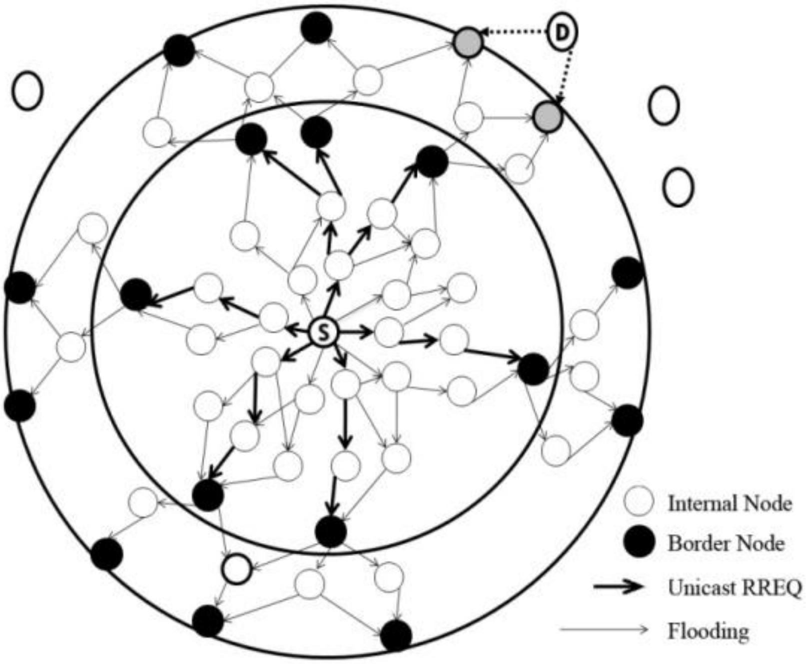


Figure 9 EAODVSA without fault

Figure 9, shows a high density MANET with source node S and destination node D. To search for node D, node S initiates standard flooding (all sectors) with TTL=3 but all other nodes perform flooding using sectorized antenna, as described in section 4. The figure describes the second iteration of the algorithm with incremented TTL=2, where the source node S sends unicast RREQ to all border or ring 1 nodes (shown in black). Now each border node of ring 1 performs sectorized flooding to search for destination node D up to ring 2.

6.2.2 EAODVSA with Fault

1. Initiate only one iteration of EAODVSA with current node as source and the next to next node(PS-address) in RREQ unicast path as destination, with TTL=2, and

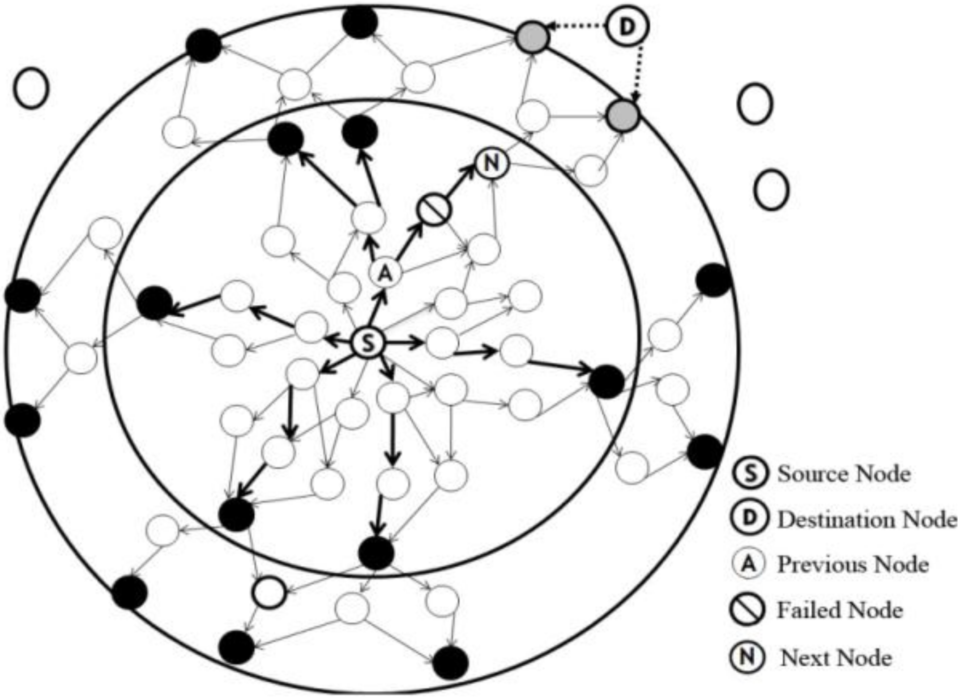


Figure 10 Failure during route discovery

in the sector of The next node (failed node or S-address) antenna and also in 2 more sectors adjacent (left and right) to this sector.

2. If destination found with receiving D-flag=1 then forward the original RREQ for the original destination.
3. Else if destination(next to next node) not found, then initiate EAODVSA with current node as source and destination remaining as original destination i.e. current node behaves as new border node without changing TTL.

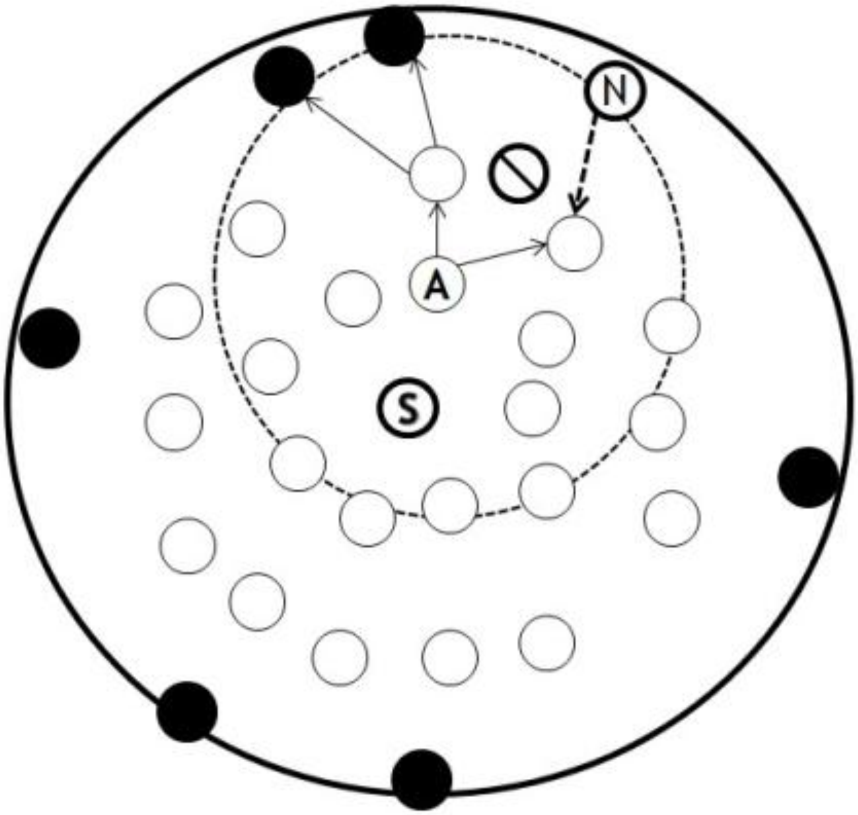
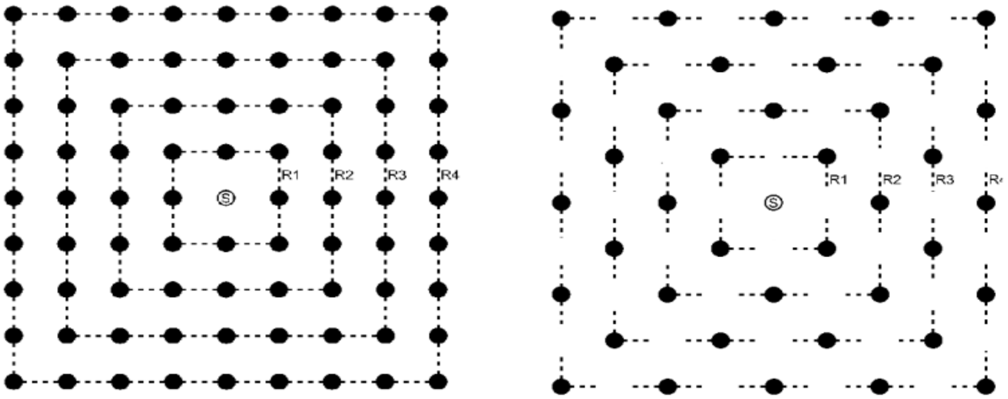


Figure 11 Failure recovery during unicast RREQ

Figure11, shows failure recovery during unicast RREQ initiated by source node S to border node N. On failure of next node to A, node initiates flooding (described in EAODVSA with fault) to search for node N. On receiving RREQ, node N continues unicast transmission along the path to border node (in this case node N is border node).

