A novel approach for improvement in flooding of AODV routing for MANET using sector antenna

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CERTIFICATE

This is to certify that **Rajiv Kumar Asati (2K11/ISY/18)** has carried out the major project titled **"A Novel Approach For Improvement In Flooding Of AODV Routing For MANET Using Sector Antenna"** as a partial requirement for the award of Master of Technology degree in Information Systems by **Delhi Technological University**.

The major project is a bonafide piece of work carried out and completed under my supervision and guidance during the academic session **2011-2013**. The matter contained in this report has not been submitted elsewhere for the award of any other degree.

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Abstract

A set of wireless nodes or routers coming together to form a network in which every node acts as a router can be defined as a mobile ad hoc network (MANET). This kind of networks is currently one of the most important research subjects, due to the huge variety of applications (emergency, military, etc.). In MANETs, each node acts both as host and as router, thus, it must be capable of forwarding packets to other nodes. Topologies of these networks change frequently. AODV routing protocol is a type of reactive routing which uses blindly flooding for finding the destination node. For highly density network, AODV routing protocol causes extra redundant route request packet which consumes unnecessary bandwidth of the network and wastes energy of computing nodes. Because energy consumption is major concern in the mobile ad hoc network. So in the proposed strategy, improvement of the basic flooding technique of AODV routing by using sector antenna for different regular topologies or models have been implemented. All the standard model provides a set of nodes with uniform density and distribution. The number of messages sent along various links or the number of links which are used is an effective and accurate metric for comparative analysis. The proposed algorithm uses sector antenna to reduce redundant rebroadcast in flooding of AODV routing. Hence resulted in to saving the energy of the nodes and consumes less bandwidth of the network as compared to simple flooding of AODV routing.

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Chapter 1: Introduction

There are generally two types of networks. One is wired networks and second is wireless networks. MANET belongs to the wireless networks. MANET is acronym for Mobile Ad-hoc NETwork. Routing protocols define the strategies for finding the path to the different nodes in both types of network. There are so many routing protocols available for wired networks. But these routing protocols do not best suited for wireless networks because of the different nature of wireless network as compared to wired network. Hence some other routing protocols to be designed for mobile ad hoc networks.

1.1: Motivation

Mobile ad hoc networks (MANETs) are autonomous systems of mobile hosts connected by wireless links. This kind of networks is becoming more and more important because of the large number of applications, for example:

1. Personal networks: Laptops, PDA's (Personal Digital Assistants), communication equipment etc.

2. Military applications: tanks, planes, soldiers, etc.

3. Civil applications: Transport service networks, sport arenas, boats etc.

4. Emergency operations: searching and rescue equipment, police and fireman etc.

To achieve efficient communication between nodes connected to the network new routing protocols are appearing. This is because the traditional routing protocols for wired networks do not take into account the limitations that appear in the MANETs environment.

It was observed that AODV routing protocol for MANET requires improvement, this thesis work was done to achieve the goal of improvement of flooding of AODV.

1.2 Related Work

Ad-Hoc On-Demand Distance Vector Routing Protocol (AODV) [1] finds route between nodes only when it is demanded. It does not maintain topology information about all other nodes in the network. In AODV routing, each and every time the node initiates the route discovery for some destination using simple flooding for broadcasting the Route Request (RREQ) across the network. Energy efficiency is an important concern in MANETs where nodes rely on limited power and computational resource. So, to control the network wide broadcast of the RREQs, the source node uses the Expanding Ring Search (ERS) technique [2], which allows a source to broadcast the RREQ of increasingly larger areas of the network if a route to the destination is not found. Unintentionally, some nodes in ERS technique rebroadcast the RREQs unnecessarily.

There has been significant work on routing in MANETs [3] [1]. AODV is an on-demand driven protocol which finds routes between a source destination pair only when it is required. Traditional AODV extensively uses blind flooding for forwarding the RREQ packets from source to all other nodes in the network to find route. The RREQ is broadcasted to entire network so every neighbour nodes will receive and process it. All the nodes which receive the RREQ for the first time check its routing table. If there is route, it unicasts the RREP to the source node, else it will rebroadcast the RREQ to its neighbours node. If the RREQ is not the first time to see, it will silently discard the RREQ. And, if the node is the destination, it unicasts the RREP to the source. When the source node gets the RREP from the destination node, it starts sending the packet to the destination. When a route has been established, it is being maintained by the source node as long as the route is needed. If any of the intermediate nodes losses connectivity due to the mobile nature of the nodes, the RERR will be sent to the source and the source sends packets through the alternate paths or it will restart the route discovery process. Thus the route discovery process leads to energy consumption in all nodes.

So the ERS [1] [4] is applied to AODV for route discovery process to reduce overhead and to use energy efficiently by using the Time to Live (TTL) mechanism. The ERS belongs to the reactive protocols. The aim of ERS is to find the destination or the information regarding the destination by controlled flooding of the RREQ across the network to forward the packets from source to destination. The TTL value determines the maximum number of hops that the RREQ can go through. To use the ERS, the source node sets the TTL values of the RREQ to an initial TTL_START value and initiate the route discovery. If no reply is received to the source node within the discovery period, the source then increases the RREQs broadcast id and then re-initialize the RREQ with TTL value increased by TTL_INCREMENT value. This process of increasing TTL value continues until the TTL_THRESHOLD value is reached, beyond which the RREQ is broadcasted across the entire network till it reaches RREQ_RETRIES.

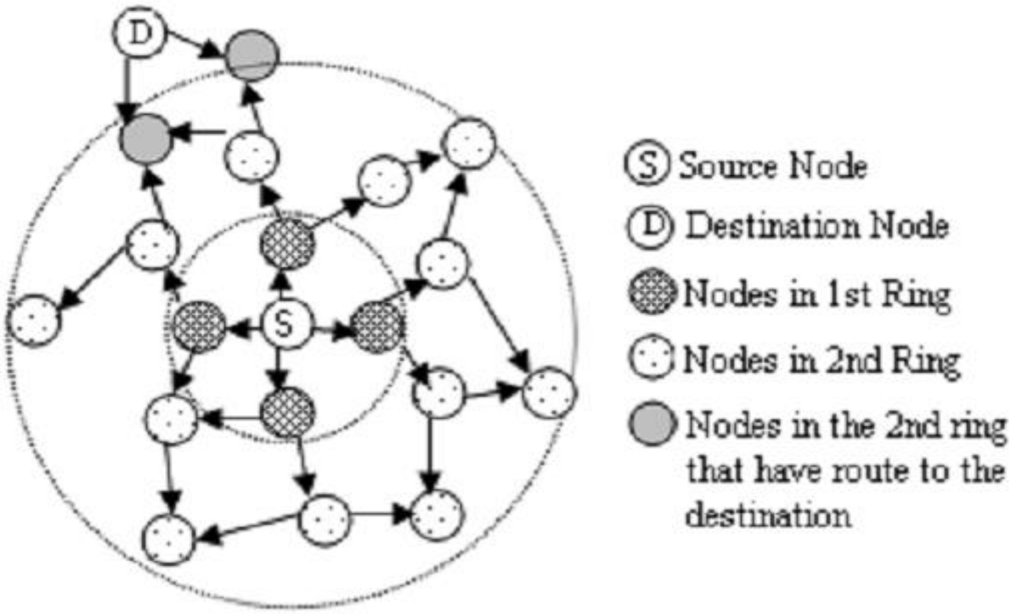

Figure 1.1: Example of ERS technique of 20 nodes

In the Fig.1.1, when the source node S wants to send packet to destination node D, node S has to find the path to node D using ERS. The ERS starts searching for the destination node D by increasing the TTL value and forms the ring structured search as in the Fig.1.1. For simplicity, initial TTL value has been taken as 1, i.e. the S can send the RREQ to its one hop neighbours and forms the 1^{st} ring. The nodes in the 1^{st} ring does not have any information about destination and so the source again restarts the search with increased broadcast Id and TTL value. The TTL value for the 2^{nd} ring is 3, and some nodes in the 2^{nd} ring have route to the destination. So that nodes will unicasts the Route Reply (RREP) to the source. And when the route to D has not been found out in 2^{nd} search, then the S will rebroadcasts the RREQ using this ring search technique till it finds the route to the destination.

The ERS method has the following restrictions. If the destination node is very far from the source node, then the source node has to send or broadcast multiple RREQ messages. Consequently, intermediate nodes have to receive and process this RREQ message repeatedly. This leads to routing overhead and wastage of energy. To overcome this problem, so many strategy have been proposed.

1.3: Problem Statement

The problem in AODV algorithm is that there are some redundant flooding in the network. One node sends the route request packet to its neighbour node then these neighbours node again sends the packet to their neighbours. Then this process repeats again and again until destination node is not found or whole network are explored. So same node continuously receive the same route request packet again and again and therefore wastes own energy and unnecessarily these redundant packets consumes the bandwidth. So the main aim is to remove this redundant flooding by the network. This research involves the development of the technique by which energy of the node is saved and it also drops the number of route request packets. So the technique of flooding is the main problem in AODV protocol. So the flooding problem is constrained.

1.4: Scope of Proposed Work

In the proposed work, flooding is controlled by imposing some constraint on it. Hence by controlling the redundant flooding, AODV routing has less energy consumption and routing overhead. After improvements in flooding technique, ERS is applied to AODV routing to obtained more improvements. Hence the scope of proposed work is in the application of mobile ad hoc network where energy of mobile nodes is very important measurement. With energy consumption, routing overhead is also an important feature. In military and rescue operations, this proposed work will have the advantage over traditional AODV routing due to less consumption of energy and less routing overhead.

Chapter 2: Mobile Ad Hoc Network (MANET)

2.1: Definition and Origin

MANET stands for mobile ad-hoc network. Ad hoc is a latin word which means that ‘for this purpose’ [5]. We define the mobile ad-hoc network as an autonomous system of mobile hosts (also serving as routers) connected by wireless links, the union of which forms a communication network neighbours in the form of an arbitrary graph. Each and every device in MANET is free to move independently in any direction [5]. And therefore each device of MANET acts as a router. In other words, MANET is a self-configuring infrastructure-less network of mobile devices connected by wireless [5]. Figure 2.1 illustrates the difference between the cellular network and mobile ad hoc network (MANET).

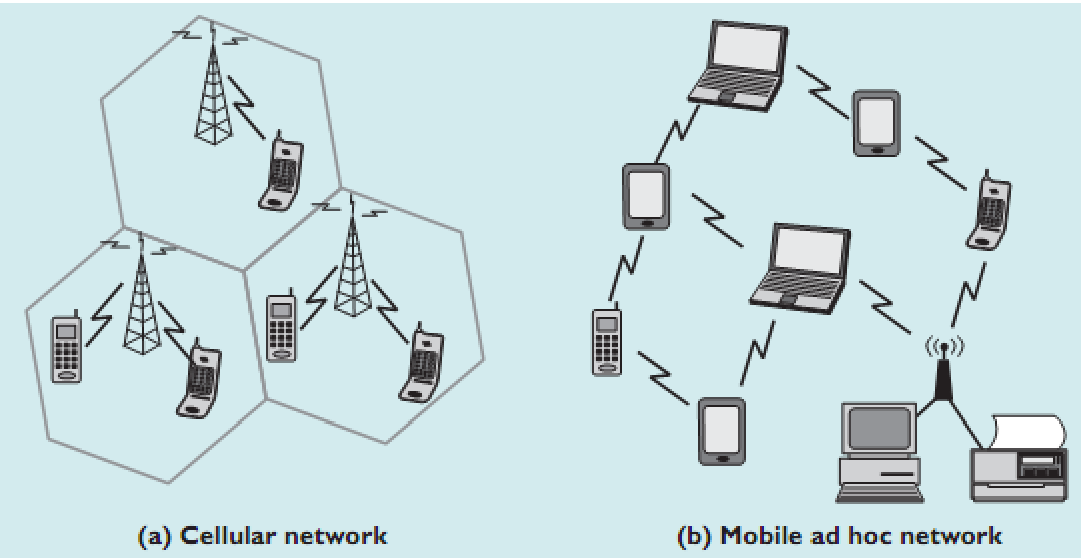

Figure 2.1: Cellular network vs mobile ad hoc network

2.2: Types of MANET’s

There are mainly three types of MANET.

