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Improving Performance of AODV using non-flooding route discovery technique

By

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A Thesis Submitted to the Department of Computer Networking in Partial Fulfillment for the Degree of Master of Science in Computer Networking

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I, hereby, declare that the materials contained in this thesis have not been previously submitted for a degree in this or any other university. I further declare that this thesis is solely based on my own research work. I also declare that all information contained in this document has been obtained and presented in accordance with academic rules and ethical conduct. I understand that my thesis may be made electronically available to the general public for reference purpose.

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Dedication

To My Beloved Family

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Abbreviations

AODV	Ad hoc On demand Distance Vector
AOMDV	Ad hoc On demand Multipath Distance Vector
CBR	Constant Bit Rate
CGSR	Clusterhead-Gateway Switch Routing
DSDV	Destination-Sequenced Distance-Vector Routing
DSR	Dynamic Source Routing
IAODV	Improved Ad hoc On demand Distance Vector
IZRP	Improved Zone Routing Protocol
MANET	Mobile Ad hoc Network
NAM	Network Animator
ND	Node Degree
NS	Network Simulator
NS-2	Network Simulator Version 2
OLSR	Optimized Link State Routing
OTCL	Object-oriented Tool Command Language
RREQ	Route Request
RREP	Route Reply
RERR	Route Error
TCL	Tool Command Language
TTL	Time to Live
WRP	Wireless Routing Protocol
ZRP	Zone Routing Protocol

Abstract

Mobile Ad-hoc Network (MANET) is an infrastructure-less network (i.e., decentralized, self-configuring, and dynamic in nature). Nodes constitute the networks act as host (i.e., source and destination nodes) and router (i.e., intermediate nodes) interchangeably. One of the unique features that characterize MANETs is resource scarcity (i.e., nodes battery power and bandwidth is too limited). So to make the MANETs' protocols to perform efficiently regardless of change of topology the available bandwidth need to be used efficiently which can be achieved by optimizing the route discovery technique. Hence, the goal of this thesis is to optimize the performance of AODV by modifying its route discovery technique. The proposed route discovery technique improves the performance of AODV by minimizing unnecessary redundant control message, i.e., Route Request (RREQ) message. To minimize the unnecessary redundant control message during route discovery phase a non-flooding technique is integrated with the original AODV routing protocol. AODV is one of the well tested and documented reactive routing protocols and it is one of the typical examples of reactive routing protocols. AODV uses flooding technique on demand during a route discovery. Even if AODV generates less routing traffic when compared with proactive routing protocols problem arises when the number of nodes increases. Thus in this thesis, we replaced the flooding technique used in AODV with non-flooding, i.e. all nodes that receive RREQ packets will not rebroadcast RREQ packets in order to minimize redundant control messages. In our improved IAODV maximum node degree is used to rebroadcast RREQ packet. From the available neighbor nodes, the node with maximum node degree is chosen to rebroadcast RREQ packet. This minimizes the overhead that resulted during unnecessary and redundant exchange of RREQ packets in route discovery phase. This results in an efficient use of bandwidth.

To evaluate the performance of the proposed work (i.e., IAODV)we have used Network Simulator Version 2.35 (NS2.35). The simulation result shows the reduction of Routing Overheadachieved through non-flooding technique improved Packet delivery ratio.

Keyword: *Node degree, MANETs, AODV, RREQ rebroadcast*.

1 Chapter One: Introduction

1.1 Background

Wireless networks can be broadly categorized into two classes: infrastructure-based wireless networks and infrastructure-less wireless networks (ad-hoc wireless networks) [1]. *Infrastructure-based* wireless networks rely on a dedicated device (fixed infrastructure) like access point. On the other hand, the infrastructure-less wireless networks are multi-hop networks, i.e., intermediate nodes relay the message until it reaches the destination.

(a) (b)

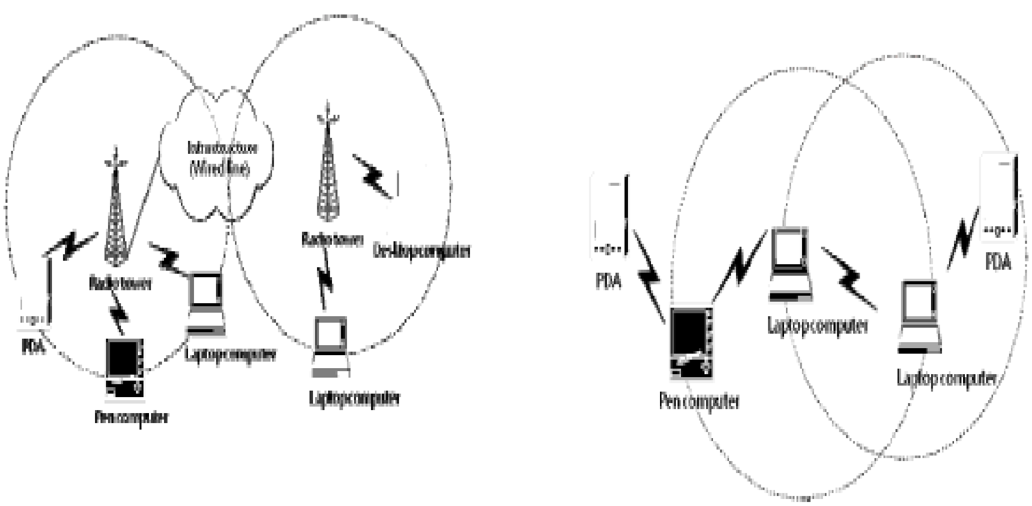


Figure 1.1(a) Infrastructured and (b) Infrastructureless Wireless Network [35]

In general MANETs is characterized by its unique features like absence offixed infrastructure, mobility and by its constrained resources, i.e., limited bandwidth and battery power. Personal area networks, military environments, civilian environments, and emergency situations are some of the potential application areas of MANETs [2].

The nodes mobility (one of the unique characteristics of MANETs) makes route discovery a challenging task. A route discovery, as it is well known in network protocol, is a process of finding a route (path) to a destination node. During a route discovery a source node launch a route discovery process by rebroadcasting Route Request (RREQ) packets. To achieve a better dissemination of message (RREQ packet) despite the frequent link breakage due to node mobility, several MANETs' protocols are proposed and implemented.

Based on their route discovery and route maintenance techniques, MANETs' protocols can be broadly classified in to three categories, namely, proactive (table-driven), reactive (on-demand-driven), and hybrid routing protocols.

Proactive Routing Protocol:Routes from a given node to every other nodesare discovered and maintained pro-actively [4].The main drawback of proactive routing protocols is scalability issue. As the number of nodes increase the number of RREQ packet also increase exponentially. In other words, in large size networks the control messages (RREQ packets) consume high bandwidth which makes proactive routing protocols an expensive technique for large size networks.To make proactive routing protocols bandwidth efficient routing protocols, reactive routing protocols are proposed. In reactive routing protocols, source nodes discover route reactively (i.e., on demand). As a result traffic overhead due to route discovery is minimum in the case of reactive routing protocols compared to proactive routing protocols. Reactive routing protocols achieves less traffic overhead compared to proactive routing protocols at the expense of latency (i.e., in the case of proactive protocols route discovery delay is almost null since routes are readily available).

To exploit the good features of proactive routing protocols (i.e., less route discovery delay) and reactive routing protocols (less traffic overhead), hybrid routing protocols combine proactive and reactive into a single routing protocol. In hybrid routing protocol routes are discovered pro-actively if the source and destination are located within inner zone; else routes are discovered reactively. Despite all the attempts to handle unnecessary and redundant traffic to make MANETs' routing protocols bandwidth efficient, route discovery using flooding technique need to be optimized by further reducing the impact of routing overhead on the performance of MANETs. Among the three broad categories of MANETs' routing protocols (which have been discussed earlier), reactive routing protocols have a potential for further scalability. This can be achieved by optimizing its route discovery technique.