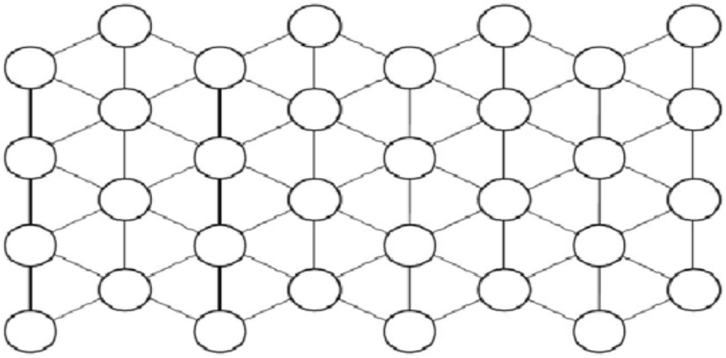
Chapter 7 RESULTS AND ANALYSIS

We consider three regular topologies here: standard eight neighbours regular 2D grid model, standard four neighbours regular 2D grid model and hexagonal topologies. These topologies are shown in figure12 .In regular topology, total nodes belonging to the rings follow a regular pattern. There are total R rings in the topology, ring R being R hops away from the source node. For hexagonal and 2D grid (8 neighbours and 4 neighbours), nodes that are 1 hop away



8 neighbour grid model

4 neighbours grid model



Hexagonal

Figure 12 Regular Topologies

from the source belong to first ring, nodes that are 2 hop away from the source belong to second ring. In standard eight neighbours regular 2D grid model and four neighbours regular 2D Grid model, each node has directly connected to 8 neighbours and 4 neighbours respectively, whereas in hexagonal topology each node has 6 neighbours.

Transmission cost can include many things, such as, processing cost, network bandwidth, energy constraint etc. In our work, we consider number of transmitted RREQ messages in the network, for a particular query.

7.1 Result and Analysis of Selective Flooding Applied on AODV

To analyze the effect of selective flooding applied on AODV, we generate graph of number of links used in route discovery in AODV for both blind flooding as well as selective flooding using sectorized antenna. We used three different sectorized system, those are three sector antenna, four sector antenna and eight sector antenna. We applied blind flooding as well as efficient flooding using all three sectorized antenna on all three models, behaviour of hexagonal shown by equation (1) - (4), behaviour of four neighbor 2-D grid shown by equation (5) - (8) and eight neighbor 2-D grid model behaviour model is described by equation (9)-(12).

Figure 13, 14 and 15 shows the number of transmitted RREQ packet in blind flooding and selective efficient flooding using sectorized antenna for standard hexagonal, four neighbor 2-D grid and eight neighbor 2-D grid models respectively. In these three figures, red color is used to show number of transmitted RREQ in traditional blind flooding based AODV, whereas Blue, Green and Orange colors shows number of transmitted RREQ for selective flooding using eight sector, four sector and three sector antenna respectively. Figure 13 and 15 shows, eight sector antenna transmits least query messages for route discovery whereas three and four sector antenna transmit relatively higher for hexagonal and eight neighbour 2-D grid models. But for the four neighbor 2-D grid model, figure 14 shows three sector antenna sends least RREQ, whereas four and eight sector antenna transmit near about same number of query messages which is higher.

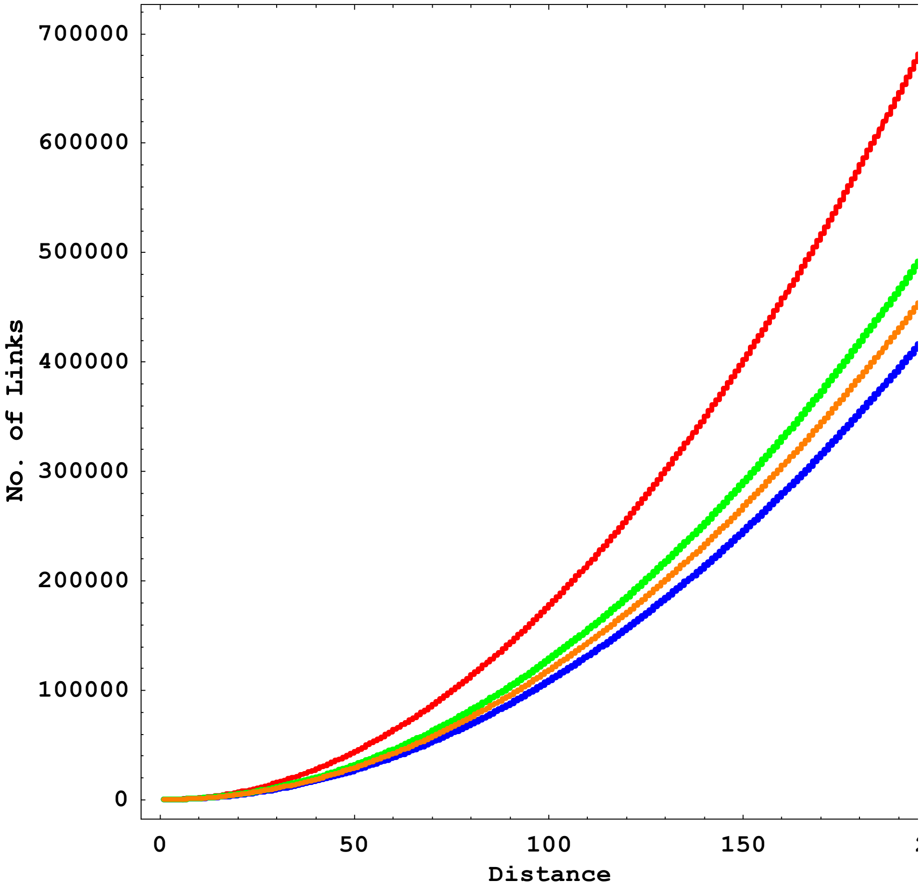


Figure 13 No. of links used in route discovery in AODV for Hexagonal Model

For Hexagonal Model

$$\text{No. of Links in AODV using omnidirectional antenna}, N_{omni} = 6 + 6 \times \sum_{i=0}^{R-1} (6 \times i) \dots\dots\dots\dots\dots\dots (1)$$

$$\text{No. of Links in AODV using three sector antenna}, N_{three} = 6 + 4 \times \sum_{i=0}^{R-1} (6 \times i) \dots\dots\dots\dots\dots\dots\dots\dots (2)$$

$$\text{No. of Links in AODV using four sector antenna}, N_{four} = 6 + 4 \times \sum_{i=0}^{R-1} (4 \times i) + 5 \times \sum_{i=0}^{R-1} (2 \times i) \dots. (3)$$

$$\text{No. of Links in AODV using four sector antenna}, N_{eight} = 6 + 4 \times \sum_{i=0}^{R-1} (4 \times i) + 3 \times \sum_{i=0}^{R-1} (2 \times i) \dots. (4)$$