1. Vehicular ad-hoc network (VANET) – VANET are used for communication among the vehicles in the road and the road side equipment [5].

2. Intelligent vehicular ad-hoc network (InVANET) – InVANET are used for using artificial intelligence. With the support of artificial intelligence InVANET are capable of manage the vehicles in vehicle to vehicle collisions, accidents etc.

3. Internet based mobile ad-hoc network (iMANET) – iMANET are used for linking mobile nodes and fixed internet gateway nodes. Normal ad-hoc routing algorithm don't apply directly in these networks.

2.3: characteristics of MANET's

There are so many characteristics and complexities of mobile ad hoc network. They are as follows.

1. Multi hop routing

2. Heterogeneous devices

3. Infrastructure less and autonomous

4. Dynamic topology of network

5. Scalability of network

6. Self creation, self organized, self administration

7. Energy constrained operation

8. Bandwidth constrained variable capacity links

2.4: Applications of MANET's

The applications and services of MANET are as follows in the below table 2.1.

Applications	**Scenarios/services**
tactical networks	Military communications and operations.

	Automated battlefields.
Emergency services	Search and rescue operations. Disaster recovery. Policing or firefighting. Supporting doctors and nurses in hospital.
Commercial and civilian environments	E-commerce: electronic payments anytime and anywhere. Business: dynamic database access, mobile offices. Vehicular services: road or accident guidance, transmission of road and weather conditions, taxi cab network, inter-vehicle network. Sports stadiums, trade fairs, shopping malls. Networks of visitors at airports.
Education	Universities and campus settings. Virtual classrooms. Ad-hoc communications during meetings or lectures.
Entertainment	Multi-user games. Robotic pets.
Sensor networks	Home applications: smart sensors and actuators embedded in consumer electronics. Body area networks (BAN). Data tracking of environmental conditions, animal movements, chemical/biological detection.
Coverage extension	Extending cellular network access Linking up with the Internet, intranets, etc.

Table 2.1: Applications of MANET

Chapter 3: Routing Protocols in MANET

Routing protocols are the standard rules and regulations that controls how the route is decided by the nodes in MANET. Routing is a process that exchanges the data and information between the nodes of a network. It means routing is a mechanism of forwarding packets towards its destinations using most efficient path. Most efficient path is that which involves least cost. This least cost includes transfer time, number of hopes, bandwidth etc.

3.1: Table Driven (Proactive) routing protocols

In proactive routing protocol, each and every node continuously maintains complete routing information of network. And these nodes periodically distributes the information of a network. This act is achieved by flooding network periodically with network status information to find out any possible changes in the network topology. The main disadvantage of this algorithm is that huge information is to be transferred throughout the network hence results high bandwidth consumption. The examples of this protocols are –

- OLSR (optimized link state routing)
- DSDV (destination sequenced distance vector)
- BATMAN (better approach to mobile ad-hoc networking)

3.1.1: Optimized Link State Routing Protocol (OLSR)

OLSR [6] is a proactive link state routing protocol. It is a point to point routing protocol based in the link state algorithm [7]. Each node maintains a route to the rest of the nodes of the ad hoc network. The nodes of the ad hoc network periodically exchange messages about the link state, but it uses the 'multipoint replaying' [8] strategy to minimize the messages quantity and the number of nodes that send in broadcast mode the routing messages.

The main advantages offered by this protocol are as follows.

- The proactive characteristic of the protocol provides that the protocol has all the routing information to all participating hosts in the network. OLSR protocol needs that each host periodically sends the updated topology information throughout the entire network. This increases the protocol bandwidth usage. However, the use of MPRs minimizes the flooding in comparison with other proactive routing protocols.
- OLSR protocol is well suited for the application which does not allow the long delays in the transmission of the data packets. The best application for OLSR protocol is a dense network, where the majority of the communication is concentrated between a large numbers of nodes [6].
- OLSR has also extensions to allow hosts to have multiple OLSR interface addresses and provide the external routing information giving the possibility for routing to the external addresses. Based on this information there is the possibility to have hosts in the ad hoc network which can act as gateways to another possible network.

The disadvantages of this protocol are as follows.

- As proactive routing protocol, a great number of periodical messages are sent. Besides the HELLO messages, there are Topology Control messages, forwarded around all the nodes in the network. The use of MPRs solves in part that problem, but the overhead in terms of packets is still high in comparison with the reactive routing protocols.

3.1.2: Destination Sequenced Distance Vector protocol (DSDV)

DSDV [9] is a hope by hope distance vector routing protocol in which each node has a routing table that for all reachable destinations stores the next hop and count of hops for that destination. DSDV requires that each node periodically broadcast routing information. The advantage with DSDV is that DSDV guarantees loop-freedom.

To guarantee loop-freedom DSDV uses a sequence numbers to tag each route. The sequence number shows the freshness of route and routes with higher sequence numbers are favourable. A route R is considered more favourable than R' if R has greater sequence number or, if the routes have the same sequence number but R has lower hop count. The sequence number is increased when a node A detects that a route to a destination D has broken. So the next time node A advertises its routes, it will advertise the route to D with an infinite hop-count and a sequence number that is larger than before.

DSDV basically is distance vector with small adjustments to make it better suited for ad-hoc networks. These adjustments consists of triggered updates that will make care of topology changes in the time between broadcasts. To reduce the amount of information in these packets there are two types of update messages defined: full and incremental dump. The full dump carries all available routing information and the incremental dump that only carries the information that has changes since the last dump.

Because DSDV is dependent on periodic broadcast, it needs some time to converge before a route can be used. This converge time can probably be considered negligible in a static wired network, because in this network, the topology is not changing so frequently. On the other hand, in an ad hoc network where the topology is expected to be very dynamic, this converge time will probably mean a lot of dropped packets before a valid route is detected. The periodic broadcasts also add an excessive amount of routing overhead into the network.

The advantages offered by this protocol is as follows.

- DSDV does not bloat packets. Source routing algorithms, on the other hand, put the whole route in packets, adding to their size, increasing the chance of collisions, and reducing throughput.
- Routes to all destinations are always available.

- Less delay for route setup.

The disadvantages of this protocol are as follows.

- DSDV discovers routes even if they are not needed.
- Heavy control overhead because of updates.
- Updates can choke the whole bandwidth.
- Not scalable.
- Very bad for large networks or high mobility.

3.2: On Demand (Reactive) Routing Protocols

On demand routing protocol find the routes on demand by flooding the route request packet. Flooding is the major concept in this routing. 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 protocols are –

- DSR (dynamic source routing)
- AODV (ad-hoc on demand distance vector routing)
- ACOR (admission control enabled on demand routing)
- TORA (temporally ordered routing algorithm)

3.2.1: Dynamic Source Routing Protocol (DSR)

DSR [10] is a reactive routing protocol. It uses source routing. The source node must determine the path of the packet. The path is attached in the packet header and it allows to update the information stored in the nodes from the path. There are no periodical updates. Hence, when a node needs a path to another one, it determines the route with its stored information and with a discovery route protocol.

This protocol has 2 parts: the discovery and the maintenance of the routes.

Basic route recovery –

When a node sends a packet to a destination, firstly it looks at its Route Cache the routes previously learned. If no route is found in its cache, then the node begins the route discovery process with a Route Request Packet (RREQ) broadcast. This packet includes the destination address, the source address and an identification number (request id). Each node receiving the RREQ, looks for the destination in its cache. If it does not know the route to the destination, it adds its address to the 'route record' in the RREQ and propagates it by transmitting it as a local broadcast packet (with the same request id). To limit the number of RREQ's, if one node receiving the RREQ has recently seen another RREQ from the same source, with the same request id, or if it finds its own address in the route record, then it discards the RREQ. In Figure 3.1 the development of the route record while the RREQ is spreading through the network is shown.

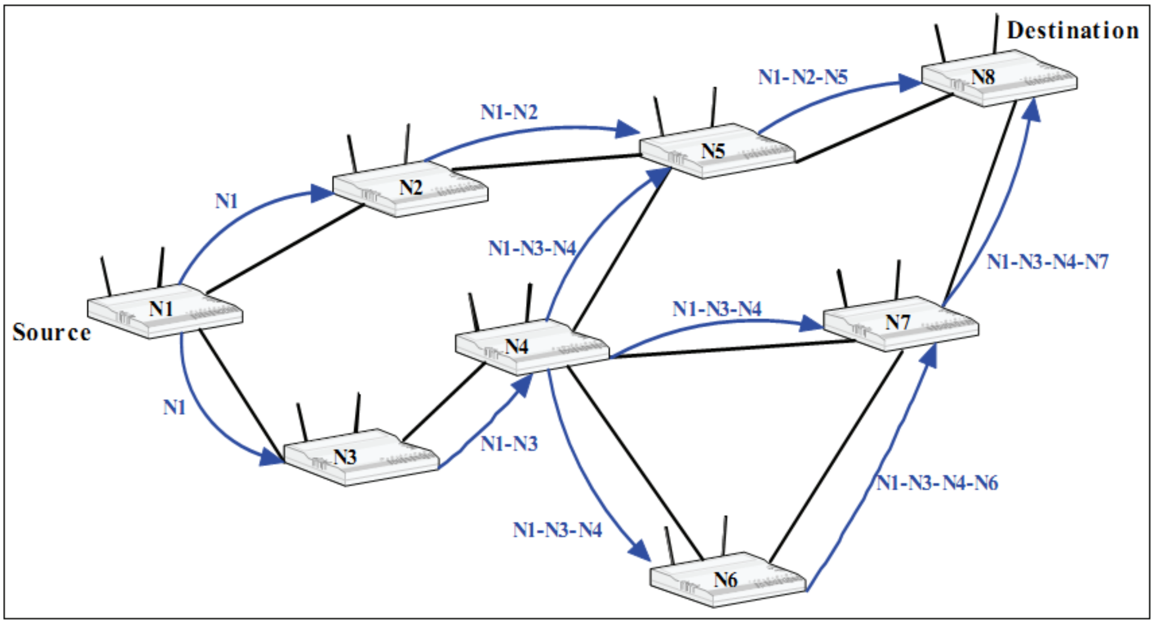

Figure 3.1: Construction of the route record in the route discovery. Each node adds its address to the route record field in the RREQ message. Nx-Ny-…indicates the addresses attached in the RREQ.

A RREP (Route Reply) is sent when the RREQ reaches the destination or an intermediate node that has the route to the destination. When the RREQ reaches the destination, it has the route record with the sequence of nodes crossed. If the node that generates the RREP is the destination, then it copies the route record sent in the RREQ. If the node that generates the RREP is an intermediate node, then it adds to the route record sent the route to the destination stored by it. If the links are bidirectional the RREP is sent by the reverse path. If the links are not symmetric, the node that sends the RREP must update its previous stored entry to the source (or to begin a route discovery to the source). In Figure 3.2, it is shown the RREP broadcast to the source.