Hence, the goal of this thesis is to optimize one of the well tested and documented reactive routing protocols, namely, Ad-hoc On-demand Distance Vector (AODV). AODV is one of the typical examples of reactive routing protocols [4]. AODV uses flooding technique on demand during a route discovery. As a result compared to proactive routing protocol, AODV generates less routing traffic [5], [6], and [7]. This shows the potential scalability of AODV. This feature of AODV motivated us to further optimize the protocol using our own technique.

1.2 Statement of the problem

Route discovery is a challenging task in unstructured networks (MANETs). Among the several unique features of infrastructure-less networks (MANETs) node mobility makes route discovery a challenging task. Due to node mobility links appear and disappear spontaneously. As a result, source nodes frequently launch route discovery by broadcasting control message (RREQ packets) which are flooded by intermediate nodes. Though AODV generates RREQ packets on demand (which is perfect for small size networks), the size of the networks and node mobility greatly affect the performance of AODV. In other words, the performance of AODV declines due to high routing overhead (which is unaffordable in bandwidth constrained networks) in large size network and high node mobility.

Unable to handle unnecessary and redundant control messages (RREQ packet) during route discovery leads to broadcast storms (i.e., frequent contention and collision). In the presence of broadcast storms the performance of the networks declines in terms of packet delivery ratio and latency. For instance, in large size networks and in the presence of high mobility the performance of AODV in terms of packet delivery ratio and end-to-end latency start to decline significantly. The main reason for this is that AODV uses flooding technique during route discovery. In other words, handling unnecessary and redundant RREQ packets of AODV further, makes AODV adaptable to the changing scenario of the networks (i.e., enhance its scalability). As a result we are motivated to optimize the route discovery technique (flooding) of AODV by integrating non-flooding technique to existing AODV. Therefore, the goal of this thesis is to reduce unnecessary and redundant RREQ packets to make AODV adaptable dynamic in scenarios.

1.3 Objectives

General Objective

The general objective of this thesis is to Improve AODV using non-flooding route discovery technique.

Specific Objectives

The specific objectives of this thesis are listed below.

- Study the domain from existing related works.
- Study and analyze the possible issues of AODV during route discovery.
- Identify the possible parameter to be used in the proposed work to optimize the route discovery of AODV.
- Design an algorithm for the proposed solution and implement the solution of the proposed work.
- Identify evaluation metrics to be used to test the performance of the proposed work with the original AODV.
- Finally discuss the simulation result with relevant justification (scientific justification)

1.4 Methods

The research methodology used to achieve the specified objective of the thesis is described as follows:

1.4.1 Literature review

To understand the various route discovery techniques in the domain, the research gap in domain and the evaluation metrics used to test the performance of the protocols, related literature works are reviewed in depth.The reviewed related works also enable the researcher to identify research gap in the domain and to define the scope of the proposed thesis.

1.4.2 Designing an Algorithm

To improve performance of AODV an algorithm is designed in this thesis. The algorithm uses a non-flooding technique and it is integrated in the route discovery phase of the original AODV routing protocol. This technique helps to minimize the number of RREQ packets that are exchanged between neighbor nodes and reduces the overhead caused by routing.

1.4.3 Implementation of the solution using NS2

To implement the solution of the proposed work, we have used NS2 simulator. Network simulator version 2 (NS2) is an event driven simulator targeting networking research. So, we found NS2 is the right tool to study the behavior of the proposed work. Besides, the performance metrics of the proposed work is calculated using awk script. Awk is designated for text processing and data extraction which makes it a preferred utility to analyze simulation results.

1.4.4 Evaluation of Performance

The performance of the proposed protocol is evaluated against the performance of the original AODV protocol. The metrics that are used in our work to evaluate the performance of the proposed work against existing works are: Routing overheads, Packet delivery ratio and Packet end-to-end delay.

- *Routing overhead:* This is the total number of routing packets divided by total number of delivered data packets. This performance metric is a good indicator whether the proposed work is able to reduce the unnecessary and redundant packets compared to the original AODV.

- *Packet delivery ratio:* - is the ratio of the number of packets transmitted by a traffic source and the number of packets received by a traffic sink. It measures the loss rate as seen by transport protocols and as such it characterizes both the correctness and efficiency of ad hoc routing protocols. This is an indicator whether we are achieved desirable reduction of routing overhead.

- *End-to-end delay:* This is the time from the generation of the packet by the sender up to its reception at the destination's application layer and it is measured in seconds. In our case the shortest path may not be selected always as it is the case in the original AODV.

1.5 Scope and Limitations

The focus of this thesis is to reduce routing overhead by modifying the route discovery of AODV. We have adopted all features of AODV except route discovery technique. The original

AODV uses flooding technique during route discovery which is replaced by non-flooding technique (i.e., not all nodes received RREQ packets are expected to rebroadcast RREQ packets in order to minimize redundant control messages). Not all nodes rebroadcast received RREQ packet thusshortest path may not be selected as in the case of AODV.

1.6 Organization of the Thesis

This thesis work comprises of six chapters. The next chapter covers the literature review on MANETs such as different types of networks, characteristics, design challenges, applications and routing protocols in MANET. Chapter 3 discusses about different related research works. In Chapter 4, the design of the proposed algorithm is presented. Chapter 5 presents an experimental set up, simulation results and performance evaluation. Finally, Conclusion is presented in Chapter6.

2 Chapter two: Literature review

2.1 Mobile ad hoc network overview

In 1970's the wireless network is increasingly popular in communication industry. These networks provide mobile users with ubiquitous computing capability and information access regardless of the users' location. The mobile wireless networks are classified into two types: Infrastructure and Infrastructure less networks (multi-hope).The infrastructure network are connected through a wired to one the base Station (one computer) to another based station. But in infrastructure less network have no fixed routers, every node could be router. All nodes are capable of movement and can be connected dynamically in arbitrary manner. The infrastructure-less networks is also knows as Mobile ad hoc Networks (MANET) [8]. The following figure shows the overall structure of MANET.

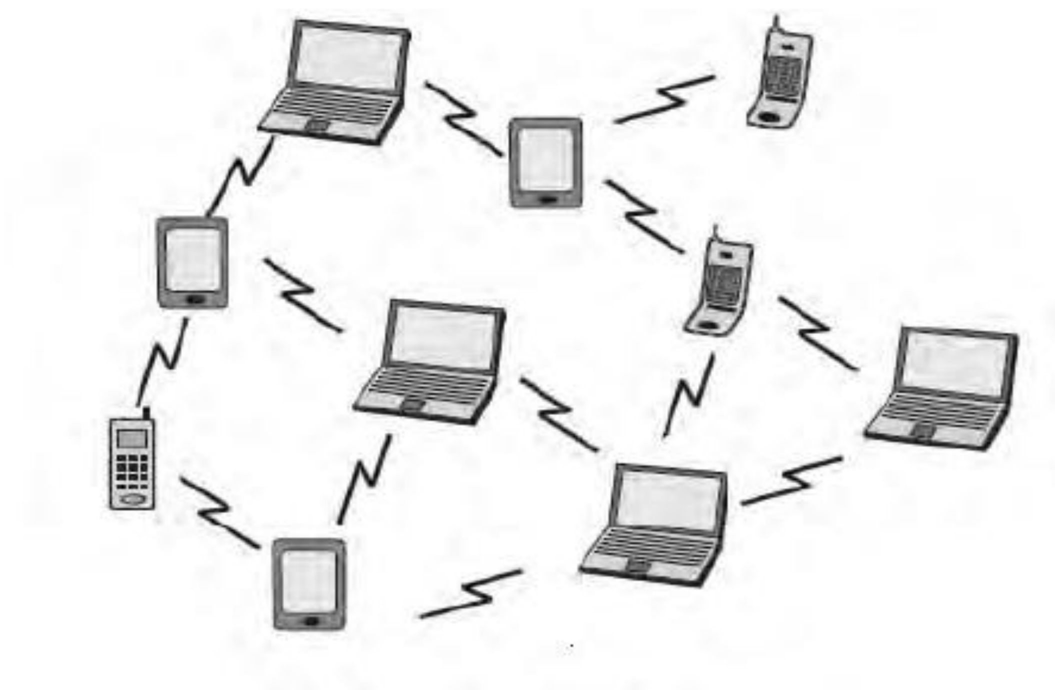


Figure 2.1Mobile ad hoc Network [10]

MANET is a kind of wireless network, which is self-configuring, infrastructures less network where devices are connected in wireless mode. The devices of MANET network are free to move independently in any direction, thus it is easy to establish links between devices when a new node joins the network. Each device must forward traffic unrelated to its own use, and therefore be a router. The primary goal of MANET is each device to continuously maintain the information required to properly route traffic. Such networks may operate by themselves or may be connected to the larger Internet. The achievement of MANET is in the huge growth of laptops and wireless or Wi-Fi networking [8].