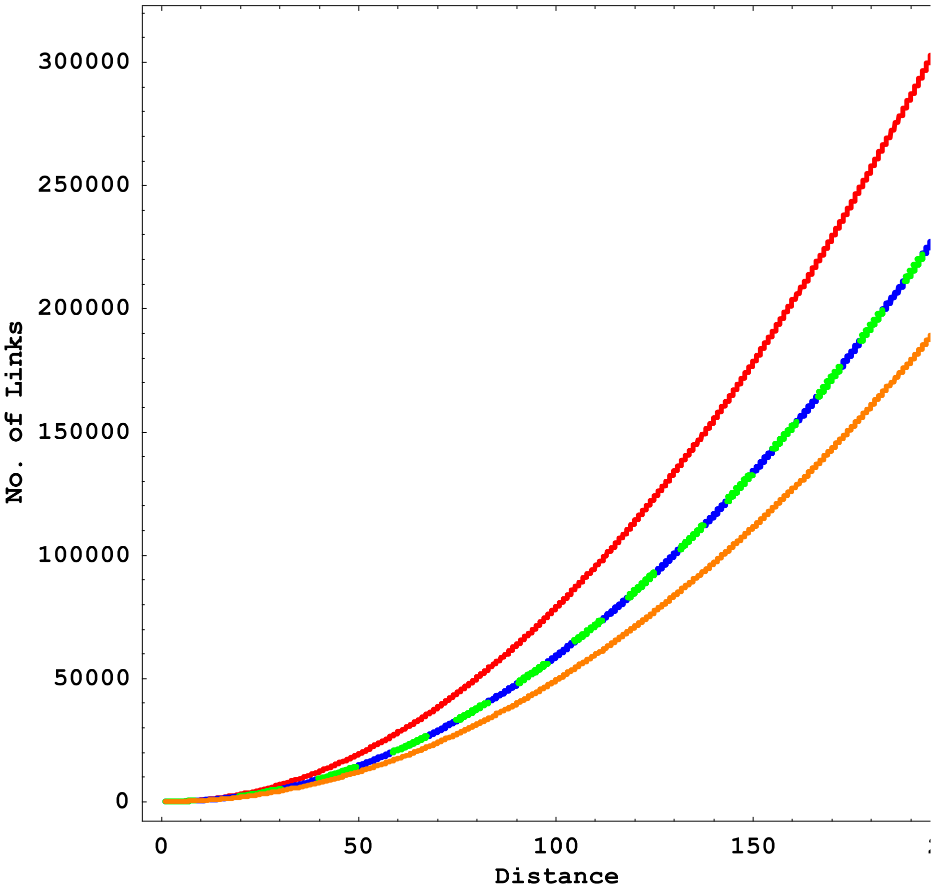


Figure 14 No. of links used in route discovery for in AODV Four Neighbour 2-D Grid

For Four Neighbor 2-D Grid Model

$$No.of\ Links\ in\ AODV\ using\ omnidirectional\ antenna, N_{omni} = 4 + 4 \times \sum_{i=0}^{R-1} (4 \times i) \ldots\ldots\ldots\ldots.\ldots\ldots (5)$$

$$No.of\ Links\ in\ AODV\ using\ three\ antenna, N_{three} = 4 + 3 \times \sum_{i=0}^{R-1} (2 \times i) + 2 \times \sum_{i=0}^{R-1} (2 \times i) \ldots\ldots\ldots\ldots. (6)$$

$$No.of\ Links\ in\ AODV\ using\ four\ sector\ antenna, N_{four} = 4 + 3 \times \sum_{i=0}^{R-1} (4 \times i) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots. (7)$$

$$No.of\ Links\ in\ AODV\ using\ eight\ sector\ antenna, N_{eight} = 4 + 3 \times \sum_{i=0}^{R-1} (4 \times i) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (8)$$

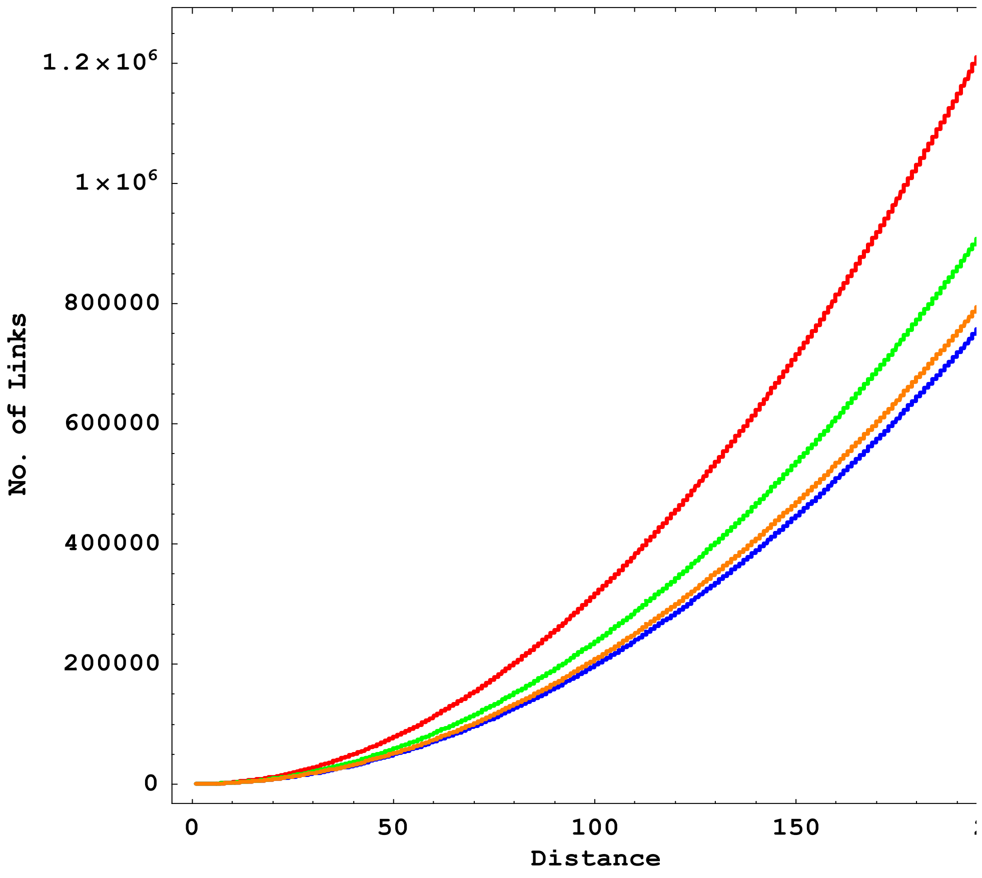


Figure 15 No. of links used in route discovery in AODV for Eight Neighbour 2-D Grid

For Eight Neighbor 2-D Grid Model

$$No.of\ Links\ in\ AODV\ using\ omnidirectional\ antenna, N_{omni} = 8 + 8 \times \sum_{i=0}^{R-1} (8 \times i) \ldots\ldots\ldots\ldots\ldots\ldots\ldots (9)$$

$$No.of\ Links\ in\ AODV\ using\ three\ antenna, N_{three} = 8 + 5 \times \sum_{i=0}^{R-1} (6 \times i) + 6 \times \sum_{i=0}^{R-1} (2 \times i) \ldots\ldots\ldots\ldots (10)$$

$$No.of\ Links\ in\ AODV\ using\ four\ sector\ antenna, N_{four} = 8 + 6 \times \sum_{i=0}^{R-1} (8 \times i) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (11)$$

$$No.of\ Links\ in\ AODV\ using\ eight\ sector\ antenna, N_{eight} = 8 + 5 \times \sum_{i=0}^{R-1} (8 \times i) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots . (12)$$

Fig 16, 17 and 18 shows the percentage reduction in number of links in selective flooding based AODV using sectorized antenna in comparison with blind flooding based AODV for standard hexagonal, four neighbor 2-D grid and eight neighbor 2-D grid models respectively. In these three figures, blue, Green and Orange colors are used to show percentage reduction using eight sector antenna four sector and three sector antenna respectively. Figure 16 and 18 shows, eight sector antenna gives best performance with more than 37 percent reduction whereas three and four sector antenna provide lower performance than eight sector antenna for hexagonal and eight neighbour 2-D grid models. Three sector antenna provides little less than 34 percent for both models. Figure 17 shows three sector antenna suited most for the four neighbor 2-D grid model, as it gains highest 37 percent improvement. Four sector and eight sector antenna provide same reduction of 25 percent for four neighbor grid model.