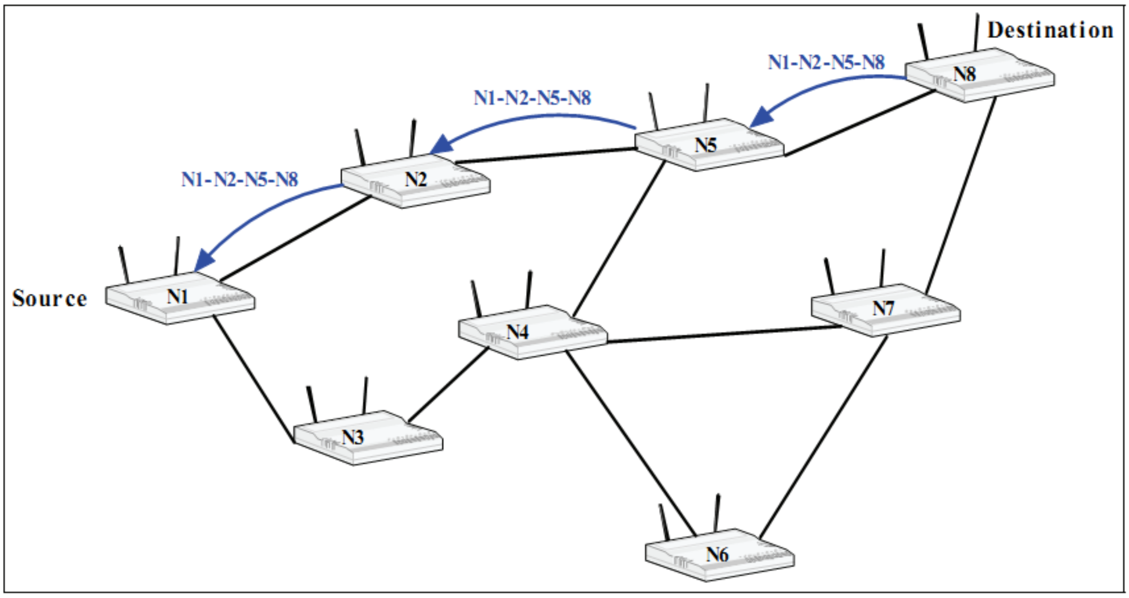

Figure 3.2: Forwarding of the RREP with the route record

Basic route maintenance –

The maintenance of the routes is useful to check the operation of a route and to report any routing error to the source. This check is made between consecutive nodes. When there is a problem in the transmission found by the link level, the RERR (Route Error) packets are sent by the node. This RERR has the addresses of both nodes in which the link failed. For example, in the situation illustrated in Figure 3.3 N1 has originated a packet for N8 using a source route through intermediate nodes N2 and N5. In this case, N1 is responsible for the reception of the packet at N2, N2 is responsible for the reception at N5, and N5 is responsible for the reception at the final destination N8.

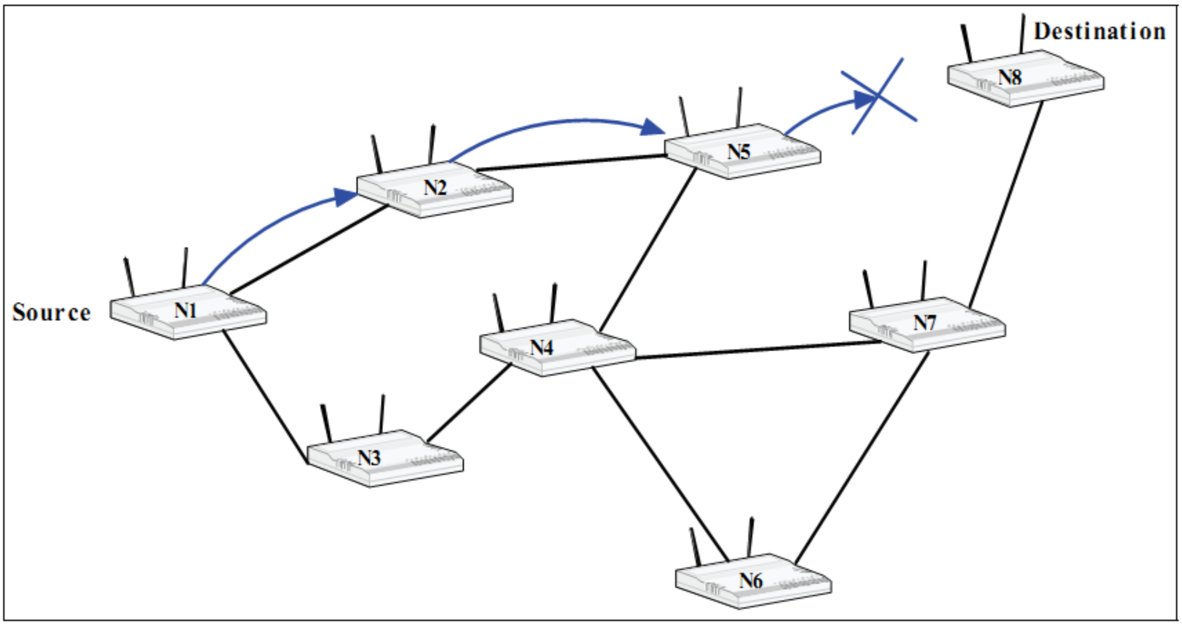

Figure 3.3: Route Maintenance example: N5 is unable to forward a packet from N1 to N8 over its link to next hop N8

As N5 is unable to deliver the packet to N8, N5 returns a Route Error to N1 stating that the link from N5 to N8 is currently 'broken'. N1 then removes this broken link from its cache. In other words, when a node receives a RERR, it deletes the link failed in its routes list, and all the routes that have this link are cut at this point. Besides the RERRs, ACKs (acknowledgements) can be used to verify the links availability.

The advantages of this protocol are as follows,

- Its first advantage is the small overload in terms of packets to obtain routes, since DSR only manages the routes between nodes who wish to communicate. DSR uses caching, and that can reduce the load of future route discovery.

- Another advantage is that only one RREQ process can produce some routes to the destination, thanks to the responses of the caches of intermediate nodes. If we want to compare the following protocols: DSDV, OLSR, AODV and DSR, the DSR is the only who has numerous paths.
- There are no periodical updates.

The disadvantages of this protocol are as follows.

- Using DSR, when a source sends a packet to any destination, the route is within the header. It is quite obvious that we are introducing byte overhead if the number of nodes is large in the network.
- Another disadvantage is with the concept of flooding. It can reach all the nodes in the network, when it is unnecessary. Besides, we have to prevent the collisions produced by the RREQ broadcasts (we can introduce random delays before sending the RREQ).
- Broken links can not be repaired locally.
- Due to caching, it performs badly in the mobility.

3.3: Hybrid Routing Protocol

Hybrid routing protocol (both proactive and reactive) combines the advantages of both the strategy. The routing is initially established some proactively prospected routes and then serves the demand from additionally activated nodes through reactive flooding. Hence combines the both approach. The main disadvantage of this algorithm is that reaction to traffic demand depends of the gradient of traffic volume [11]. The example of this algorithm is

- ZRP (zone routing protocol)

3.3.1: Zone Routing Protocol

The Zone Routing Protocol (ZRP) [12] is a hybrid routing protocol. It combines the advantages from reactive and proactive routing protocols. This protocol divides its network in different zones. These zones are the nodes local neighbourhood. Each node has its own zone. Each node can be into multiple overlapping zones, and each zone can be of a different size. The size of a zone is given by a radius of length [13], where the number of hops is the perimeter of the zone. Within each zone it is used a proactive routing protocol. Therefore, each node into the zone knows how to reach its neighbours. However, if the packets are sent to a node outside of the zone, it is used a reactive routing protocol.

ZRP [14] runs three routing protocols:

- Intra zone Routing Protocol (IARP)
- Intra zone Routing Protocol (IARP)
- Border cast Resolution Protocol (BRP)

IARP is a link state routing protocol. It operates within a zone and learns the routes proactively. Hence, each node has a routing table to reach the nodes within its zone.

IERP uses the border nodes to find a route to a destination node outside of the zone. IERP uses the BRP. BRP is responsible for the forwarding of a route request.

When the Route Discovery process begins, the source node asks to its routing table and if necessary, it starts a route search between different zones to reach a destination. If a route is broken by a node's mobility into the same zone where the node was, the routing tables used for the proactive routing protocol must be updated. If the node's mobility is from one zone to another one, then it is necessary to execute a query between zones.

To use a reactive routing protocol to find a route from a source node to a destination node placed in another zone reduces the control overhead (in comparison with the proactive ones) and the delays in the Route Discovery (in comparison with the pure reactive ones), since these routes are discovered much faster. The reason is because to find a route to a node placed outside the routing zone, the route request is send only to the border router within the zone where the destination is. This border router can answer to the request since it has a routing table to do the proactive routing and knows how to reach the destination.

The disadvantage of ZRP [15] is that it becomes a proactive routing protocol if the radius is big. Otherwise, if the radius is small, it becomes a reactive routing protocol.

In Figure 3.4 Route Discovery process is shown; the node S sends information to the node X, and by IARP decides X is not in the same zone that S. The search travels through the border nodes to find the zone where X is. Finally, the border node G discovers that X is in its zone and sends a route response to S.

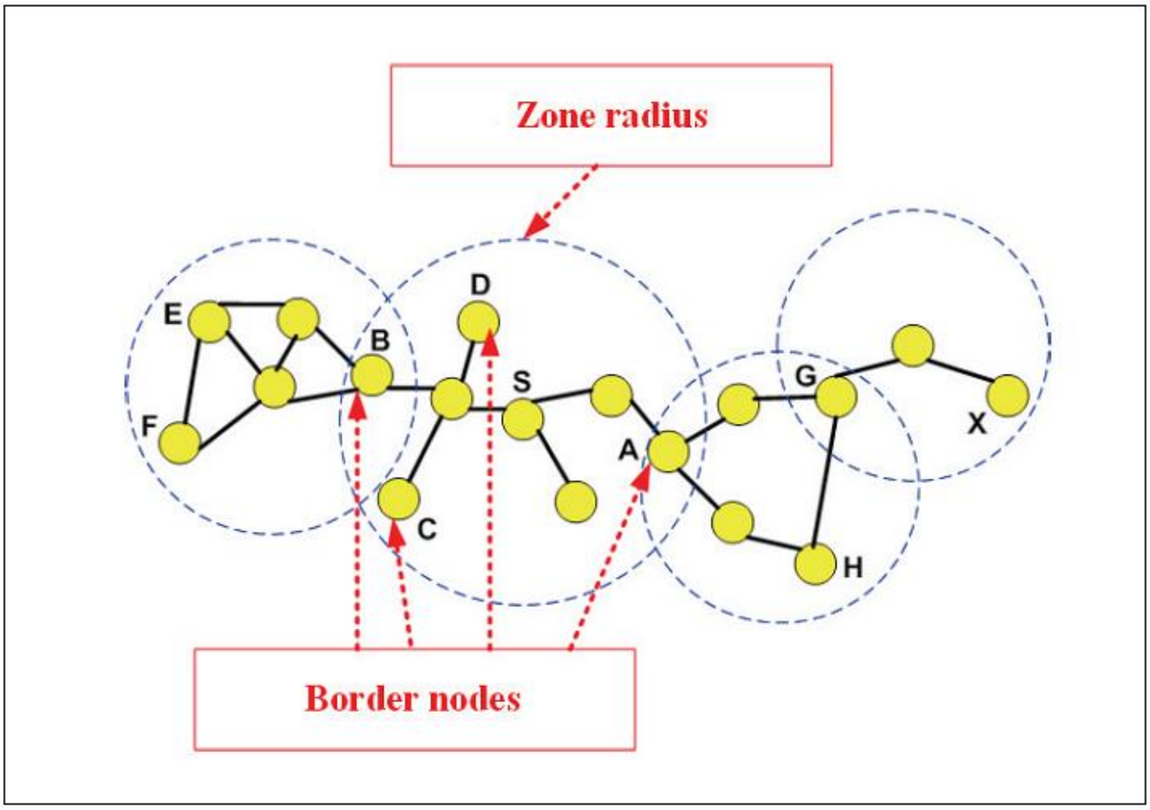

Figure 3.4: Example of a Route Discovery in an ad hoc network using the routing protocol ZRP. For node S, the zone radius is 2, and the border nodes are A, B, C and D.