The Communication in MANET takes place by using multi-hop paths. Nodes in the MANET share the wireless medium and the topology of the network changes erratically and dynamically. In MANET, breaking of communication link is very frequent, as nodes are free to move to anywhere. The density of nodes and the number of nodes depends on the applications in which we are using MANET [9].

There are many research issues in MANET that are in progress, especially around MANET routing. This area is given much emphasis since devices in such network are mobile.

MANET has given rise to many applications, like Tactical networks, Wireless Sensor Network, Data Networks, Device Networks, etc. With many applications, there are still some design issues and challenges to overcome.

2.2 Characteristics of MANET

The following characteristics of MANET are listed in works [8], [11], [10].

- **Lack of fixed infrastructure:** The absence of a fixed or control infrastructure is a key feature of MANET. This eliminates the possibility to establish a centralized authority to control the network characteristics. Due to this absence of authority, traditional techniques of network management and security are scarcely applicable to MANET.

- **Dynamism of Topology:** The nodes of MANET are randomly, frequently and unpredictably mobile within the network. These nodes may leave or join the network at any point of time, thereby significantly affecting the status of trust among nodes and the complexity of routing. Such mobility entails that topology of the network as well as the connectivity between the hosts is unpredictable. So the management of the network environment is a function of the participating nodes.

- **Cooperation or Distributed Operation:** If the source node and destination node are out of range with each other than the communication between them takes place with the cooperation of other nodes such that a valid and optimum chain of mutually connected nodes is formed. This is also called as multi-hop communication. In multi hop communication each node is to act as a host as well as router simultaneously.

- **Resource Constraints:** MANET is a set of mobile devices which are of lower limited power capacity, computational capacity, memory, bandwidth etc. So in order to achieve a secure and reliable communication between nodes, these resource constraints make the task more enduring all of the routing protocols in MANET depends on active cooperation of nodes to provide routing between the nodes and to establish and operate the network.

- **Multi-hop Routing:** MANET possess the capability of multi hop routing which is employed for communication between nodes when they are beyond each other's radio range, that means there are intermediate nodes acting as routers which forward and relay packets.

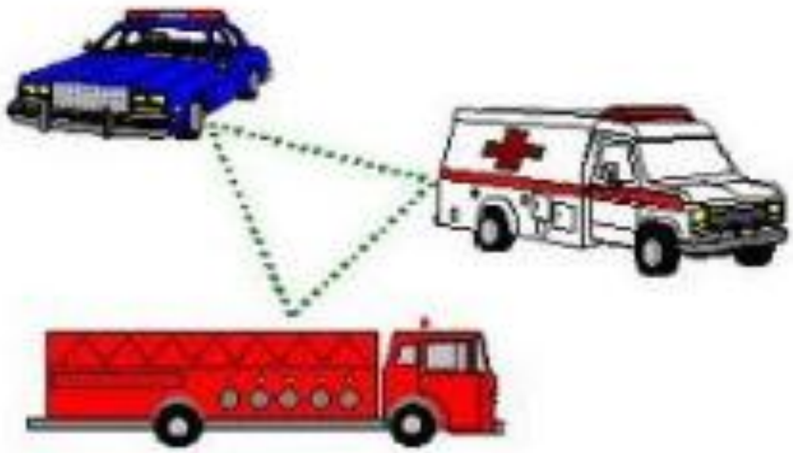
- **Fast Installation:** Since MANET does not requireaccess points or base stations, their installation isremarkably flexible. Furthermore, they take little time toinstall which can prove a benefit in times of naturaldisasters such as earthquakes, floods, etc.

2.3 Applications of MANET

MANET is supposed to be useful in disaster recovery, battle field communications and rescue operations where infra-structured networks do not exist or got damaged due to disaster [8],[11]. It is feasible for ground communication and information sharing. Some of MANET applications are listed below:

- **Emergency Service:** MANET provide support in case of disaster recovery, rescue operation, military communication, replacing fixed infrastructure in times of natural disaster such as earthquakes, floods, etc., and firefighting, policing and aiding doctors or nurses in hospitals. The following picture shows the application of MANET in emergency situations and military communication in battle fields.

(a)



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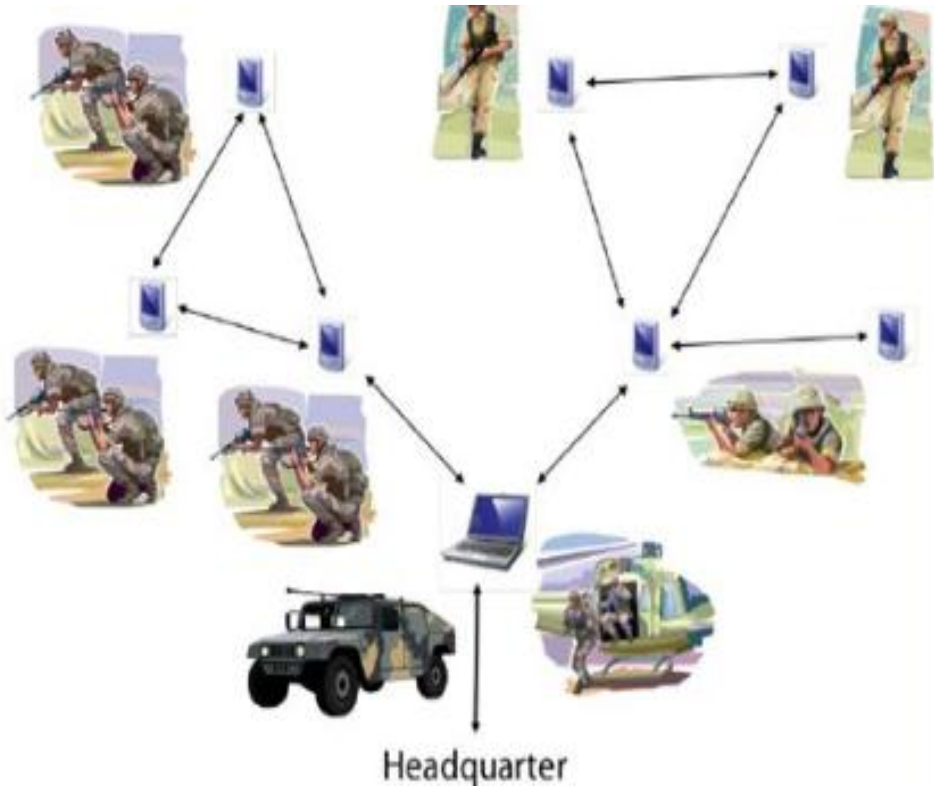

Figure 2.2(a) Emergency and (b) Military Communication in MANET [17]

- **Commercial or Civilian Environment:** Another important application of MANET is e-commerce and electronic payments can be done anytime, anywhere. MANETs have their applications in trade fairs, sports stadiums, shopping malls, etc.