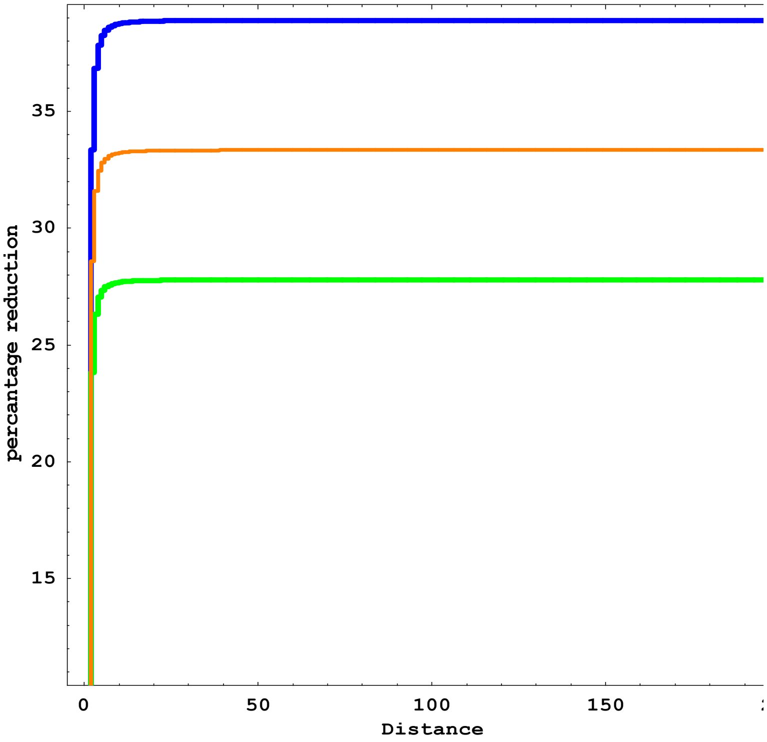


Figure 16 Percentage Reduction in number of links in AODV for Hexagonal Model

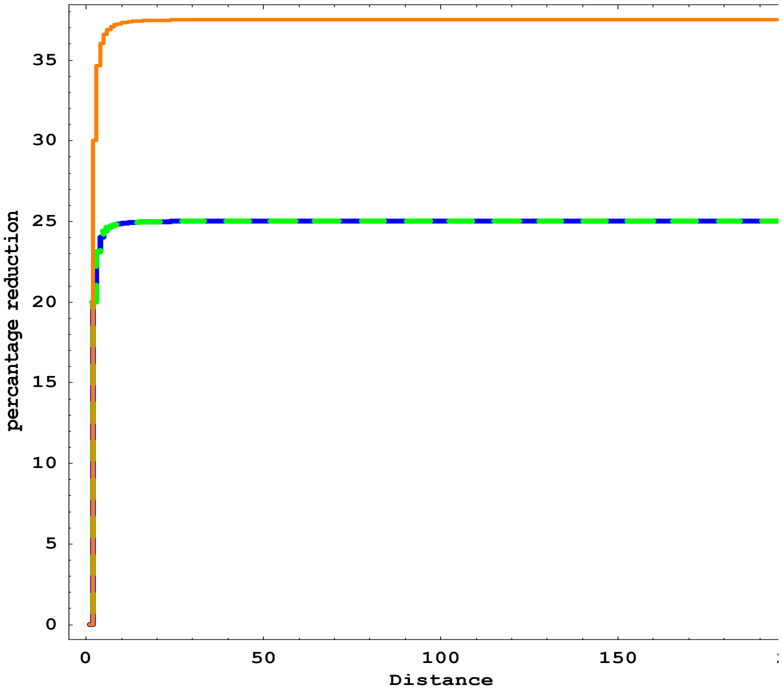


Figure 17 Percentage Reduction in number of links in AODV for Four Neighbour 2-D Grid

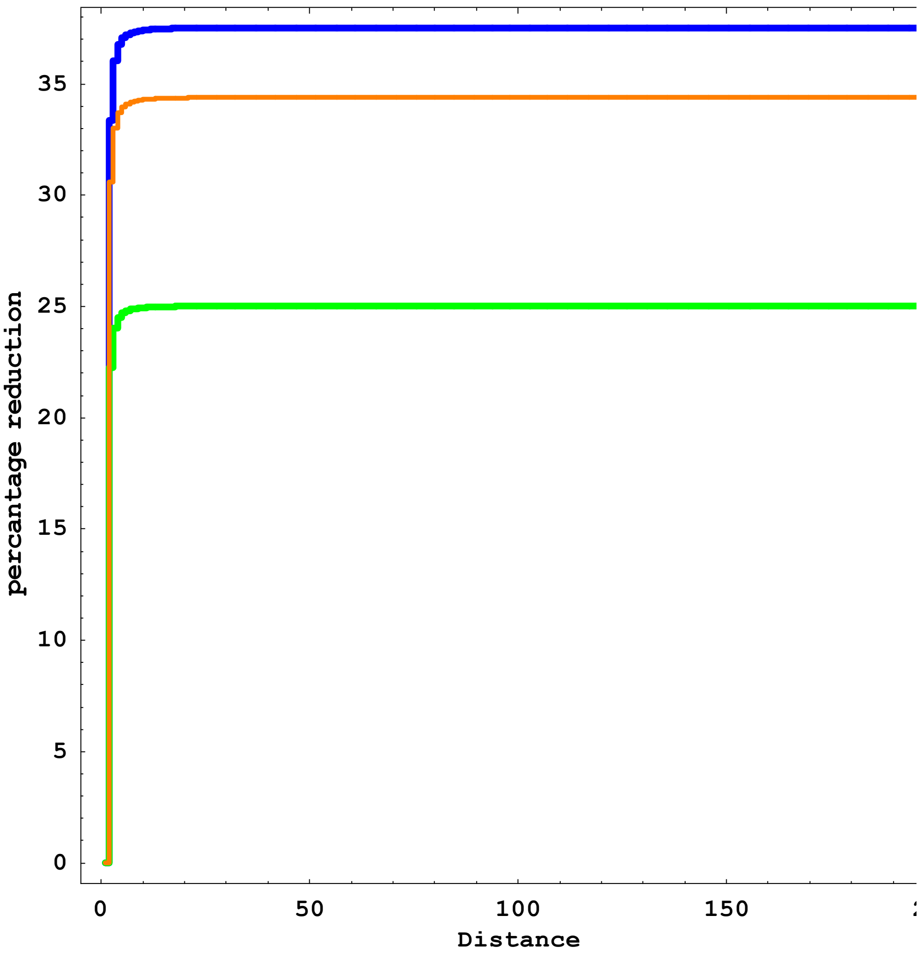


Figure 18 Percentage Reduction in number of links in AODV for Eight Neighbour 2-D Grid

7.2 Result and Analysis of Selective Flooding Applied on ERS

ERS is used to control flooding but it follows the same concept of flooding as AODV. The performance of ERS algorithms depends on initial TTL, *t*, TTL increment, *s*, distance between source and destination nodes, *d*, average number of neighbours of a node, N_{avg} and number of border nodes of i^th^ ring, NB_i. To theoretically analyze the performance, we applied blind flooding based ERS and as well as efficient flooding based ERS using all three sectorized antennas on all three models described earlier. behaviour of hexagonal shown by equation (13) - (16), behaviour of four neighbor 2-D grid shown by equation (17) - (20) and eight neighbor 2-D grid model behaviour model is described by equation (21)-(24).