Even though the hybrid nature of the ZRP seems to indicate that it is a hierarchical protocol, it is important to point out that the ZRP is in fact a flat protocol. ZRP is more efficient for large networks.

The advantages of this algorithm are as follows.

- ZRP is more suitable than other protocols for large networks spanning diverse mobility patterns by providing the benefits of both reactive and pro-active routing in a flat network that takes advantage of a near-hierarchical approach.

The disadvantages of this algorithm are as follows.

- If zones greatly overlap, redundant Route Request messages flood the network.
- Optimum zone radius must be determined for each situation.

- High stress for intermediate nodes on link failure.

3.4: Reactive vs Proactive

Proactive routing protocols loose more time updating their routing tables. Therefore when the topology changes frequently, most of the current routes in the tables can be wrong. Hence, these protocols are recommended for ad-hoc networks semi dynamics. Reactive routing protocols have delay in route determination, because of the flooding mechanism. They are recommended for networks with nodes moving constantly. Intuitively, we can think in the advantages and disadvantages of both looking the table 3.1:

Parameters	Proactive/Table-driven	Reactive/On Demand driven
Route availability	Always available	Available when required
Latency	Minimum	Long delays when there is not an available route
Route updating periodically	Yes	No
Movement	Advertises to other nodes to update the routing tables.	Only advertises if affect to the source node. Uses alternative routes.
Control traffic	Greater than On Demand driven	Increase if mobility of the active routers increase.
Energy consumption	Greater	Depends of the nodes mobility

Table 3.1: Comparison between proactive and reactive routing protocols

Advantage of proactive protocol –

- A route can be selected immediately without delay.

Disadvantage of proactive protocol –

- Produce more control traffic.
- Takes a lot of bandwidth.
- Produce network congestion.

Advantages of reactive protocol –

- Lower bandwidth is used for maintaining routing tables.
- More energy-efficient.
- Effective route maintenance.

Disadvantage of reactive protocol –

- Have higher latencies when it comes to route discovery.

Reactive protocols face scaling problems when the number of nodes is large and have many "active nodes". But how big this problem is it depends on which protocol is used and in which scenario it is working.

In the Table-driven case, the problem is the time to update the routing tables. These protocols require nodes to exchange their routing tables periodically (or if changes in the topology happen each). Thus, each node has its routing table updated. However, this information exchange can cause message broadcast storm when the mobility is high.

Chapter 4: Ad Hoc on Demand Distance Vector Routing Protocol (AODV)

AODV protocol is used for mobile devices or other wireless ad-hoc networks. AODV routing protocol uses the flooding for routing. This protocol belongs to the category of reactive routing protocol of mobile ad-hoc networks. It finds a route to the destination only when demanded. AODV is capable of both type of routing (unicast and multicast). It also avoids the counting to infinity problem by using sequence numbers. This protocol offers quick adaptation to dynamic link conditions, low processing and memory overhead, low network utilization and determines unicast routes to destinations within the ad-hoc network. It uses destination sequenced numbers to ensure loop freedom at all times avoiding problems such as counting to infinity associated with other distance routing protocol. The AODV algorithms enables dynamic, self-starting, multi hop routing between actively participating mobile nodes wishing to establish and maintain an ad hoc network. AODV allows mobile nodes to get routes quickly for new destinations, and does not need nodes to maintain routes to destinations that are not in active communication. AODV allows mobile nodes to respond to link breakages and changes in structure of network topology in a regular way. The operation of AODV is loop-free, and by avoiding counting to infinity problem offers quick convergence when the ad hoc network topology changes (typically, when a node moves in the network) [16].

4.1: Overview

Route requests (RREQs), Route replies (RREPs), Route errors (RERRs) are the message type defined by the AODV [16]. When a route to a new destination is demanded, the node broadcasts a RREQ packet to find a route to the destination. A route can be find out when the RREQ packet reaches either the destination itself, or an intermediate node with a 'fresh enough' route to the destination. A 'fresh enough' route is a valid route entry for the destination whose associated sequence number is at least as great as that contained in the RREQ packet. The route is made available by unicasting a RREP back to the origination of the RREQ packet.

Each node receiving the request caches a route back to the originator of the request, so that the RREP packet can be unicast from the destination along a path to that originator, or likewise from any intermediate node that is able to satisfy the request [16].

Nodes monitor the link status of next hops in active routes. When a link breakage in an active route is find out, a RERR packet is used to notify other nodes that the loss of that link has occurred. The RERR packet indicates those destinations which are no long reachable by way of the broken link [16].

AODV is a routing protocol, and it deals with route table management .Route table information must be kept even for short-lived routes, such as are created to temporarily store reverse paths towards nodes originating RREQs. AODV protocol uses the below following fields with each route table entry:

- Destination IP Address
- Destination Sequence Number
- Valid Destination Sequence Number flag
- Other state and routing flags (e.g., valid, invalid, repairable, being repaired)
- Network Interface
- Hop Count (number of hops needed to reach destination)
- Next Hop
- List of Precursors
- Lifetime (expiration or deletion time of the route)

For avoiding the routing loops managing the sequence number is crucial, even when links break and a node is no longer reachable to supply its own information about its sequence number. A destination becomes unreachable from neighbor node when there is a link breakage or is deactivated. When these abnormal conditions occur, the route is invalidated by operations involving the sequence number and marking the route table entry state as invalid [16].

4.2: AODV Terminology

Some terminologies in AODV protocol are as follows.

Active route – A route towards a destination that has a routing table entry that is marked as valid. Only active routes can be participated to forward data packets.

Broadcast – Broadcasting means transmitting to the IP Limited Broadcast address, 255.255.255.255. A broadcast packet may not be blindly forwarded, but broadcasting is useful to enable dissemination of AODV messages throughout the ad hoc network.

Destination – An IP address to which data packets are to be transmitted. Same as "destination node". A node knows it is the destination node for a typical data packet when its address appears in the appropriate field of the IP header.

Forwarding node – A node that participates to forward packets destined for another node, by retransmitting them to a next hop that is closer to the unicast destination along a path that has been set up using routing control messages.

Forward route – A route that is set up to send data packets from a node originating. Route Discovery operation towards its desired destination.

Invalid route – A route that has expired, denoted by a state of invalid flag in the routing table entry. An invalid route is used to store previously valid route information for an extended period of time. An invalid route cannot be used to forward data packets, but it can provide information useful for route repairs, and also for future RREQ messages.

Originating node – A node that initiates an AODV route discovery message to be processed and possibly retransmitted by other nodes in the ad hoc network. The node initiating a Route Discovery process and broadcasting the RREQ packet is called the originating node of the RREQ packet.

Reverse route – A route set up to forward a reply (RREP) packet back to the originator from the destination or from an intermediate node having a route to the destination.

Sequence number – A monotonically increasing number maintained by each originating node. It is used by other nodes to determine the freshness of the information contained from the originating node.

4.3: Working of AODV

The AODV protocol [17] is a reactive routing protocol. It is a Single Scope protocol and it is based on DSDV [9]. The improvement consists of minimizing the number of broadcasts required to create routes. Since it is an on demand routing protocol, the nodes who are not in the selected path need not maintain the route neither participate in the exchange of tables.

When a node wants to transmit to a destination and it does not have the valid route, it must begin the Path Discovery process. Firstly, it sends a broadcast of the Route Request (RREQ) packet to its neighbours, and they relay the packet to their neighbours and so on until they reach the destination or any intermediate node which has a 'fresh' route to the destination (Figure 4.1). Just like in DSDV [9] sequence numbers are used to identify the most recent routes and to solve the loops.

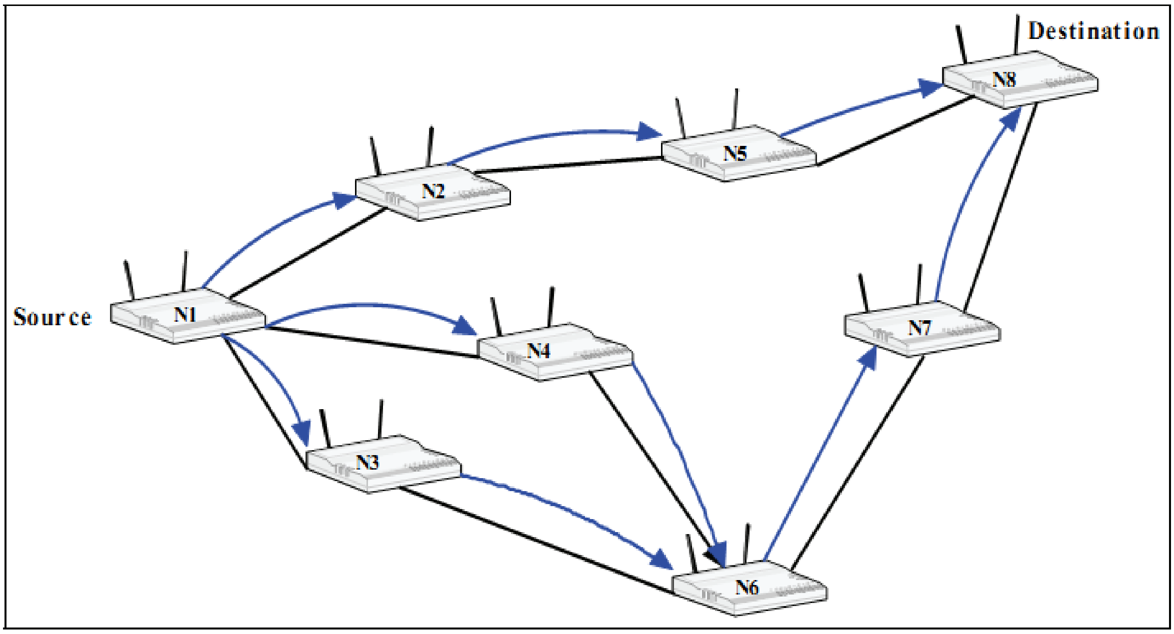

Figure 4.1: Propagation of the RREQ

Each node maintains two counters: the sequence number of the node (to solve the loops) and the broadcast ID which is incremented when a broadcast is started in the node. To identify only one RREQ (see Figure 4.3) it is used the broadcast ID and the IP (Internet Protocol) address of the source node.

The RREQ has the following fields: Source address, Source sequence number, Broadcast id, Destination address, Destination sequence number, and the number of hops to the destination.