- **Vehicular Service:** MANET can provide guidance about roads or accidents, information about weather and roads can be transmitted and there is also taxi cab network and inter-vehicle networking. This is referred as VANET (Vehicular Ad hoc Network). VANET delivers communications with neighboring vehicles and between vehicles and nearby fixed equipment, usually described as roadside equipment. The main aim of VANET is to deliver safety and comfort for travelers. To perform such application it needs a special electronic device will be placed inside individual vehicle which will provide Ad hoc Network connectivity for the passengers. For all vehicle support with VANET device will be a mobile node in the Ad hoc network possible to exchange or share information each other through ad hoc manner. When a situation occurs collision warning, road sign alarms and in place traffic view will give the driver vital tools to choose the best path from available alternative roads. In addition to this it provides multimedia application and internet connectivity facilities for travelers, all provided within the wireless coverage of individual vehicles. It also used to minimizing moving at random direction, each vehicles have a habit of to move in an organized way. And finally, all vehicles are limited in their range of motion, without moving abnormally, since it causes problem for other vehicles.

Figure 2.3Vehicular Ad hoc Network (VANET) [32]

- **Education:** Mobile ad hoc network set-ups are found in university campus settings. Virtual classrooms and communicating in an ad hoc manner during lectures or meetings is a reality because of MANET.

2.4 MANET Design Issues

In the previous section we have discussed the different characteristics and applications of MANET. The following are the factors that challenge the performance of Ad hoc network, while designing topology in MANET [21].

i. Power Demands: Because of the nodes in Ad hoc devices have limited battery power, long lasting energy of these devices has always been a challenge. So that, how to efficiently use the residual energy of nodes in Ad hoc networks is the critical issue.

ii. Providing Reliability: Since Ad hoc networks are formed on the go, the link stability for reliable communication is always a challenge.

iii. Data Rate Enhancement: One of the key parameter which is used to determine the performance of any routing protocol is throughput. With the increased use of wireless devices, providing methods to enhance the throughput has thus far been a challenge.

iv. Security: The data transmitted and available resources in Ad hoc network are greatly exploited due to the existence of malicious nodes. The security issue in ad hoc network is a fast growing area of research.

2.5 Routing protocols in MANET

Routing is the process of selecting the best available route among the available route from one node (source) to another node (destination) in any network [21].The traditional routing algorithm such as link-state and distance-vector do not scale in large mobile ad-hoc networks. This is because periodic or frequent route updates in large networks may consume significant part of the available bandwidth, increase channel contention and may require each node to frequently recharge their power supply. To overcome the problems associated with the link-state and distance-vector algorithms a number of routing protocols have been proposed for MANETs.

As mobile ad hoc networks are characterized by a multi-hop network topology that can change frequently due to mobility, efficient routing protocols are needed to establish communication paths between nodes, without causing excessive control traffic overhead or computational burden on the power constrained devices. A large number of solutions have already been proposed. Ad hoc routing protocols are categorized into three groups: proactive, reactive and hybrid routing.

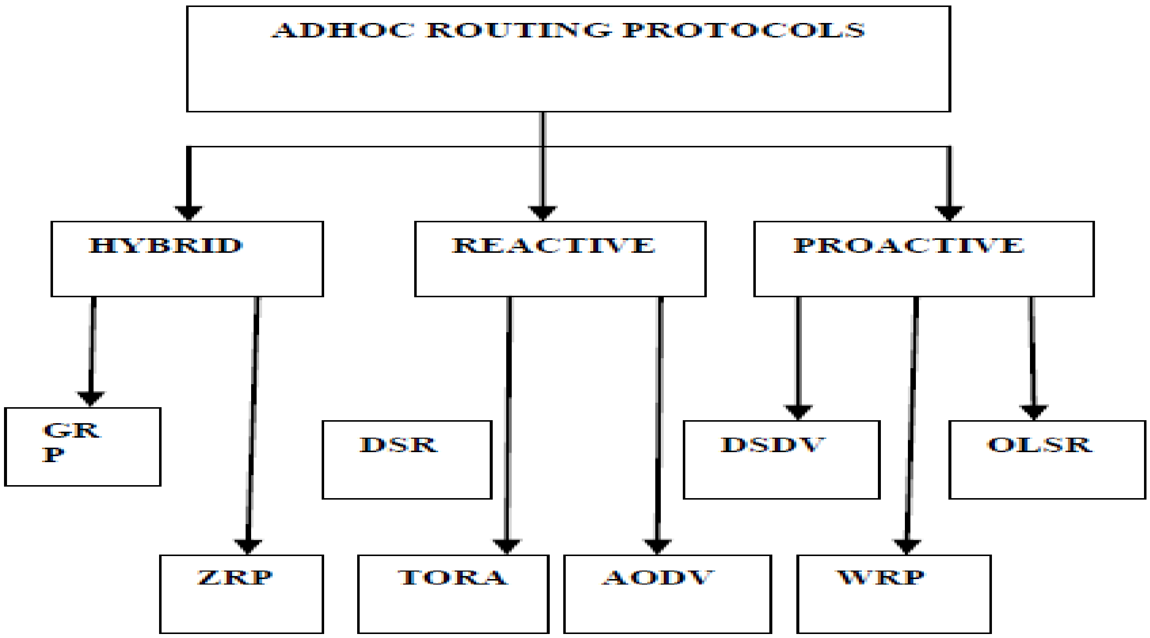

Figure 2.4Categories of MANET routing protocol [2]

2.5.1 Proactive Routing Protocol:

The proactive protocol is also known as table driven routing protocol. These protocols are mostly based on shortest path algorithms. The proactive protocols do not have initial route discovery delay but consumes lot of bandwidth for periodic updates of topology. The proactive protocols are appropriate for supporting minimum number of mobile nodes in networks, since they need to update node routing table for any change occur in topology, at this time to creates additional routing overhead [37].There are several routing protocols that fall under this category [12],[38].

A. Destination Sequenced Distance Vector (DSDV)

DSDV is a table-driven proactive routing protocol, which is based upon Bellman-Ford routing algorithm [12], [13], [14]. The improvements made to the Bellman-Ford algorithm include freedom from loops in routing tables. Each node in the network maintains a routing table in which all the possible combinations of destinations, number of routing hops are recorded. Thus routing information is already available, regardless of whether the source node requires a route or not. Each entry is marked with a sequence number assigned by the destination node. The sequence numbers enable the mobile nodes to distinguish stale routes from new ones, thereby avoiding the formation of routing loops. Routing table updates are periodically transmitted throughout the network in order to maintain table consistency. To help alleviate the potentially large amount of network traffic that such updates can generate, route updates can employ two possible types of packets. The first is known as a full dump. This type of packet carries all available routing information and can require multiple network protocol data units (NPDUs). During periods of occasional movement, these packets are transmitted infrequently. Smaller incremental packets are used to relay only that information which has changed since the last full dump.

Each of these broadcasts should fit into a standard-size NPDU, thereby decreasing the amount of traffic generated. The mobile nodes maintain an additional table where they store the data sent in the incremental routing information packets. New route broadcasts contain the address of the destination, the number of hops to reach the destination, the sequence number of the information received regarding the destination, as well as a new sequence number unique to the broadcast. The route labeled with the most recent sequence number is always used. In the event that two updates have the same sequence number, the route with the smaller metric is used in order to optimize (shorten) the path. Mobiles also keep track of the settling time of routes, or the weighted average time that routes to a destination will fluctuate before the route with the best metric is received. By delaying the broadcast of a routing update by the length of the settling time, mobiles can reduce network traffic and optimize routes by eliminating those broadcasts that would occur if a better route was discovered in the very near future.

In DSDV, updated routing tables are sent periodically throughout the wireless network to maintain the consistency. Due to this a lot of control traffic in the network generate, that is the disadvantage of this protocol.