Figure 19, 20 and 21 shows number of RREQ message transmitted for route discovery based on blind flooding and selective efficient flooding using sectorized antenna for standard hexagonal, four neighbour 2-D grid and eight neighbor 2-D grid models respectively in ERS routing technique along with AODV. We are using ERS along with AODV it gives same kind of performance characteristics like we got previously for AODV. Figure 19 and 21 show, eight sector antenna sends least query messages for hexagonal and eight neighbour 2-D grid models and figure 20 shows, three sector transmits least number of RREQ for four neighbor grid. Four and eight sector antenna transmit near about same number of query messages for four neighbour 2-D grid model as shown in figure 20.

$$No.of\ Links\ in\ AODV\ using\ omnidirectional\ antenna, N_{omni}$$
$$= 6 \times \sum_{i=1}^{\lceil (d-1-t)/s \rceil} 3 \times (t + s \times i) \times (t + s \times i + 1)\ + 6 \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots .(13)$$

$$No.of\ Links\ in\ AODV\ using\ three\ sector\ antenna, N_{three}$$
$$= 4 \times \sum_{i=1}^{\lceil (d-1-t)/s \rceil} 3 \times (t + s \times i) \times (t + s \times i + 1)\ + 6 \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots .(14)$$

$$No.of\ Links\ in\ AODV\ using\ four\ sector\ antenna, N_{three}$$
$$= (4 \times 2/3) \times \sum_{i=1}^{\lceil (d-1-t)/s \rceil} 3 \times (t + s \times i) \times (t + s \times i + 1)\ + (5 \times 1/3)$$
$$\times \sum_{i=1}^{\lceil (d-1-t)/s \rceil} 3 \times (t + s \times i) \times (t + s \times i + 1)\ + 6 \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots .(15)$$

$$No.of\ Links\ in\ AODV\ using\ eight\ sector\ antenna, N_{eight}$$
$$= (4 \times 2/3) \times \sum_{i=1}^{\lceil (d-1-t)/s \rceil} 3 \times (t + s \times i) \times (t + s \times i + 1)\ + (3 \times 1/3)$$
$$\times \sum_{i=1}^{\lceil (d-1-t)/s \rceil} 3 \times (t + s \times i) \times (t + s \times i + 1)\ + 6 \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots .(16)$$

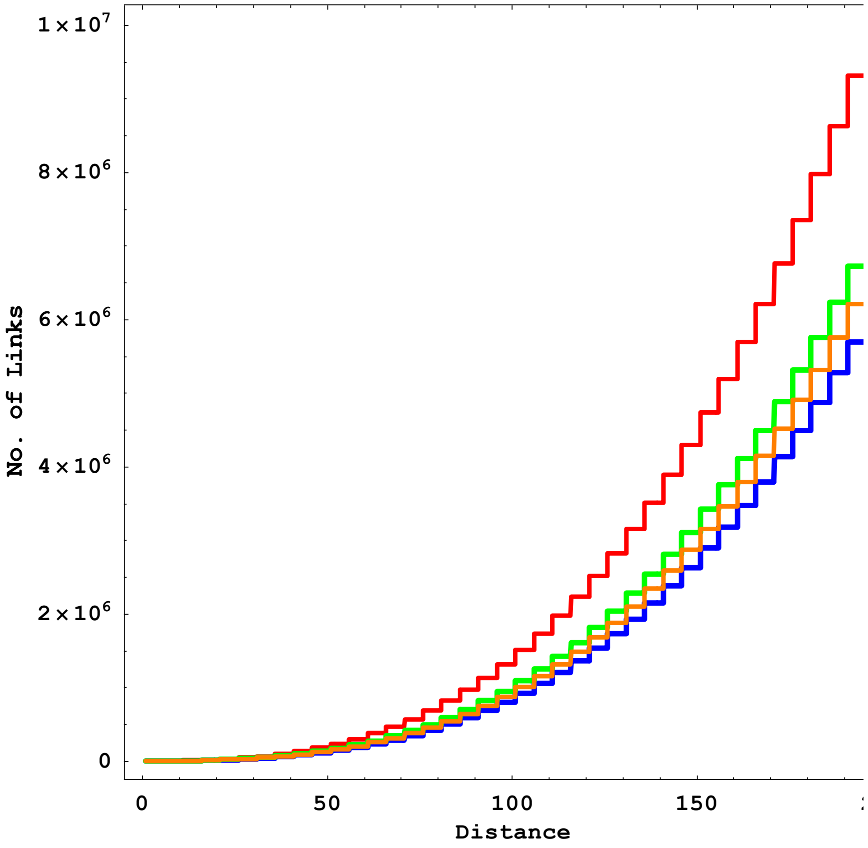


Figure 19 No. of links used in route discovery in ERS for Hexagonal Model

For Four neighbor 2-D grid model

No. of Links in AODV using omnidirectional antenna, N_{omni}

$$= 4 \times \sum_{i=1}^{\lceil (d-1-t)/s \rceil} 2 \times (t + s \times i) \times (t + s \times i + 1) \; + 4 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.(17)$$

No. of Links in AODV using three sector antenna, N_{three}

$$= (3 \times 1/2) \times \sum_{i=1}^{\lceil (d-1-t)/s \rceil} 2 \times (t + s \times i) \times (t + s \times i + 1) \; + (2 \times 1/2)$$

$$\times \sum_{i=1}^{\lceil (d-1-t)/s \rceil} 2 \times (t + s \times i) \times (t + s \times i + 1) \; + 8 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..(18)$$

No. of Links in AODV using four sector antenna, N_{four}

$$= 3 \times \sum_{i=1}^{\lceil (d-1-t)/s \rceil} 2 \times (t + s \times i) \times (t + s \times i + 1) \; + 4 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.(19)$$

No. of Links in AODV using eight sector antenna, N_{eight}

$$= 3 \times \sum_{i=1}^{\lceil (d-1-t)/s \rceil} 2 \times (t + s \times i) \times (t + s \times i + 1) \; + 4 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.(20)$$

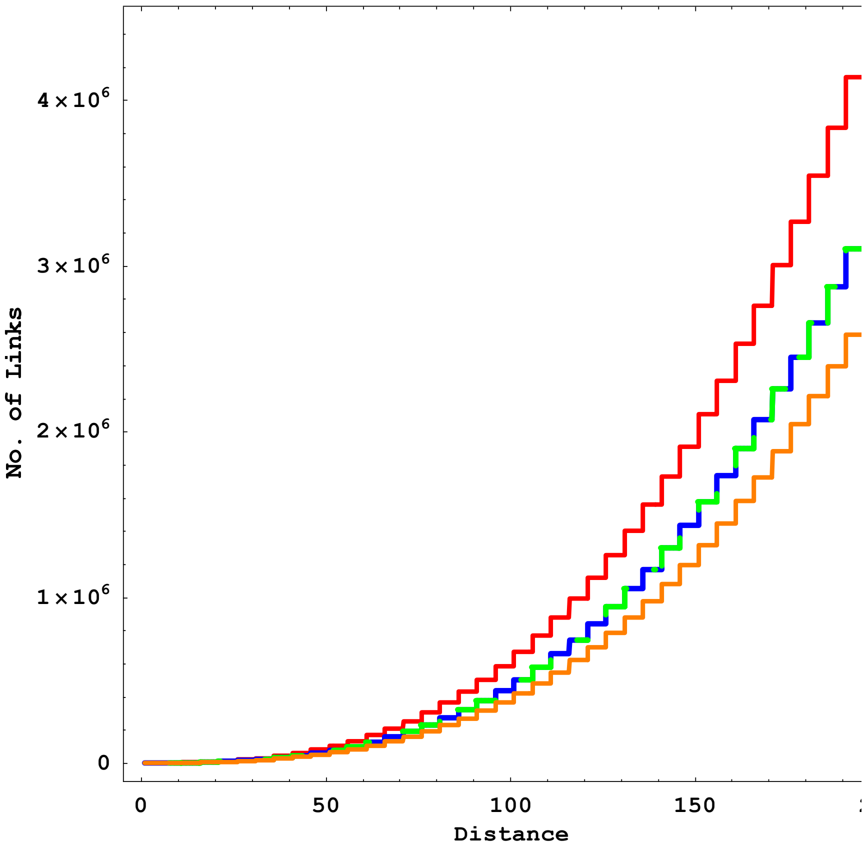


Figure 20 No. of links used in route discovery in ERS for Four Neighbour 2-D Grid Model