The intermediate nodes only answer to the RREQ if they have a path to the destination with a sequence number greater or equal to the sequence number of the RREQ. Hence, only if they have paths equal (in age) or more recent. While the RREQ is sent, the intermediate nodes increase the field 'number of hops to the destination' and also store in its routing table the address of the neighbour from whom they first received the message, in order to establish a 'Reverse Path' (Figure 4.2). The copies of the same RREQ received later which are coming from the other neighbours are deleted.

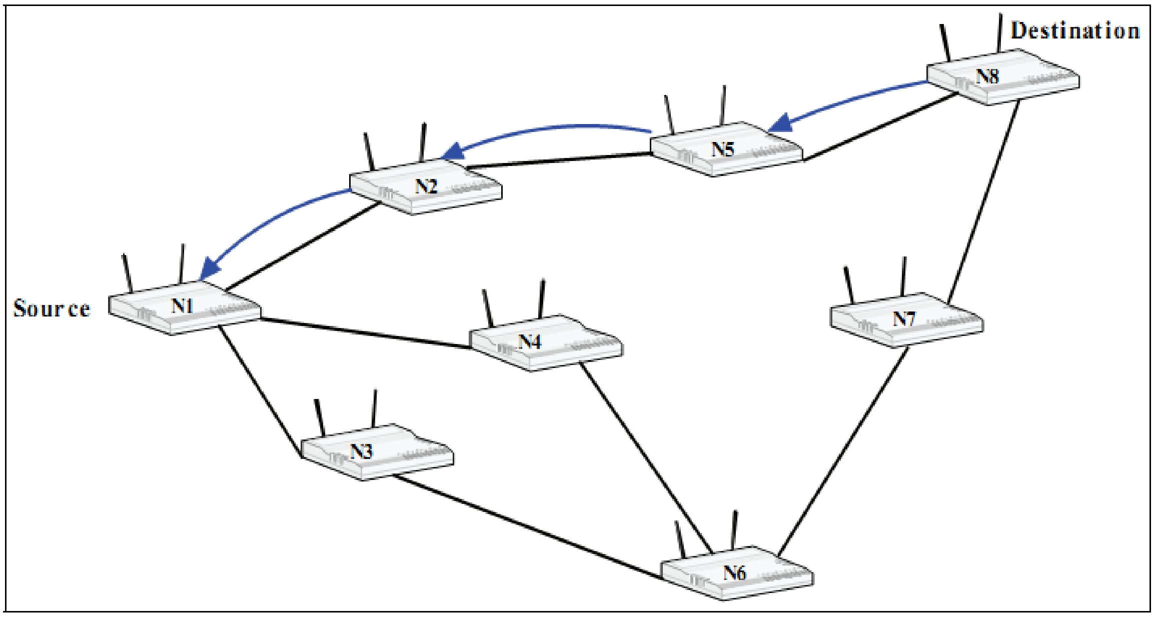

Figure 4.2: Path of the RREP to the Source

When the 'destination node/intermediate node with the fresh route' has been found, it answers with a Route Reply (RREP) to the neighbour from which it received the first RREQ. The RREP has the following fields: Source address, Destination address, Number of Hops to the destination, Sequence number of the destination, Expiration time for the Reverse Path (Figure 4.4). Then, the RREP uses the return path established to the source node. In its path, every node forwarding the RREP sets the reverse path as the freshest path to the destination node. Therefore, AODV can only use bidirectional links.

If a source node moves, it is capable of restarting the discovery protocol to find a new path to the destination. If an intermediate node moves, its previous neighbour (in source-destination way) must forward a RREP not requested with a fresh sequence number (greater than the known sequence number) and with a number of hops to destination infinite to the source node. In this way, the source node restarts the path discovery process if it is still needed.

Hello messages (periodic broadcasts) are used to inform mobile node about all the neighbourhood nodes. These are a special type of RREP not solicited, of which sequence number is equal to the sequence number of the last RREP sent and which has a TTL=1 (Time To Life) to not flood the network. They can be used to maintain the network connectivity, although other methods used more often exist for this function, like for example, to listen to the neighbour nodes transmissions.

Src_addr	Src_Seq_Nr	Bcast_ID	Dest_addr	Dest_Seq_Nr	Hop_cnt

Figure 4.3: RREQ packet

Src_addr	Dest_addr	Hop_cnt	Dest_Seq_Nr	Exp_Time_RP

Figure 4.4: RREP packet

4.4 Advantages

- Minimal space complexity: The algorithm makes sure that the nodes that are not participated in the active path do not maintain routing information about this route. After a node receives the RREQ packet and sets a reverse path in its routing table and propagates the RREQ packet to its neighbours, if it does not receive any RREP packet from its neighbours for this request, it deletes the routing information that it has recorded.
- Simple: It is simple with each node acts as a router, maintaining a simple routing table, and the source node initiating path discovery request, making the network self-starting. AODV is a simple protocol that aims to resolve more recent and shorter paths.
- Most effective routing information: After propagating an RREP packet, if a node finds receives an RREP packet with smaller hop-count, it updates its routing info with this better path and propagates it.

- Most current routing information: The route information is obtained when demand. Also, after propagating RREP packet, if a node finds receives an RREP packet with greater destination sequence number, it updates its routing information in routing table with this latest path and propagates it.
- Highly Scalable: The nature of algorithm is highly scalable because it has the minimum space complexity and redundant broadcasts avoided when it compared with DSDV.
- Coping up with dynamic topology and broken links: When the nodes in the network move from one place to other place and the topology is changed or the links in the active path are broken, the intermediate node that obtained this link breakage propagates an RERR message. And the source node re-initializes the path discovery if it still desires the route. This ensures fast response to broken links.
- Loop free routes: this algorithm provide loop free routes by using sequence number concept.
- Maximum utilization of the bandwidth: This can be considered the major achievement of the algorithm. Because the algorithm does not require periodic global advertisements, the requirement 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 packet from another source for same destination. Also, any RREPs that are received by the nodes are compared with the RREP packet that was propagated last using the destination sequence numbers and are discarded if they are not better than the already propagated RREPs.

- AODV has low control signalization because there are not periodic updates about the routing and the overload in terms of packets is small since it is a reactive protocol. Also, the processing signalization is low because the AODV messages are simple and require small calculation. Besides, the problems of loops are solved.

4.5: Disadvantages

- Overhead on the bandwidth: this overhead will be occurring compared to DSR, when RREQ packet travels from node to node in the process of discovering the route information 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.
- No reuse of routing information: AODV lacks an efficient route maintenance methodology. The routing information is always obtained on demand, including for common case traffic [18].
- It is vulnerable to misuse: The messages can be misused for insider attacks including route disruption, route invasion, node isolation, and resource consumption [19].
- AODV lacks support for high throughput routing metrics: AODV is designed to support the shortest hop count metric. This metric favours long, low bandwidth links over short, high-bandwidth links [18].
- Requirement on broadcast medium: The algorithm expects/requires that the nodes in the broadcast medium can detect each other's broadcasts.
- High route discovery latency: AODV is belonging to a reactive routing method. This means that AODV routing does not discover a route until a flow is initiated. This route discovery latency result can be high in large-scale mesh networks.
- AODV works only with bidirectional links. Although AODV only manages the routes between nodes who wish to communicate. Thus, in comparison with DSR the overhead in terms of packets is higher.

- Inconsistent route may appear.
- Multiple RREP can lead to heavy control overhead.
- Periodic beaconing.

Chapter 5: Proposed Approach

5.1: Problems with AODV

Simple flooding is used in AODV routing protocol to find out the destination node. When one node of a network wants to communicate to some other node of a network then sender node just broadcast the RREQ packet to all the nodes which is in the direct range of the sender node (neighbor nodes). Then these neighbor nodes receives the RREQ packet and reads the content of the packet and if receiving node is not the destination node then this receiving node will broadcast this RREQ packet in the range of their nodes. And if it is the destination node itself then it simply unicasts the RREP packet to the sender or immediate predecessor node. In this way, flooding is done in the network to find out the destination node or establish a connection to the destination node.

The problem in AODV algorithm is that there are some redundant flooding in the network. One node sends the route request packet to its neighbour node and then these neighbour nodes again sends the packet to their neighbours. Then this process repeats again and again until destination node is not found or whole network is explored. So same node continuously receive the same RREQ packet again and again and therefore wastes its energy and unnecessarily these redundant packets consumes the bandwidth of the network. Hence this redundant flooding wastes the energy of the node and also consumes the bandwidth of the network. There are so many techniques which improves the AODV algorithm. For example energy efficient ERS (expanding ring search) [20] and EEAODV (energy efficient AODV) [21] are the techniques which are used for improving the AODV algorithm in terms of energy consumption. These techniques are energy efficient because energy consumption is the major issue in mobile ad hoc network due to the limited resources available. So the main aim is to remove this redundant flooding by the network. A technique is developed by which energy of the nodes is saved and it also drops the number of redundant route request packets.

5.2: Sector Antenna

A sector antenna is a type of directional microwave antenna with a sector-shaped radiation pattern. The word "sector" is used in the geometric sense; some portion of the circumference of a circle measured in degrees of arc. 60°, 90° and 120° designs are typical, often with a few degrees extra to ensure overlap and mounted in multiples when wider or full-circle coverage is required. The largest use of these antennas is as antennas for cell phone base-station sites. They are also used for other types of mobile communications, for example in Wi-Fi networks. They are used for limited-range distances of around 4 to 5 km [22].

A directional antenna or beam antenna is an antenna which radiates greater power in one or more directions allowing for increased performance on transmit and receive and reduced interference from unwanted sources [23]. A directional antenna is a radio-frequency (RF) wireless antenna designed to function more effectively in some directions than in others. The purpose of that directionality is improving transmission and reception of communications and reducing interference.

In radio communication, an omnidirectional antenna is a class of antenna which radiates radio wave power uniformly in all directions in one plane, with the radiated power decreasing with elevation angle above or below the plane, dropping to zero on the antenna's axis. This radiation pattern is often described as "doughnut shaped". Note that this is different from an isotropic antenna, which radiates equal power in *all* directions and has a "spherical" radiation pattern. Omnidirectional antennas are widely used for radio broadcasting antennas, and in mobile devices that use radio such as cell phones, FM radios, walkie-talkies, wireless computer networks, cordless phones, GPS as well as for base stations that communicate with mobile radios, such as police and taxi dispatchers and aircraft communications [24].

Sector antenna is used in the proposed approach. Based on angle between any of the two consecutive sectors, sector antenna can be categorized as follows.

- Three sector antenna – the angle between any of the two consecutive sectors is 120 degree.
- Four sector antenna – the angle between any of the two consecutive sectors is 90 degree.
- Eight sector antenna – the angle between any of the two consecutive sectors is 45 degree.

In the proposed approach, all three types of antenna are used with different models and then the results are evaluated and compared with simple AODV without sector antenna.

5.3: Proposed Approach (Improvements in flooding of AODV by using sector antenna)

AODV protocol uses the concept of flooding for finding the destination node. There are some definite ranges of each and every nodes of a network. The node which comes in direct range of each other, these nodes are neighbour to each other. Now suppose in mobile ad-hoc network, one node (source node) wants to communicate to the other node (destination node) of the network. First, source node sends the RREQ packet to their neighbour nodes in the network which are in direct range of the source node. Then these neighbouring nodes receives the RREQ packet and check whether they are the destination node or not on the basis of destination address contained in RREQ packet. There are so many fields in the route request packet. These fields have already discussed in the previous ad hoc on demand distance vector routing protocol chapter in detail. Now there are two cases occurs in this scenario. First the receiving node is the destination node and second, receiving node is not the destination node. If the receiving node is the destination node then it simply unicasts the RREP packet to the source node or the immediate predecessor node. And then path is established and maintained between the source node and destination node. Now suppose due to link breakage if the path is destroyed between the source node and destination node then RERR packet broadcasts to the network by the source node. If receiving node is not the destination node then it broadcasts the same RREQ packet to its neighbour nodes which is in the direct range of this node. And this whole process repeats again and again until the destination node is to be found or traversed the whole network. In this way, simple flooding is used in this AODV protocol.