Advantages of DSDV

- DSDV protocol guarantees loop free paths.
- Count to infinity problem is reduced in DSDV.
- We can avoid extra traffic with incremental updates instead of full dump updates.
- Path Selection: DSDV maintains only the best path instead of maintaining multiple paths to every destination. With this, the amount of space in routing table is reduced.

Limitations of DSDV

- Wastage of bandwidth due to unnecessary advertising of routing information even if there is no change in the network topology.

- DSDV doesn’t support Multi path Routing.
- It is difficult to determine a time delay for the advertisement of routes.
- It is difficult to maintain the routing table’s advertisement for larger network. Each and every host in the network should maintain a routing table for advertising. But for larger network this would lead to overhead, which consumes more bandwidth.

B. Wireless Routing Protocol (WRP)

The WRP protocol is a proactive routing protocol. It broadcast the update only when changes occur in the network topology, also instead of broadcasting the whole table, it broadcast the changes in the table [38]. In WRP, the source node doesn’t need to make a special request for a route like in reactive routing protocols as all the routes are maintained all the time.

All nodes in a network maintain information in the form of tables for each destination. Distance table, contains entries about the destination, next hope, distance and the predecessor of each destination. For routing the Routing table contains all the activities as in the distance table with the addition of the marker entry. The marker entry serves as a tag to identify whether the link is single path, loop or invalid. For link information Link cost table contains cost of the link to every node and for information transmission Message retransmission list contains information about the neighbor who has not acknowledge its update message and retransmit the update again.

WRP belongs to path finding algorithms and the main problem in these algorithms are that they create temporary routing loops at the time of verifying there predecessor information. But WRP give advantage over these path finding algorithms by not creating temporary routing loops, when verifying predecessor information. But on the other hand it maintain four tables for routing information that’s why it has a higher memory requirement than any other in table-driven routing protocols also it uses Hello messages which consume bandwidth and energy.

C. Global State Routing (GSR)

Similar to DSDV, Global State Routing (GSR) takes the idea of link state routing protocol. But this protocol reduces the flooding in order to improve routing messages. The algorithm of this protocol enables each to maintain the neighbor list, a next hop table, a topology table, and a distance table. For each destination node, the link state information is maintained in the topology table together with the timestamp of the information. The table of next hop contains the next hop through which the packets for destination node must be forwarded. The distance table contains the shortest distance to each destination node and the routing messages are generated on a link change. The node updates its topology table when it receives a routing control message. This protocol reconstructs its routing table and broadcasts the information to its neighbor nodes if the sequence number stored in the table is older than the sequence number of the control message

2.5.2 Reactive protocol

The Reactive protocols [12], [37] are also called on-demand routing protocols. These protocols employ a lazy approach whereby mobile devices only discover routes to destinations on-demand. The routing table is periodically updated, when some data is there to send. Thus these protocols maintain only the routes that are currently in use, as a result it is reducing the burden on the network when only a few of all vacant routes is in use at any time. For initial route discovery this protocol use flooding process, which causes routing overhead, delay and make it unsuitable for use in some applications. Another disadvantage is that, although route maintenance is limited to the routes currently in use, it may still generate a significant amount of network traffic when the network topology changes frequently. Finally, packets transmitted to the destination are likely to be lost if the route to the destination changes. Below, two of the reactive routing protocols are explained.

A. Dynamic Source Routing Protocol (DSR)

DSR is an on-demand source routing protocol. It allows source nodes to dynamically discover the paths towards any desired destination [12], [13], [15]. The DSR has two functions in routing: route discovery and route maintenance. Each node maintains aroute cache where it lists the complete routes to all destinations for which the routes are known. A source node includes the route to be followed by a data packet in its header. Routes are discovered on demand by a process known as route discovery. When a node does not have a route cache entry for the destination to which it needs to send a data packet, it initiates a route discovery by broadcasting a route REQUEST or QUERY message seeking a route to the destination. The REQUEST packet contains the identities of the source and the desired destination. Any node that receives a

REQUEST packet first checks its route cache for an existing entry to the desired destination. If it does not have such an entry, the node adds its identity to the header of the REQUEST packet and transmits it. Eventually, the REQUEST packet will flood the entire network by traversing to all the nodes tracing all possible paths. When a REQUEST packet reaches the destination, or a node that has a known route to the destination, a REPLY is sent back to the source following the same route that was traversed by that REQUEST packet in the reverse direction. This is done by simply copying the sequence of node identities obtained from the header of REQUEST packet. The REPLY packet contains the entire route to the destination, which is recorded in the source node's route cache. When an existing route breaks, it is detected by the failure of forwarding data packets on the route. Such a failure is observed by the absence of the link layer acknowledgement expected by the node where the link failure has occurred. On detecting the link failure, the node sends back an ERROR packet to the source. All nodes that receive the ERROR packet, including the source, delete all existing routes from their route caches that contain the specified link. If a route is still needed, a fresh route discovery is initiated.

This protocol makes the routing overhead traffic scales to the actual needed size automatically, which is the main advantages of DSR. On the other hand this employs the source routing, so that each data packet contains the full path it should traverse to its destination. Sometimes source routing becomes the disadvantage of DSR.

B. On-Demand Distance-Vector Routing Protocol (AODV)

AODV is pure on-demand reactive Routing Protocol, which is an extension of DSDV (Destination Sequenced Distance Vector) routing protocol in the direction of on-demand behavior. The key feature of this is that applying a distributed routing scheme. In AODV, route discovery packets are initiated and broadcasted only when a source desires to contact an intended destination for which it does not have a valid route. Furthermore, changes in network topology must be sent only to those nodes that will need this information.AODV has no work when the connection between the endpoints is reliable. The node uses a broadcast RREQs to find a route to the destination when there is a need.

To initiate the route discovery, the source floods the network with an RREQ (route request) packet to the destination node for which the route is requested. After an intermediate node receives the RREQ, it checks to see whether it is destination or whether it has a route to the destination. If node is destination or has path to destination, it generates the RREP (Route Reply) packet to the source node in the reverse path, otherwise it rebroadcasts the RREQ packet for its neighbors. When a node detects the broken line, it generates the RRER (Route Request Error) packets and initiates the new route discovery process. Thus AODV dynamically establishes the route in the network [13]. The key steps of the algorithm used by AODV for establishment of unicast routes are explained below [16], [17], and [35].

I. Route Discovery

When a node wants to send a data packet to a destination node, the entries in route table are checked to ensure whether there is a current route to that destination node or not. If it is there, the data packet is forwarded to the appropriate next hop toward the destination. If it is not there, the route discovery process is initiated. AODV initiates a route discovery process using Route Request (RREQ) and Route Reply (RREP). The source node will create a RREQ packet containing its IP address, its current sequence number, the destination's IP address, the destination's last sequence number and broadcast ID. The broadcast ID is incremented each time the source node initiates RREQ. Basically, the sequence numbers are used to determine the timeliness of each data packet and the broadcast ID & the IP address together form a unique identifier for RREQ so as to uniquely identify each request. The requests are sent using RREQ message and the information in connection with creation of a route is sent back in RREP message. The source node broadcasts the RREQ packet to its neighbors and then sets a timer to wait for a reply. To process the RREQ, the node sets up a reverse route entry for the source node in its route table. This helps to know how to forward a RREP to the source. Basically a lifetime is associated with the reverse route entry and if this entry is not used within this lifetime, the route information is deleted. If the RREQ is lost during transmission, the source node is allowed to broadcast again using route discovery mechanism.