$$No.\,of\ Links\ in\ AODV\ using\ omnidirectional\ antenna, N_{omni}$$

$$= 8 \times \sum_{i=1}^{\lceil (d-1-t)/s \rceil} 4 \times (t + s \times i) \times (t + s \times i + 1)\ + 8 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots .(21)$$

$$No.\,of\ Links\ in\ AODV\ using\ three\ sector\ antenna, N_{three}$$

$$= (5 \times 3/4) \times \sum_{i=1}^{\lceil (d-1-t)/s \rceil} 4 \times (t + s \times i) \times (t + s \times i + 1)\ + (6 \times 3/4)$$

$$\times \sum_{i=1}^{\lceil (d-1-t)/s \rceil} 4 \times (t + s \times i) \times (t + s \times i + 1)\ + 8 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ (22)$$

$$No.\,of\ Links\ in\ AODV\ using\ four\ sector\ antenna, N_{four}$$

$$= 6 \times \sum_{i=1}^{\lceil (d-1-t)/s \rceil} 4 \times (t + s \times i) \times (t + s \times i + 1)\ + 8 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots .(23)$$

$$No.\,of\ Links\ in\ AODV\ using\ eight\ sector\ antenna, N_{eight}$$

$$= 5 \times \sum_{i=1}^{\lceil (d-1-t)/s \rceil} 4 \times (t + s \times i) \times (t + s \times i + 1)\ + 8 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots .(24)$$

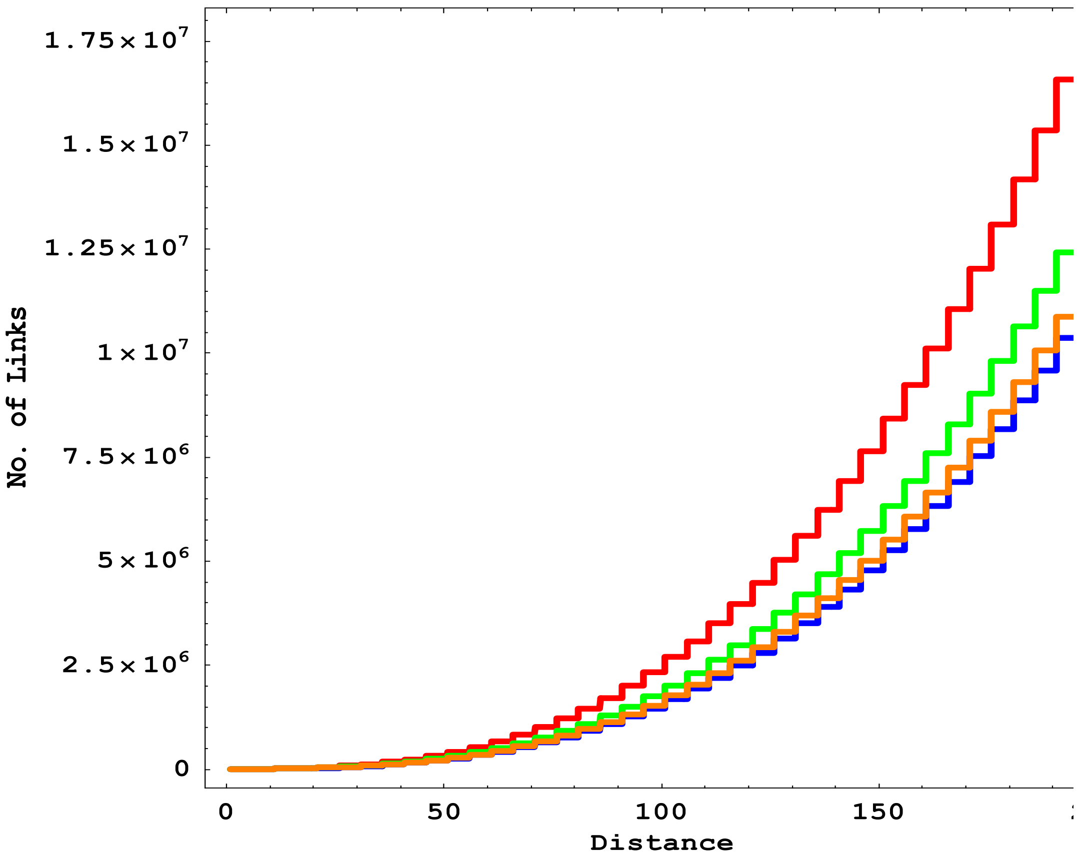


Figure 21 No. of links used in route discovery in ERS for Four Neighbour 2-D Grid Model

Figure 22, 23 and 24 shows the percentage reduction in number of links in selective flooding based ERS using sectorized antenna in comparison with blind flooding based ERS for standard hexagonal, four neighbor 2-D grid and eight neighbor 2-D grid models respectively. We got same performance characteristics for ERS as we got in AODV which is inline with the fact former is based on later. Again eight sector antenna provide best performance for eight neighbour grid and for hexagonal model with around 37 percent reduction as shown in figure 22 and 24 whereas three sector performed best for four neighbour grid with 34 percent. Four sector antenna provide least reduction in all cases as it restrict flooding only in 90 degree angular area.