But there is one problem with this traditional approach. Suppose this mobile ad hoc network is a very huge network means it has large number of nodes. Now there is always one situation exists that source node finds the destination node in only one iteration means destination node is in direct range of source node (means neighbour of source node) then after finding the node, they both establish and maintain a connection. But now what about the REREQ packets which is flooded in entire network while source node already finds a destination node. These redundant RREQ packets generates so many problems in the network. These redundant packets consumes the processing power hence energy of the mobile nodes in the network. And energy is very important measure of any ad-hoc network. They consumes the bandwidth of the network. Hence unnecessary increases the traffic in the network. So this traditional flooding in AODV protocol has so many problems. Some problems are removed by one technique named ERS (expanding ring search) [25]. Hence AODV protocol is to be used by using ERS technique for removing these problems. Now ERS (expanding ring search) [25] works in this way for removing the above problem. TTL (time to live) mechanism is used in this ERS technique. Initially assign some starting value to TTL field. Assume this value is 1. TTL value decides that how many hop counts, the RREQ packet should be broadcasts in the network. Initially source node sends the RREQ packet to its direct neighbour. Now suppose if one of the neighbour is destination node then no RREQ packets broadcasts to other neighbouring nodes of the network by any node. If none of the neighbouring node is not the destination node then time to live value is increased by 1. Hence now its value is 2. Now again source node broadcasts the RREQ packets starting from scratch up to 2 hop counts. And then again above process is repeated until source node find out the destination node. In this way, TTL value is increased linearly until destination node is found until all the nodes of the network are explored. Hence in the above approach, TTL value is incremented linearly which shows that ERS approach limits the flooding on the basis of hop counts. Because RREQ packet is broadcasted to neighbour nodes hop by hop. When destination node is found, from that time, no RREQ packets would be broadcasted to other nodes in this technique. Hence ERS technique limits the flooding and therefore consumes less bandwidth of the network. In this way, ERS approach is used to avoid unnecessary flooding in the network. But there is one disadvantage in this ERS approach. Suppose that destination node is very far from the source node. Then when the TTL value is incremented linearly, at each increment, there is a repeated flooding. With each TTL increment, RREQ packet unnecessarily rebroadcast to lower hops while we know that destination node is not in the lower hops. Because each time when TTL value is incremented, RREQ packet is broadcasted from source node again and again. Hence when destination node is very far from source node then this scheme also has disadvantages. Suppose initially TTL value is 1 and finally after incrementation TTL value is (n+1). Then there will be a total of 1 + 2 + 3 + 4 +………… + (n-1) + n = (n*(n+1))/2 number of times redundant flooding occurring in this ERS approach.

Now research improves the basic flooding technique of AODV protocol. This goal is achieved by using a sector antenna. Each and every node of network has a functionality of a sector antenna. There is a categorization of all the nodes of a network on their positions of the network. Each and every node of a network knows their topology information in the network. On the basis of their current positions, each and every node of a network belongs to one of the sector. Now source node wants to communicate to the destination node then first of all, source node broadcasts the RREQ packet to all its neighbours and then each and every neighbour reads this RREQ packet that in which sector, this packet is coming from. Because each node belongs to some sector based on their current positions in the network. After knowing the sector, this receiving node will not broadcast the RREQ packet to that particular sector in which this RREQ packet comes from. Using this concept, in which sector RREQ coming from, no node broadcast the RREQ packet in that sector. Because logically there is no need to broadcast the RREQ packet to that sector, in which sector this packet is coming from. For example, we are using three sector antenna. Suppose we give the name to three sectors, sector no 1, sector no 2, sector no 3. And assume RREQ packet comes from sector no 2 to the receiving node then this receiving node broadcasts this RREQ packet to nodes which belonging to sector no 1 and sector no 3 and do not broadcast to nodes which belonging to sector no 2. In this way, this technique by using sector antenna prevents the unnecessary flooding in same sectors. Hence therefore consumes less bandwidth of the network and consumes less energy of the node.

There are so many regular topologies or models exists for mobile ad-hoc networks for which my proposed algorithm is working.

- Hexagonal topology – in this topology, there are total seven nodes. One node is at the centre and remaining six nodes jointly provides the hexagonal shape. Each and every node having six neighbour nodes means these nodes comes in their direct range.

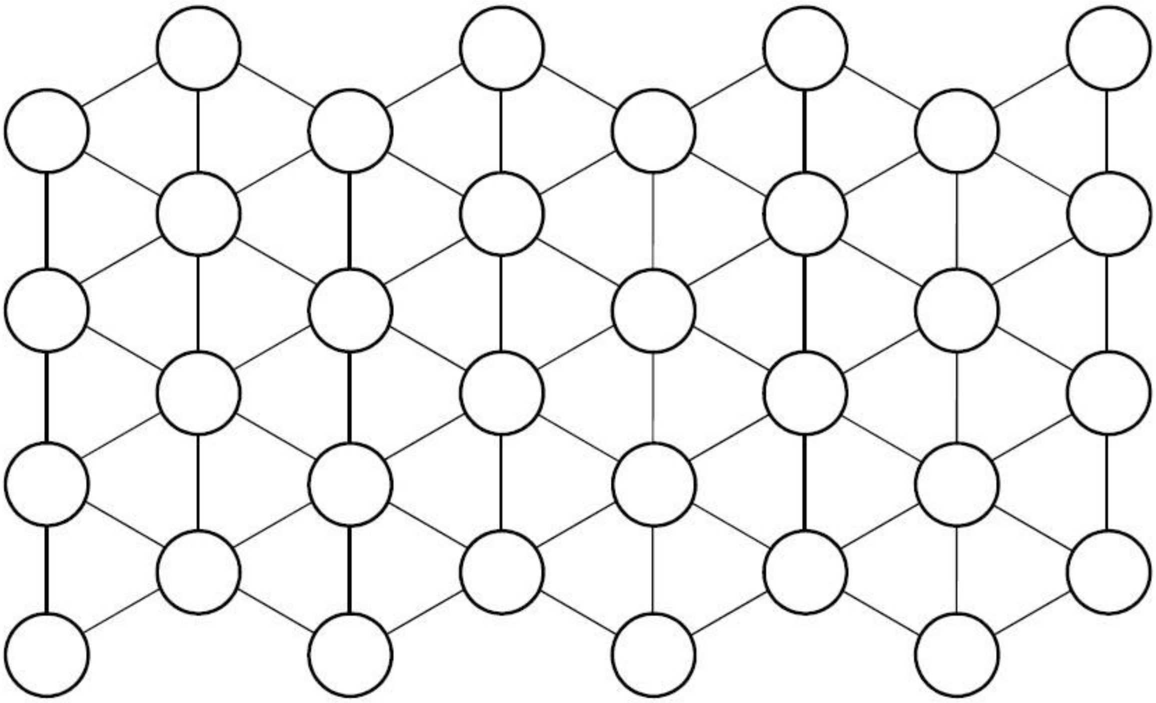

Figure 5.1: hexagonal topology

In the figure 5.1, each circle represents the nodes of the mobile ad hoc network.

- Octagonal topology or 8 neighbour standard grid model – in this topology, there are total nine nodes. One node is at the centre and the remaining eight nodes jointly form the octagonal shape. Each and every nodes having eight neighbours. In the figure 5.2, each black dot represents node of a network.

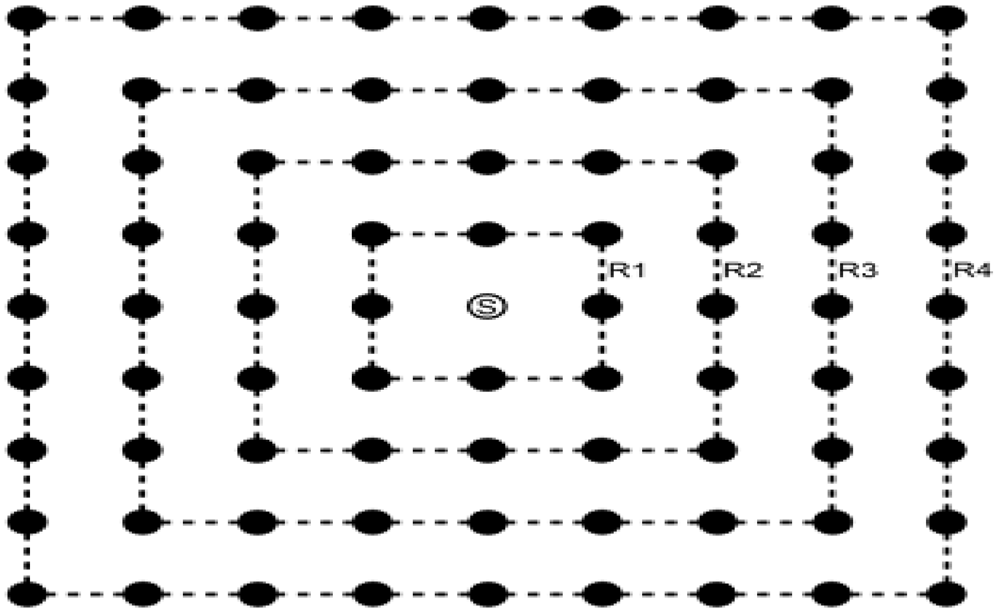

Figure 5.2: 8 neighbour standard grid model

- 4 neighbour standard grid model – in this topology, there are total five nodes. One node is at the centre and remaining four nodes jointly forms the square shape. Each and every node having four neighbours. In this figure 5.3, represents the node of the network.

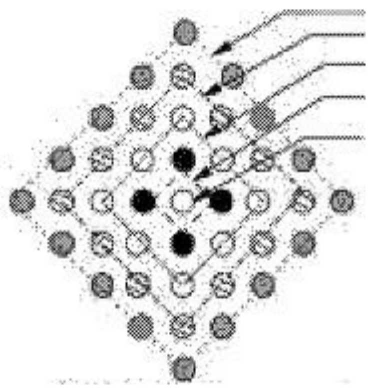

Figure 5.3: 4 neighbour standard grid model

Now in the above three topologies, applying all the sector antenna (three sector, four sector, eight sector) and then evaluate the number of links for a particular topology and sector antenna. After that compares the obtained results with traditional AODV routing without using sector antenna. The number of messages sent along various links or the number of links which are used is an effective and accurate metric for comparative analysis. The whole comparison between using sector antenna and without using sector antenna on the basis of above proposed algorithm is described in next chapter 6.

Chapter 6: Results and Analysis

To analyse the efficiency of proposed scheme, we compare the performance of traditional AODV (without sector antenna) with the proposed approach (with sector antenna). To theoretically analyse the performance, we introduced all the topology one by one describes in chapter 5.3. All the standard model provides a set of nodes with uniform density and distribution. The number of messages sent along various links or the number of links which are used is an effective and accurate metric for comparative analysis. Now one by one, we make comparison using all the topology discussed before.

➢ Using Hexagonal topology we got the following graph.