(a) **(b)**

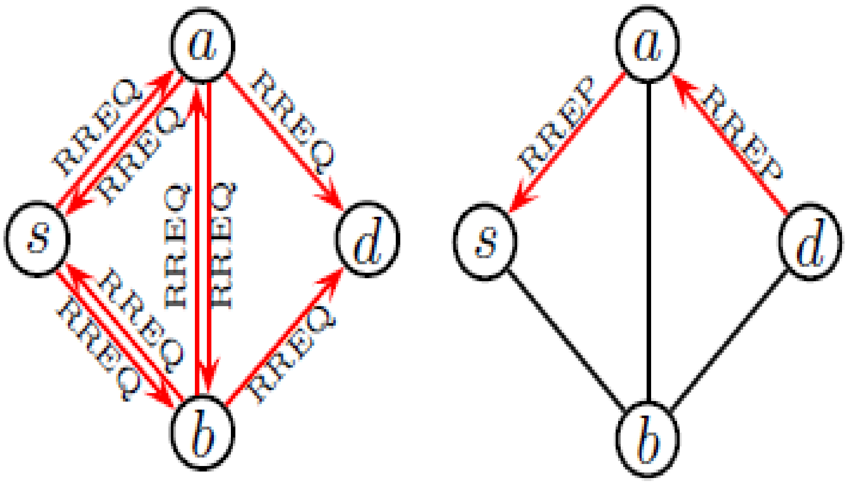

Figure 2.5(a) RREQ and (b) RREP packet exchange for AODV [31]

II. Expanding Ring Search Technique

The source node broadcasts the RREQ packet to its neighbors which in turn forwards the same to their neighbors and so forth. Especially, in case of large network, there is a need to control network-wide broadcasts of RREQ and to control the same; the source node uses an expandingring search technique. In this technique, the source node sets the Time to Live (TTL) value of the RREQ to an initial start value. If there is no reply within the discovery period, the next RREQ is broadcasted with a TTL value increased by an increment value. The process of incrementing TTL value continues until a threshold value is reached, after which the RREQ is broadcasted across the entire network.

III. Setting up of Reverse and Forward Path

There are two sequence numbers in addition to the broadcast id included in a RREQ the source sequence number and the last destination sequence number known to the source. The source sequence number is used to maintain freshness information about the reverse route to the source and the destination sequence number specifies how fresh a route to the destination must be before it can be accepted by the source. As the RREQ travels from a source to various destinations it automatically sets up the reverse path from all nodes back to the source. To setup a reverse path a node records the address of the neighbor from which it received the copy of the

RREQ. These reverse path route entries are maintained for at least enough time for the RREQ to traverse the network and produce a reply to the sender.

In forward path setup,eventually a RREQ will arrive at a node possibly the destination itself that possesses a current route to the destination. The receiving node first checks that the RREQ was received over a bidirectional link. If an intermediate node has a route entry for the desired destination it determines whether the route is current by comparing the destination sequence number in its own route entry to the destination sequence number in the RREQ. If the RREQs sequence number for the destination is greater than that recorded by the intermediate node the intermediate node must not use its recorded route to respond to the RREQ. Instead the intermediate node rebroadcasts the RREQ.When the destination node or an intermediate node with a route to the destination receives the RREQ, it creates the RREP and unicast the same towards the source node using the node from which it received the RREQ as the next hop. When RREP is routed back along the reverse path and received by an intermediate node, it sets up a forward path entry to the destination in its routing table. When the RREP reaches the source node, it means a route from source to the destination has been established and the source node can begin the data transmission.

(a) (b)

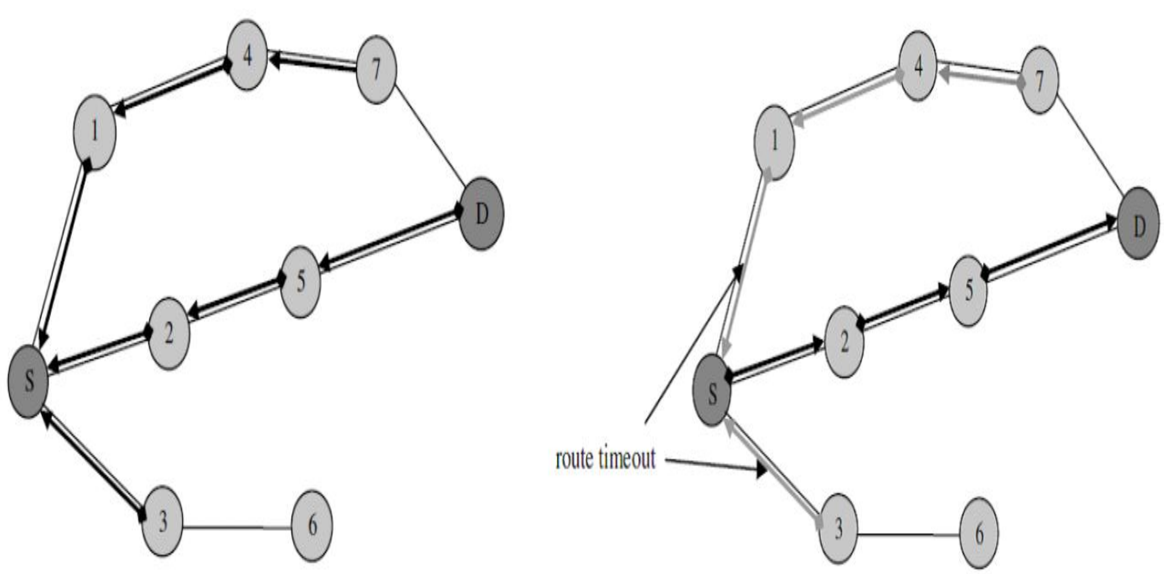

Figure 2.6 (a) Reverse and (b) Forward path setup in AODV [28]

The intermediate node can reply only when it has a route with a sequence number, sequence number that is greater than or equal to that contained in the RREQ. If it does have a current route to the destination and if the RREQ has not been processed previously the node then unicasts a route reply packet RREP back to its neighbor from which it received the RREQ. A RREP contains the following information source addr, destaddr, dest sequence, hop count and lifetime. By the time a broadcast packet arrives at a node that can supply a route to the destination a reverse path has been established to the source of the RREQ packet. As the RREP travels back to the source each node, along the path sets up a forward pointer to the node from which the RREP came, updates its timeout information for route tries to the source and destination records the latest destination sequence number for the requested destination. RREP will timeout after ACTIVE ROUTE TIMEOUT msec and will delete the reverse pointer A node receiving an RREP propagates the first RREP for a given source node towards that source if it receives further RREPs it updates its routing information and propagates the RREP only if the RREP.

IV. Route Maintenance

A route discovered between a source node and destination node is maintained as long as needed by the source node. Since there is movement of nodes in MANET and if the source node moves during an active session, it can re-initiate route discovery mechanism to establish a new route to destination. Conversely, if the destination node or some intermediate node moves, the node upstream of the break initiates Route Error (RERR) message to the affected active upstream neighbors or nodes. Consequently, these nodes propagate the RERR to their predecessor nodes. This process continues until the source node is reached. When RERR is received by the source node, it can either stop sending the data or re-initiate the route discovery mechanism by sending a new RREQ message if the route is still required.