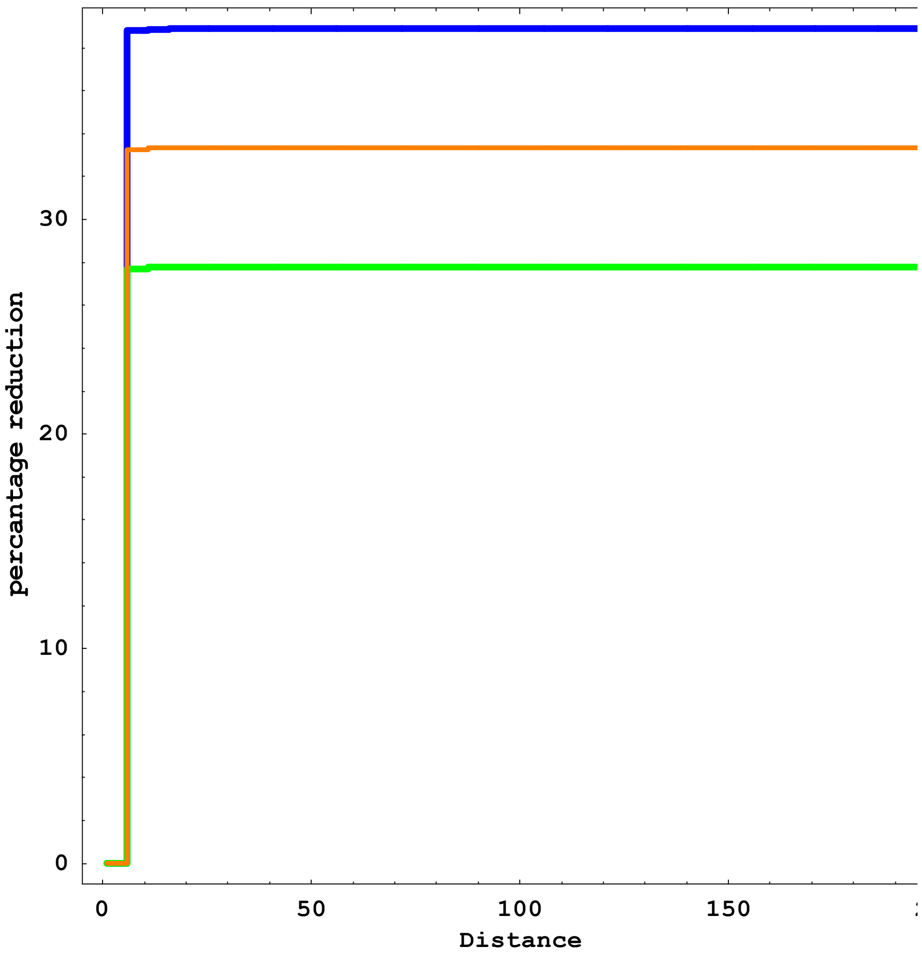


Figure 22 Percentage Reduction of Routing Overhead in ERS for Hexagonal Model

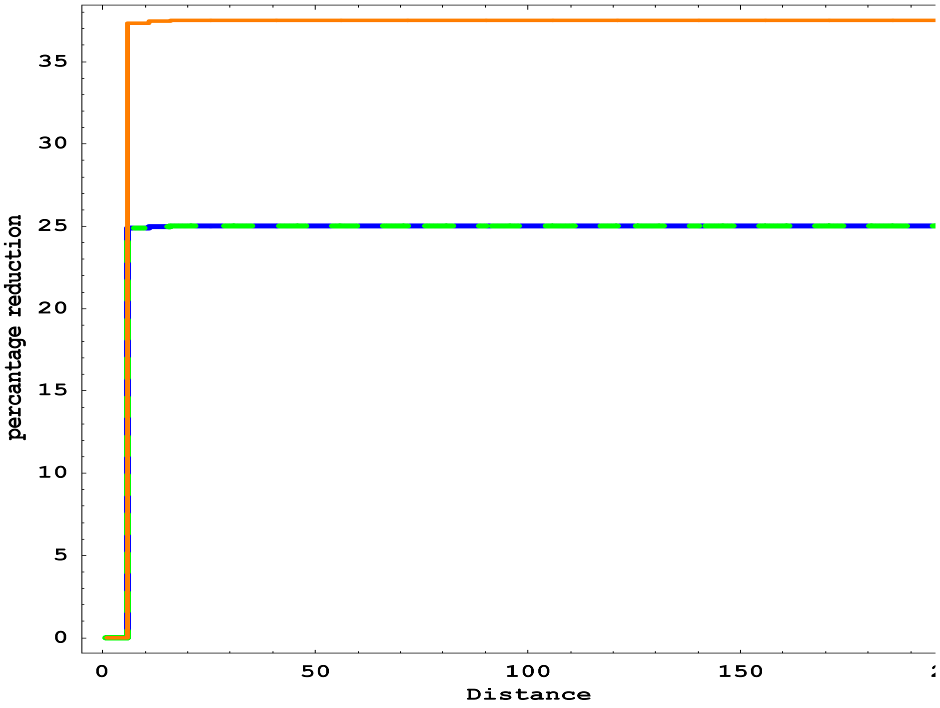


Figure 23 Percentage Reduction of Routing Overhead in ERS for Four Neighbour 2-D Grid

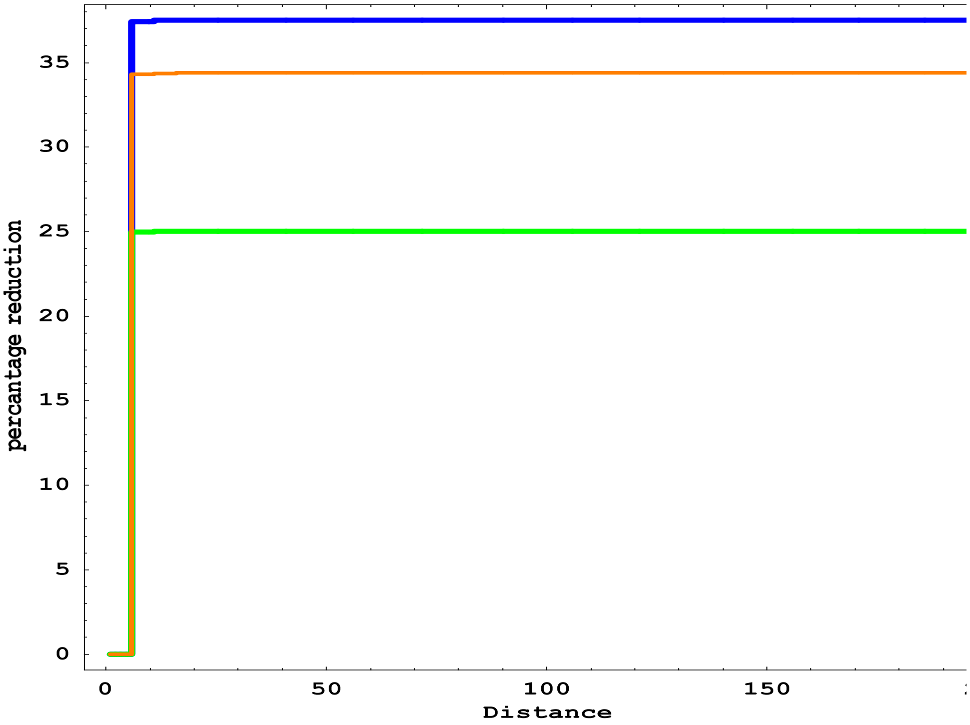


Figure 24 Percentage Reduction of Routing Overhead in ERS for Eight Neighbour 2-D Grid

7.3 Performance Analysis of EAODVSA

To analyze the efficiency of the proposed scheme, we compare the performance of ERS with that of EAODVSA. The performance of both algorithms depends on initial TTL, t, TTL increment, s, distance between source and destination nodes, d, average number of neighbours of a node, N_{avg} and number of border nodes of i^{th} ring, NB_i. To theoretically analyze the performance, we are using standard eight neighbor regular 2D grid model. We also provide a comparative general description of ERS and EAODVSA.

The number of messages sent along various links or the numbers of links which are used is an effective and accurate metric for comparative analysis. Equation (25) and (26) describe behaviour of standard model, whereas (27) and (28) provide the general behaviour. The number of links in standard ERS with AODV depends on initial flooding up to TTL, t and repeated flooding with increasing TTL value initiated by the source node, as described in (25) and (27). On the other hand, the numbers of links in EAODVSA depend on an initial flooding (improved) from source node and unicast of RREP; and repeated unicast of RREQ, flooding from border nodes of the previous ring and unicast of RREP from current border nodes, as described in (26) and (28).

Figure 25, shows the number of links of both ERS and EAODVSA with respect to distance (between source and destination) for varying TTL increment. Figure 26, shows percentage reduction in number of links, with respect to distance for similar initial TTL but different TTL increment value. The reduction of routing overhead up to around 50% is observed. Both results show the pattern of increase in performance with decreasing TTL increment and increasing distance.