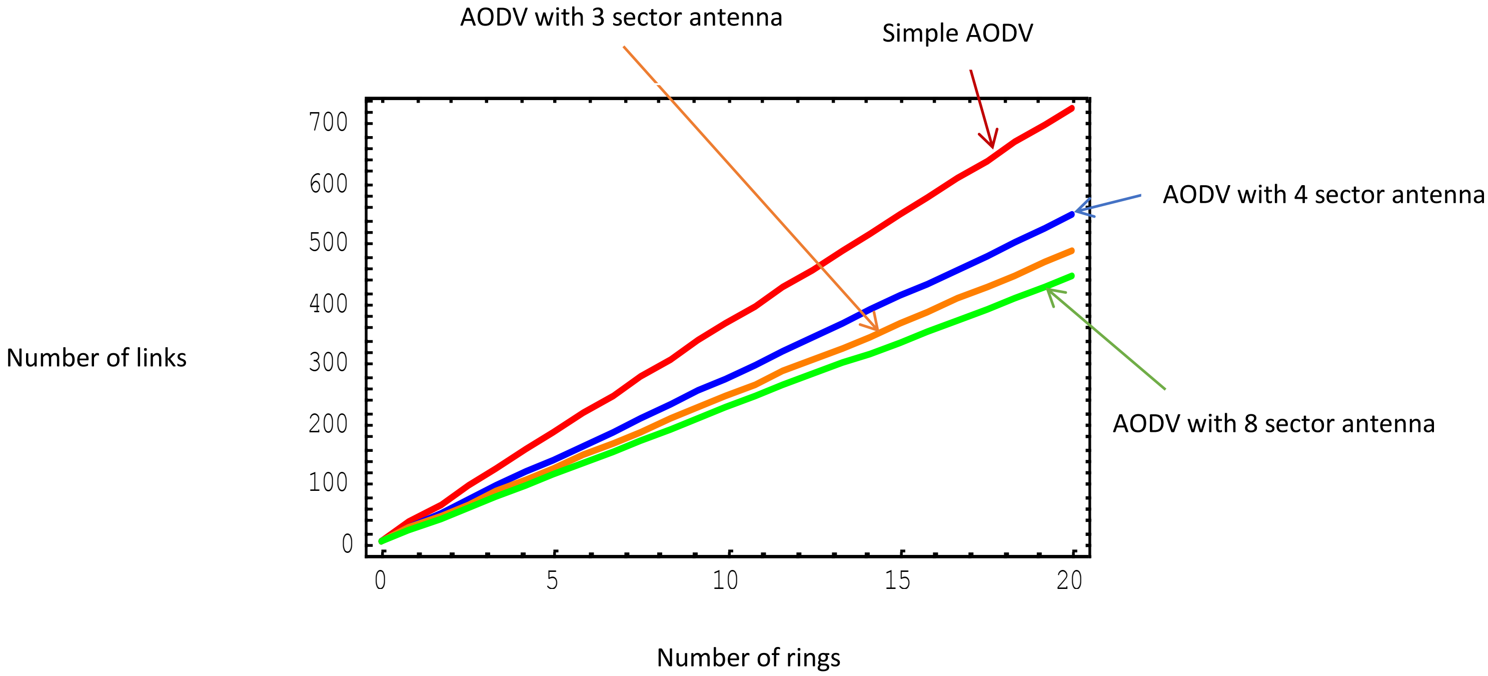

Figure 6.1: comparative analysis in terms of number of links of simple AODV and AODV with sector antenna using Hexagonal topology

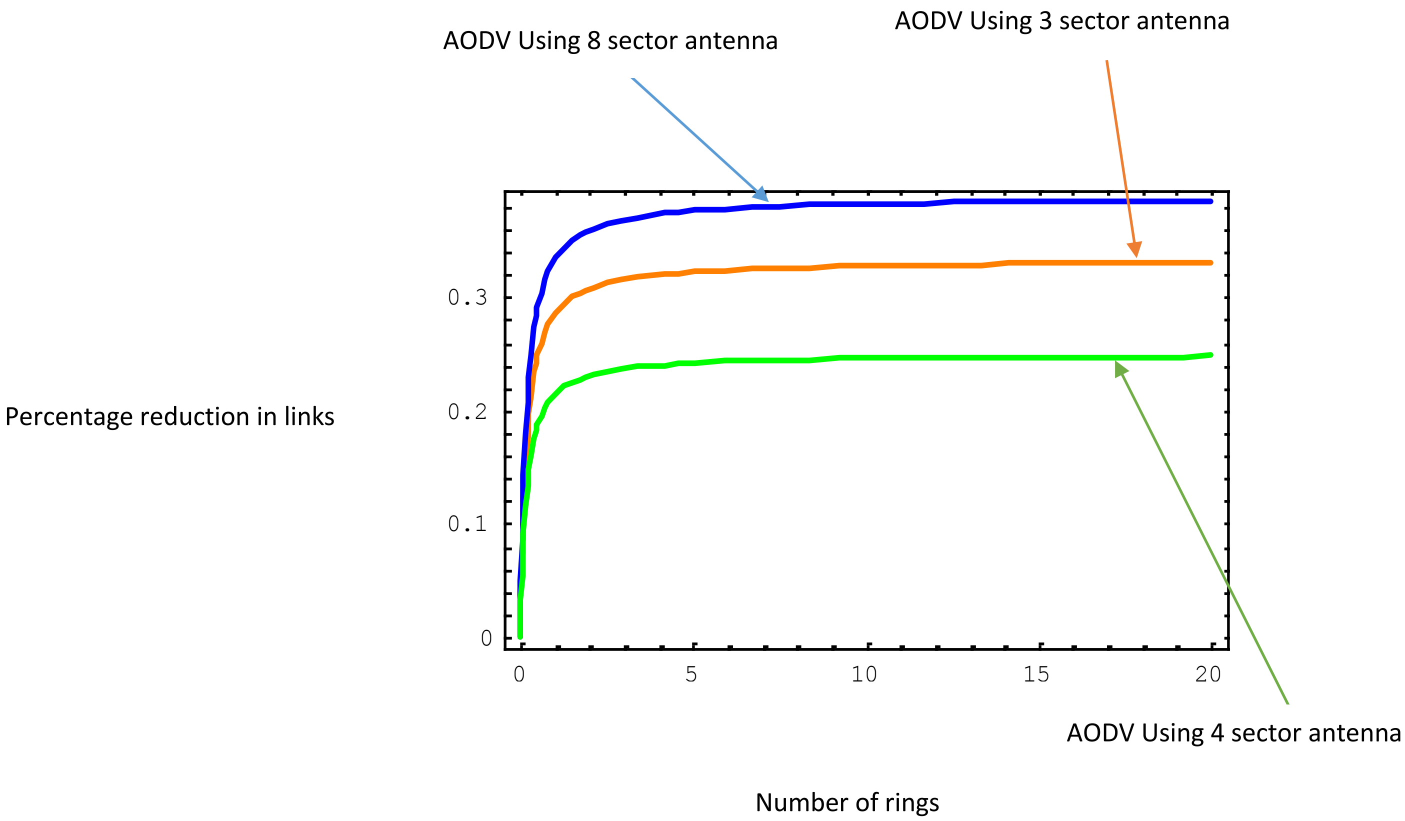

Figure 6.2: percentage profit in terms of number of links in AODV with sector antenna as compared to simple AODV using hexagonal topology

In this figure 6.2, Y-axis represents the percentage reduction in number of links. Hence the value 0.1 represents 10 percent, 0.2 represents 20 percent, 0.3 represents 30 percent. Therefore these values is representing percentage.

➢ Using 8 neighbour standard grid model we got the following graph.

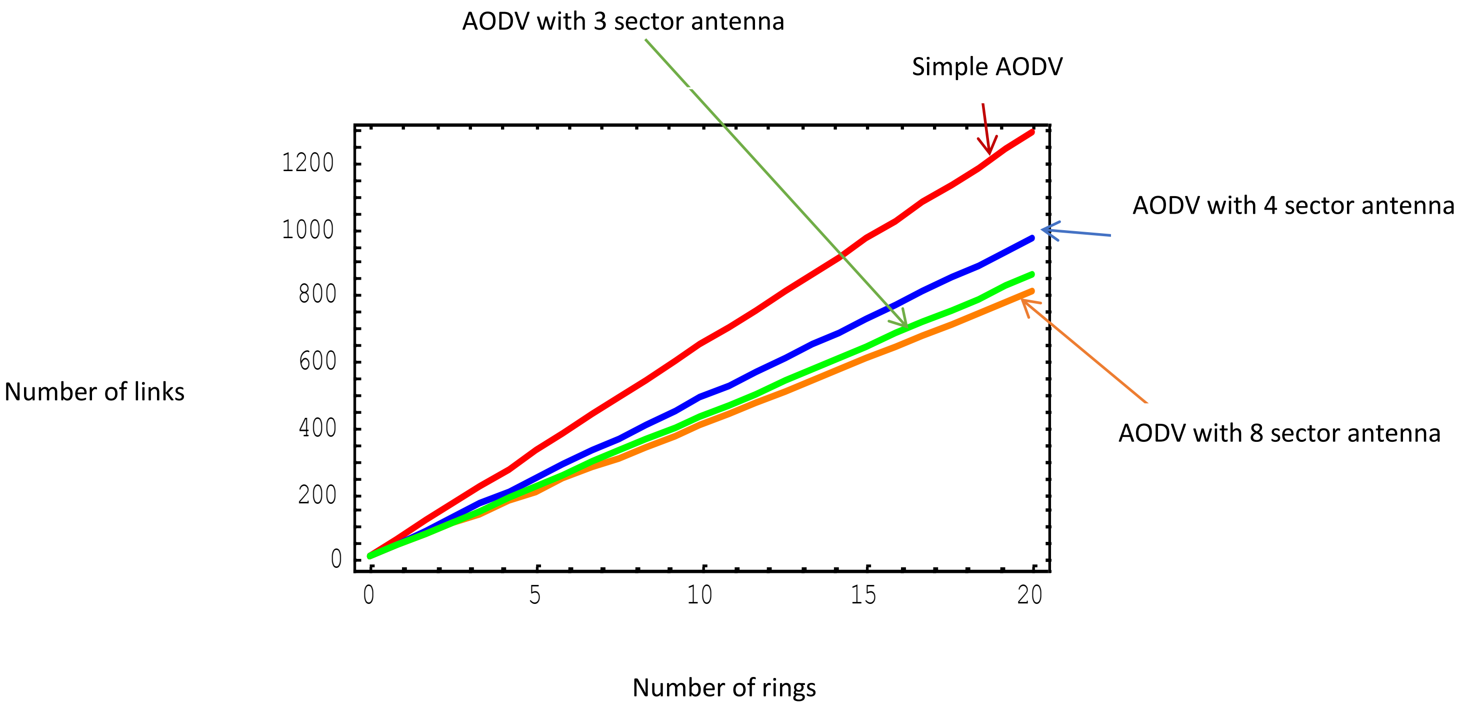

Figure 6.3: comparative analysis in terms of number of links of simple AODV and AODV with sector antenna using 8 neighbour standard grid model