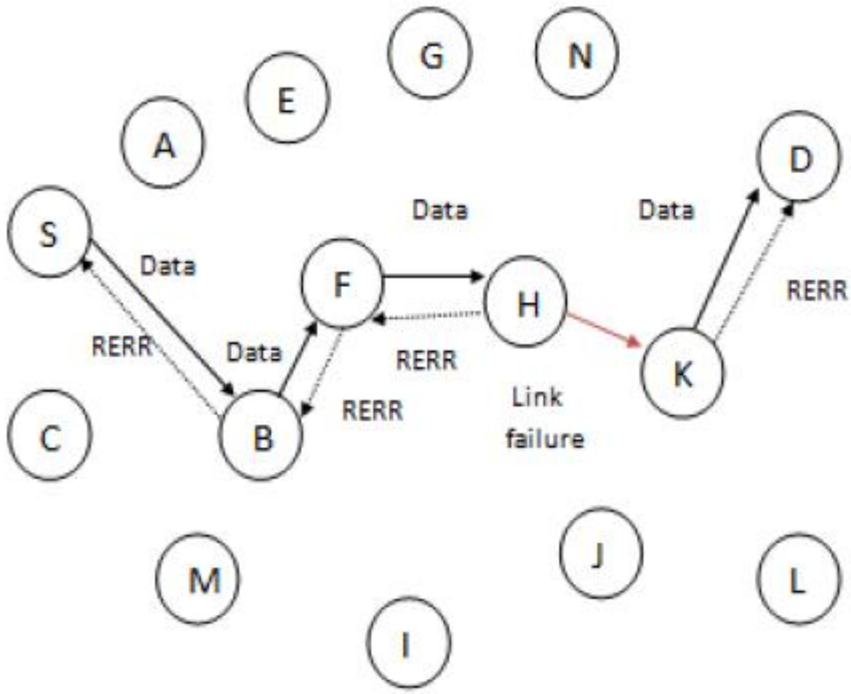

Figure 2.7Initiation of RERR packets in AODV [33]

Link failures could be detected by using link layer acknowledgments LACKS. A link failure is also indicated if attempts to forward a packet to the next hop fail. Once the next hop becomes unreachable the node upstream of the break propagates an unsolicited RREP with a fresh sequence number a sequence number that is one greater than the previously known sequence number and hop count of all active upstream neighbors. Those nodes subsequently relay that message to their active neighbors and so on. This process continues until all active source nodes receive it. It terminates because AODV maintains only loop free routes and there is only active number of nodes in the ad hoc network. Upon receiving notification of a broken link source nodes can restart the discovery process if they still require a route to the destination. To determine whether a route is still needed a node may check whether the route has been used recently as well as inspect upper level protocol control blocks to see whether connections remain open using the indicated destination. If the source node or any other node along the previous route decides it would like to route to the destination it sends out an RREQ with a destination sequence number of one greater than the previously known sequence number to ensure that it builds a new viable route and that no nodes reply if they still regard the previous route as valid.

V. Local Connectivity Management

Nodes learn of their neighbors in one of two ways, whenever a node receives a broadcast from a neighbor it updates its local connectivity information to ensure that it includes this neighbor. In the event that a node has not sent any packets to all of its active downstream neighbors within hello interval it broadcasts to its neighbors a *hello* message, a special unsolicited RREP containing its identity and sequence number. The nodes sequence number is not changed for hello messages transmissions. This hello message is prevented from being rebroadcast outside the neighborhood of the node because it contains a time to live TTL value of 0.

Neighbors that receive this packet update their local connectivity information to the node receiving a broadcast or a hello form a new neighbor or failing to receive allowed hello loss consecutive hello messages from a node previously in the neighborhood is an indication that the local connectivity has changed. Failing to receive hello messages from inactive neighbors does not trigger any protocol action.

If the message “hello” is not received from the next hop along an active path the active neighbors using that next hop are sent notification of link failure. The local connectivity management with hello messages can also be used to ensure that only nodes with bidirectional connectivity are considered to be neighbors for this purpose. Each hello sent by a node lists the nodes from which it has heard. Each node checks to make sure that it uses only routes to neighbors that have heard the nodes hello message.

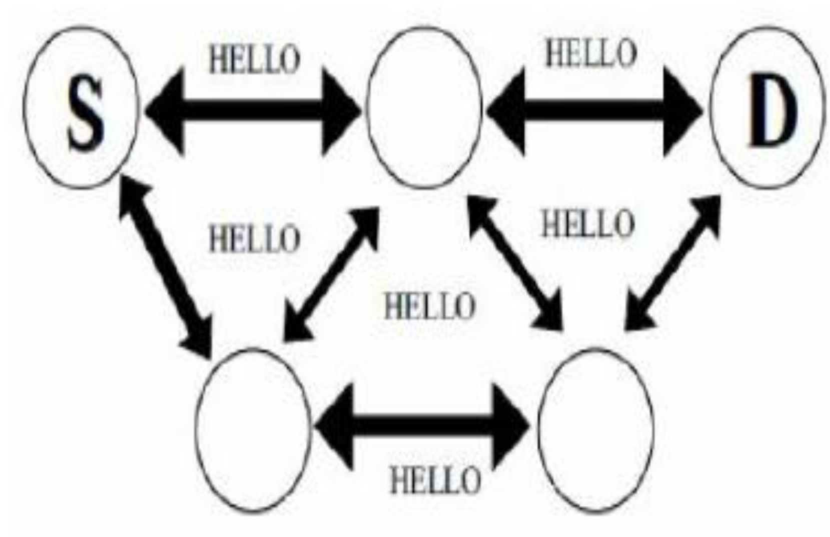

Figure 2.8Hello packet exchange in AODV [41]

As mentioned earlier AODV routing protocol makes use of Hello Messages for local Link connectivity. Every node in a network broadcasts hello messages to all its neighbors at a default hello interval of 1 second [41], [42], and [43]. In this way nodes are informed if there is a link failure by their neighbors.

VI. Benefits and Limitations of AODV

. AODV does not put any additional overheads on data packets as it does not make use of source routing. The benefits of AODV protocol are that it favors the least congested route instead of the shortest route and it also supports both unicast and multicast packet transmissions even for nodes in constant movement. It also responds very quickly to the topological changes that affects the active routes

The limitation of AODV protocol is that it expects or requires that the nodes in the broadcast medium can detect each other’s broadcasts. It is also possible that a valid route is expired and the determination of a reasonable expiry time is difficult. The reason behind this is that the nodes are mobile and their sending rates may differ widely and can change dynamically from node to node. In addition, as the size of network grows, various performance metrics begin decreasing. AODV is vulnerable to various kinds of attacks as it is based on the assumption that all nodes must cooperate and without their cooperation no route can be established.

VII. Why AODV?

AODV is one of the most popular routing protocols, which is a simple and efficient on-demand MANET routing protocol [36]. The concepts of AODV that makes it desirable for MANETs with limited bandwidth include the following:

1. *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.

2. *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 updates their routing tables also make sure of maximum utilization of the bandwidth. Since, these routing tables will repeatedly be used if that intermediate node receives any RREQ from another source for the 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.

3. *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.

4. *Most effective routing information*: After propagating a RREP message, if a node receives RREP with smaller hop-count, it updates its routing information with this better path and propagates it.

5. *Most current routing information*: The route information is obtained on demand. Also, after propagating an RREP, if a node receives RREP with greater destination sequence number, it updates its routing information with this latest path and propagates it.

6. *Loop-free routes*: The algorithm maintains loop-free routes by using the simple logic of nodes discarding the packets for same broadcast-id.

7. *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 message. And the source node re-initializes the path discovery if it still desires the route. This ensures quick response to broken links.

8. *Highly Scalable*: The algorithm is highly scalable because of the minimum space complexity and broadcasts avoided.