$No.\,of\ Links\ in\ ERS\ along\ with\ AODV,N_{ERS}$

$$= 8 \times \sum_{i=1}^{\lceil (d-1-t)/s \rceil} \left(4 \times (t + s \times i) \times (t + s \times i - 1) + 1\right) + (4 \times t \times (t-1) \times 8)$$

$$+ 8 \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (25)$$

$No.\,of\ Links\ in\ EAODVSA,N_{EAODVSA}$

$$= (4 \times t \times (t-1) \times 5) + 8 + 8 \times t^2 + \sum_{k=1}^{\lceil (d-1-t)/s \rceil} \left(4 \times 5 \times ((t + k \times s) \times (t + k \times s - 1))\right)$$

$$+ \sum_{k=1}^{\lceil (d-1-t)/s \rceil} \left(8 \times (t + (k \times s))^2 + 8 \times (t + (k-1) \times s)^2\right) \dots\dots\dots\dots\dots\dots (26)$$

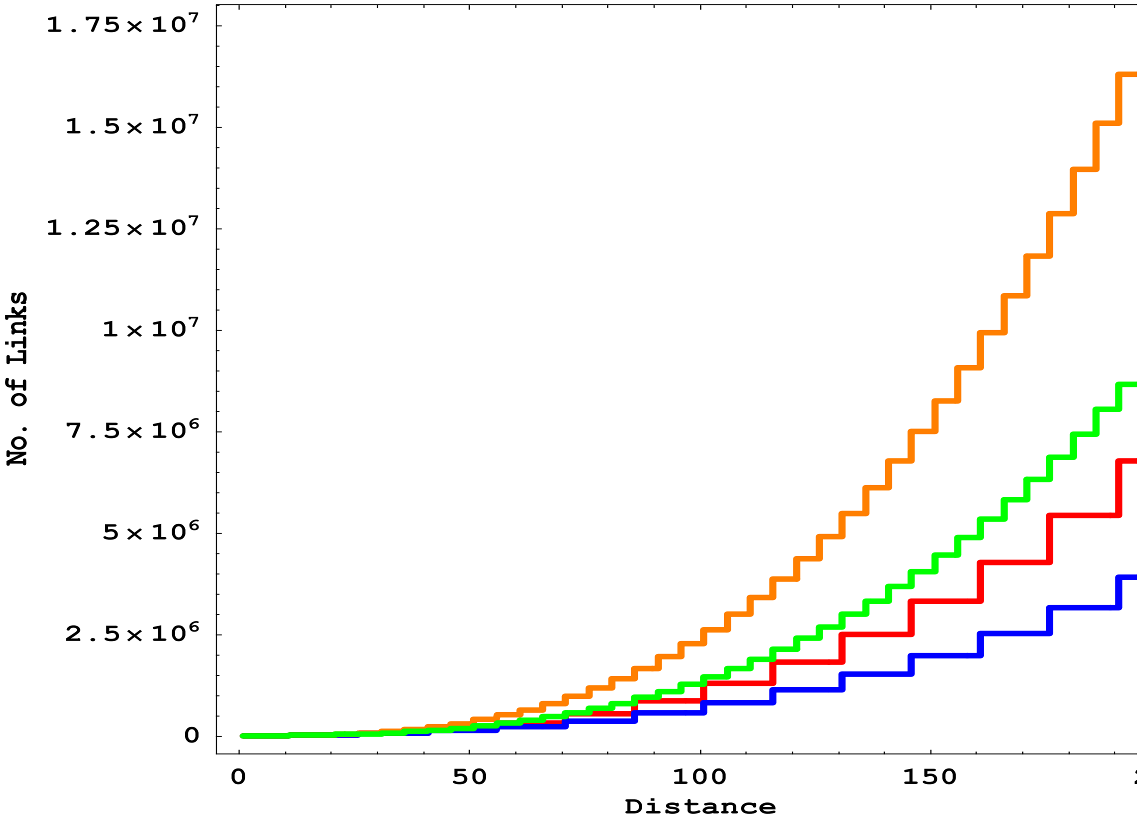


Figure 25 No. of links used in route discovery in ERS and EODVSA

$No.\,of\ Links\ in\ ERS\ along\ with\ AODV, N_{ERS}$

$$= N_{avg} \times \left(1 + \sum_{i=1}^{t-1} NB_i\right) + N_{avg} \times \sum_{k=1}^{\lceil (d-1-t)/s \rceil} \left(1 + \sum_{i=1}^{t-1+(s\times k)} NB_i\right) \ldots\ldots\ldots\ldots\ldots\ldots..\ldots\ldots (27)$$

$No.\,of\ Links\ in\ EAODVSA, N_{EAODVSA}$

$$= N_{avg} \times \left(\frac{5}{8}\right) \times (\sum_{i=1}^{t-1} NB_i) + N_{avg} + t \times NB_T + \left(\frac{5}{8}\right) \times N_{avg} \times \sum_{k=1}^{\lceil (d-1-t)/s \rceil} \left(\sum_{i=1}^{t-1+(s\times k)} NB_i\right)$$

$$+ \sum_{k=1}^{\lceil (d-1-t)/s \rceil} (NB_{t+k\times s} \times (t + k \times s) + NB_{t+(k-1)\times s} \times (t + (k-1)s)) \ldots\ldots\ldots\ldots.\ldots\ldots\ldots (28)$$

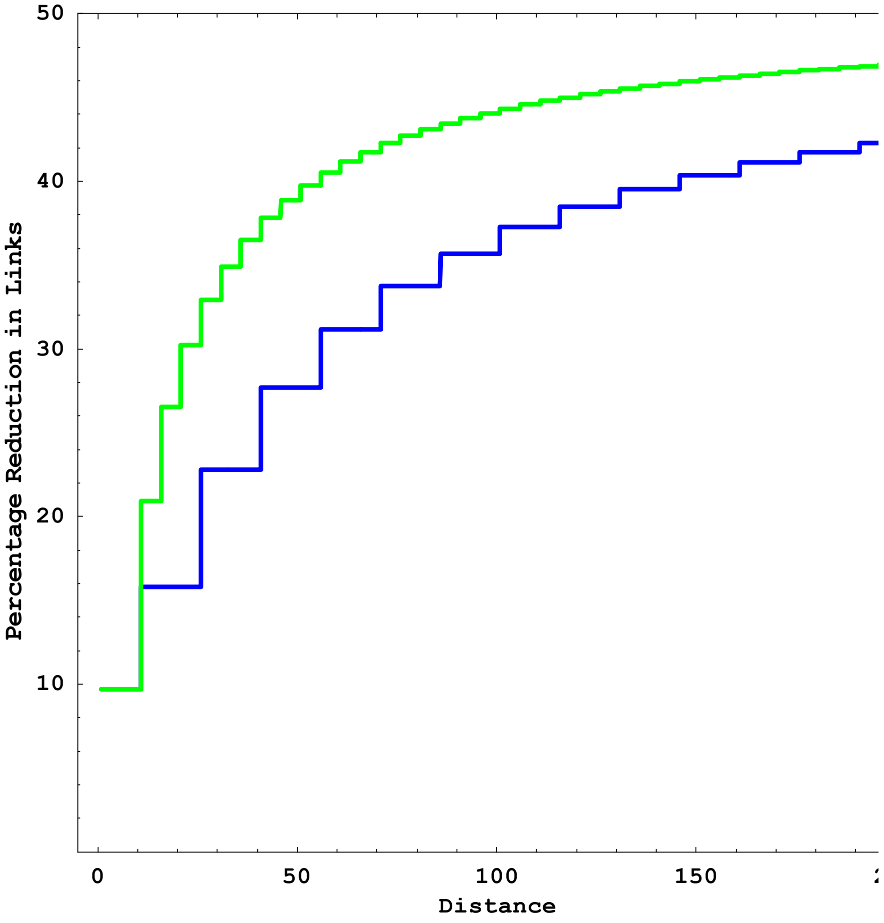


Figure 26 Comparative graph of ERS and EODVSA for reduction of routing overhead

Conclusion

In this study, we analyzed the effectiveness of selective flooding using sectorized antenna applied on AODV and ERS and for this purpose we used three different kinds of antennas which were applied on three different regular topologies, and produced reduction of up to 37% in the routing overhead during route discovery. From the detailed analysis, we conclude that the effectiveness of selective flooding using sectorized antennas is directly proportional to the density of the network. Our results also show that the flooding we proposed using eight sector antenna is a more effective way of broadcasting than three sector antenna and four sector antenna.

The proposed Efficient AODV using Sectorized Antenna (EAODVSA), algorithm is a fault tolerant technique to reduce redundant rebroadcast during modified ERS stage, which uses two techniques, modified flooding (based on sectorized antenna) and fault tolerant unicast of route request packet. It reduces routing overhead in two ways, improved flooding using sectorized antenna and reduced redundant flooding using unicasting. EAODVSA results show upto 50% reduction in routing overhead in comparison with traditional ERS algorithm.

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