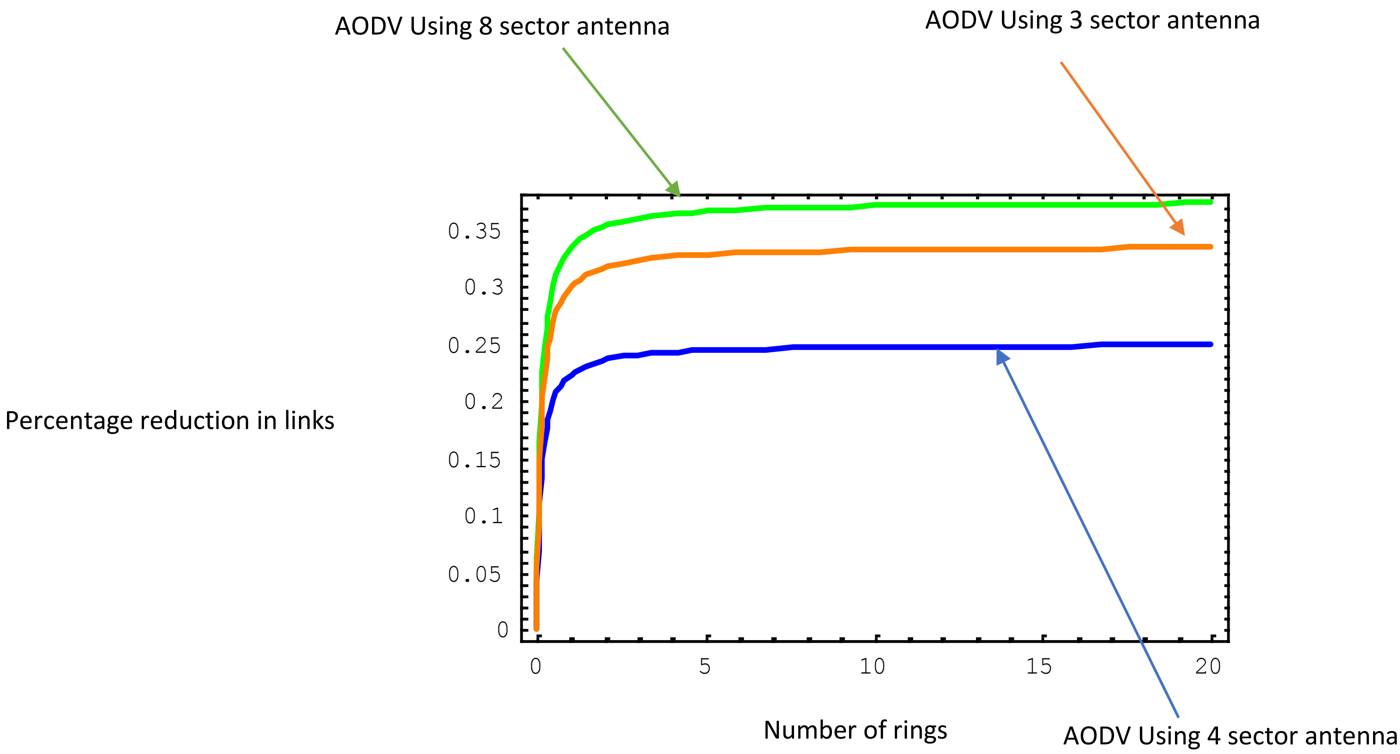

Figure 6.4: percentage profit in terms of number of links in AODV with sector antenna as compared to simple AODV using 8 neighbour standard grid model

➢ Using 4 neighbour standard grid we got the following graph.

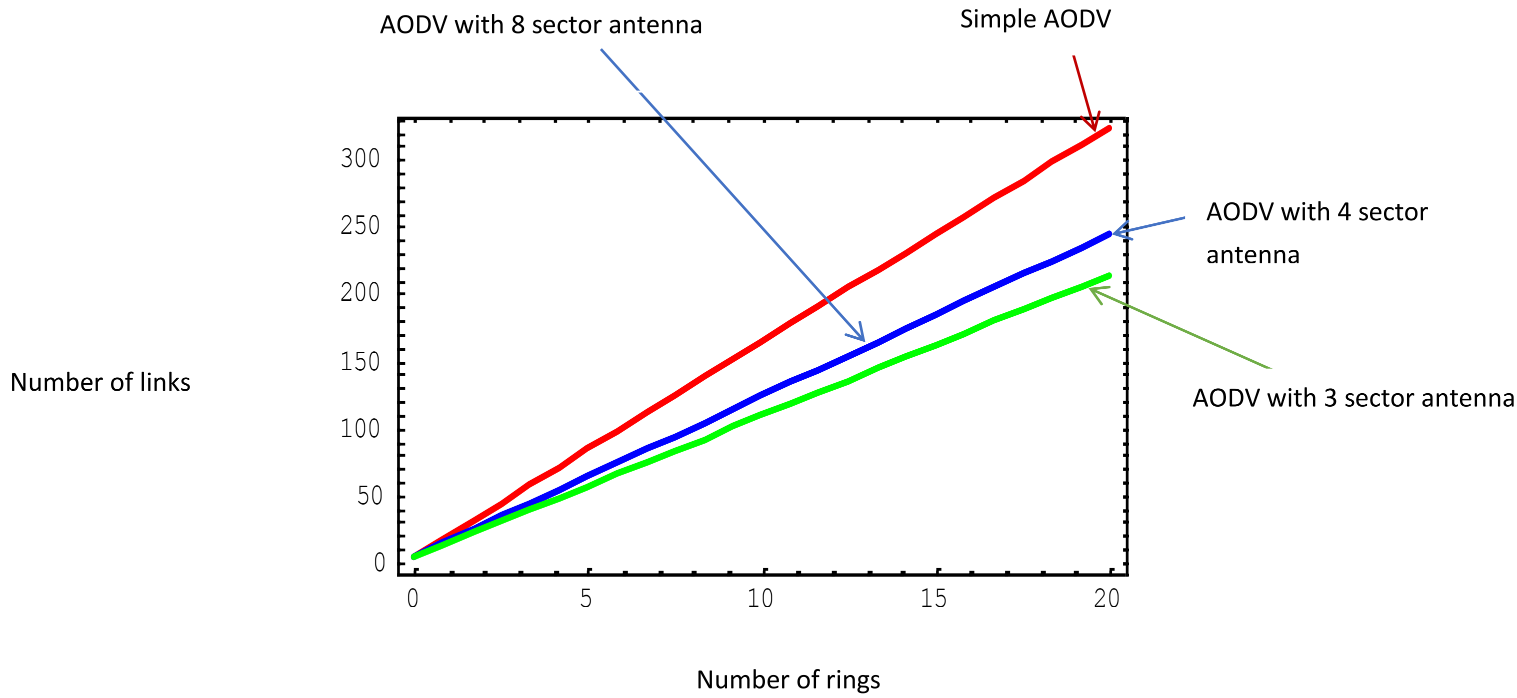

Figure 6.5: comparative analysis in terms of number of links of simple AODV and AODV with sector antenna using 4 neighbour standard grid model

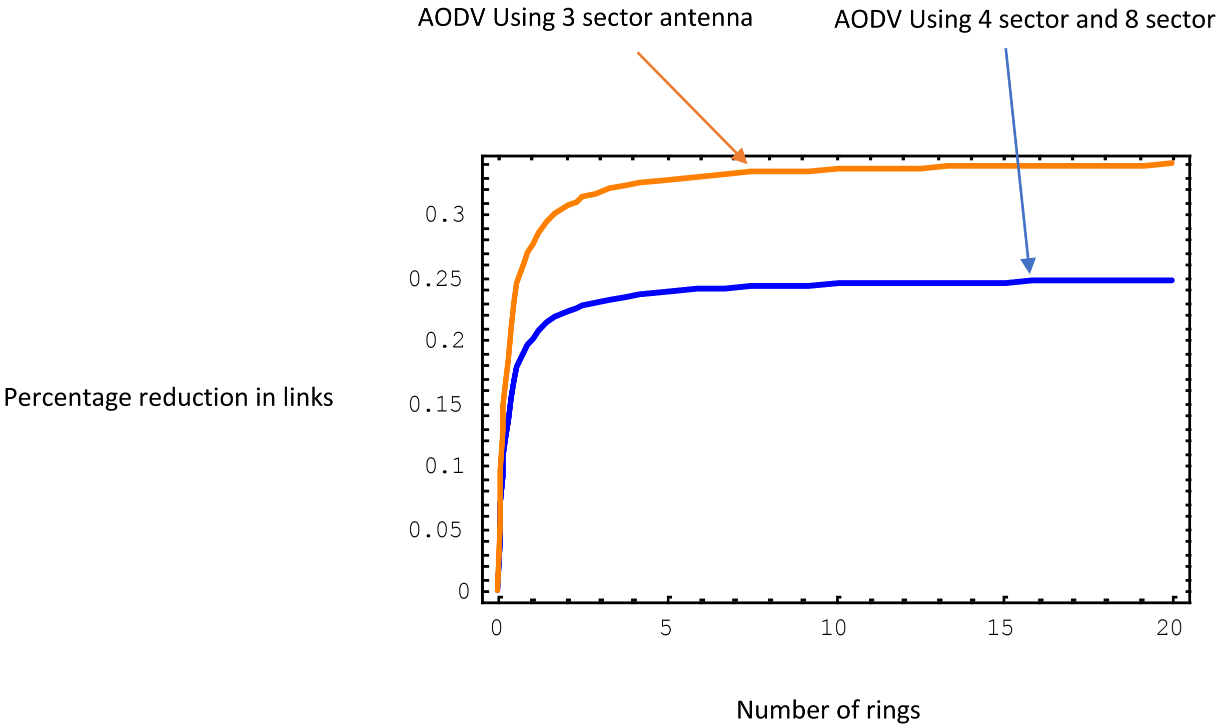

Figure 6.6: percentage profit in terms of number of links in AODV with sector antenna as compared to simple AODV using 4 neighbour standard grid model

In this comparative study, the number of links is the performance metric for comparative analysis. AODV with all the sector antenna is used against a simple AODV without sector antenna. In a graph, less number of links for all sector antennas as compared to simple AODV shows that less number of route request packet broadcasts to the network. Hence consumes less energy of the nodes and consumes less bandwidth of the network. Therefore for a particular antenna, less number of links directly reflects the results in terms of energy and bandwidth.

In hexagonal topology, figure 6.1 shows that 8 sector antenna is producing less number of links against all, hence 8 sector antenna is useful in hexagonal topology. And figure 6.2 shows that percentage profit in number of links using all sector antenna for AODV as compared to simple AODV.

In 8 neighbour standard grid model, figure 6.3 shows that here also 8 sector antenna is producing less number of links against all, hence 8 sector antenna is useful in 8 neighbour standard grid model.

In 4 neighbour standard grid model, figure 6.5 shows that 3 sector antenna is producing less number of links against all, hence 3 sector antenna is useful in 4 neighbour standard grid model.

Chapter 7: Conclusion

The proposed work describes an efficient AODV algorithm that uses sector antenna. The proposed algorithm uses sector antenna to reduce redundant broadcast in flooding of AODV routing. Proposed algorithm (based on sector antenna) is utilized to attain improved efficiency. The results and comparative analysis discussed in the results section shows that if we use any of the sector antenna for any regular topology as compared with simple AODV, less number of links are participated in broadcasting the packet as compared to simple AODV. Hence these less number of links consumes less energy of the node and consumes less bandwidth of the network. For a larger mobile ad hoc network, AODV with sector antenna as compared to without sector antenna, produces good results for number of links participated in broadcasting the packet, energy of the nodes of a network and bandwidth of the network.

And from the results graph, it is concluded that 8 sector antenna is useful in hexagonal and 8 neighbour standard grid model. And 3 sector antenna is useful in 4 neighbour standard grid model.

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