2.5.3 Hybrid Routing Protocols

The hybrid ones are adaptive [39], and also the combination of two protocols which are reactive and proactive protocols. Reactive protocols are not sensitive to delay and work for network with any movement. While, proactive protocols came with a small delay. From many research it is found that there are still no best routing protocols for all kinds of Mobile ad hoc networks. There are all routing protocols have its own different advantages and capabilities to do work but some specific environments which create a problem because all nodes of networks should be able to work in every environment of the network not for specific. So there are lots of challenges occurs that how can get high performance in every environment. In present many researchers have proposed many hybrid protocols like Zone Routing Protocol (ZRP) and Distributed Spanning Tree based routing protocol (DST)**.**

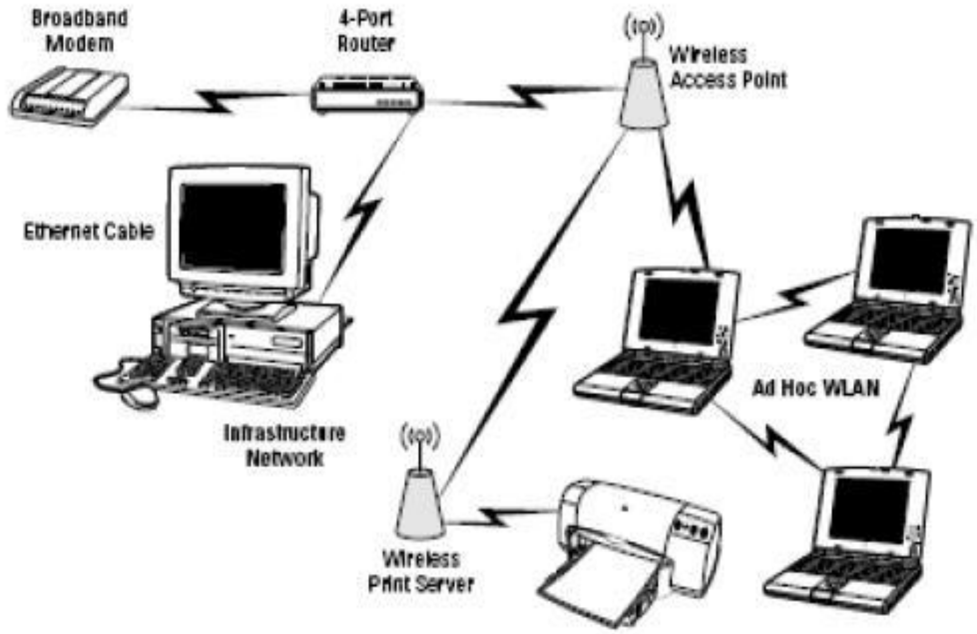

Figure 2.9Hybrid Network

A. Zone Routing Protocol (ZRP)

ZRP [19] is a hybrid routing class for mobile ad hoc Networks which restricts the nodes into sub-networks (zones). It includes the qualities of on-demand and proactive routing class. Within every zone, proactive Networks which restricts the nodes into sub-networks (zones). It incorporates the qualities of on- demand and proactive routing protocols. Within each zone, proactive routing class is modified to speed up communication surrounded by neighbors. The inter-zone contact uses on- demand routing classes to reduce unnecessary communication. The network is separated into routing zones according to detachment between mobile nodes. Specified a hop distance d and a node N, all nodes within communication hop distance at most d from N fit into the routing zone of N. Peripheral nodes of N are Ns neighboring nodes in its routing zone which are accurately d hops away from N. A significant issue of zone routing is to resolve the size of the zone. A better zone routing protocol, Independent Zone Routing (IZR), which permits adaptive and stretch reconfiguration of the reduced size of the zone, is introduced in [20]. Besides, the adaptive nature of the IZR class enhances the scalability of the ad hoc network. Each node rarely wants to update the routing information surrounded by the zone. Additionally, some limited route optimization is performed at each node, which includes the following actions: removal of unneeded routes, shortening of routes, spotted of link failures.

B. Distributed spanning trees based routing protocol (DST)

In DST [18], the nodes in the network are grouped into a number of trees. Each tree has two types of nodes; route node, and internal node. The root controls the structure of the tree and whether the tree can merge with another tree, and the rest of the nodes within each tree are the regular nodes. In order to determine a route, DST protocol proposes two different routing approaches. Those are distributed spanning tree shuttling (DST) and hybrid tree-flooding (HFT). Control packets are sent to all the neighbors in HTF and adjoining bridges in the spanning tree, where each packet is held for a period of time called holding time. In DST, the control messages disseminated from the source are rebroadcasted along the tree edges. When a control reaches down to a leaf node, it is sent up the tree until it reaches a certain height referred to as the shuttling level. The advantages of the DST based routing protocol algorithm is that, it creates a single point of failure because it depends on the root node to configure the tree.

2.5.4 Properties of MANET Routing Protocols

Ad hoc routing protocols may consist of many properties [40] and some of the common properties of mobile ad-hoc routing protocols are:

I. *Distributed Operation*: In mobile ad-hoc network, routing protocol should not be depending on a central administration which means the protocol should be distributed.

II. *Loop Free*: In order to avoid the wastages of resources such as energy and bandwidth, routing protocol the ad hoc should establish the loop free paths which improve the overall performance of the networks.

III. *Unidirectional Link Support*: For MANET routing protocols, uni-directional paths are favorable that can handle a situation where two unidirectional links form the only bidirectional connection between the nodes.

IV. *On-Demand Based Operation*: In order to minimize the control overhead in the network and to provide the better utilization of network, the ad hoc network routing protocols should be reactive.

V. *Sleep period operation*: Since ad hoc networks nodes may have energy constraints, nodes may want to stop transmitting and/or receiving the packet for arbitrary time period.

2.6 RREQ Packet forwarding in MANET

In MANET the exchange of packets, especially control packets, takes place between every node within the same transmission range [17], [32], whether it is required by a node or not. That means nodes within the same transmission range receive a control packet broadcasts whether they have path to destination or not.

One of the challenging issues here is to reduce flooding in the path discovery and maintenance since wireless bandwidth is limited. On-demand routing protocol broadcast or floods control packets to the network, to establish routes to destination nodes [33]. AODV is one of the on-demand routing protocol in MANET. There are different types of packets that are used to perform tasks like route discovery, route maintenance and manage local connectivity. These packets are called control packets. RREQ, RREP and RERR are the control packets used in AODV.

In case of high mobility and high load networks formed by many mobile nodes, a high number of broadcast control packets are generated, thereby causing collision, contention. Thissituation results wastage of bandwidth for mobile nodes in the network. Moreover, most of the routing protocols rediscover the path on link failure which adds on to the network congestion and contention. In such environment, many nodes participate in route discoveries and rediscoveries and hence a high number of control packets are generated which eventually causes contention that blocks the data transmission. Furthermore, intermediate nodes suffer from battery power depletion as it transmits the redundant control packets i.e. RREQ packets. When the mobility and density of the network is sufficiently high, most of them may not perform well [22]. The following figure depicts the flooding of RREQ packets throughout a network in AODV routing protocol.

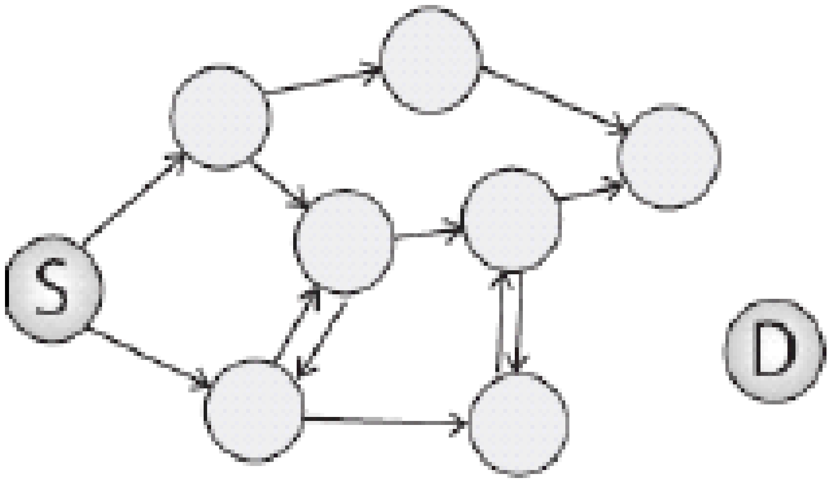

Figure 2.10Network Flood of RREQ packets in AODV [28]

Thereforean efficient way of control packet (RREQ packet) forwarding mechanism need to be developed during route discovery phase to improve the performance of routing protocols by considering this drawback. Many works have been done to reduce this problem, and it is still a research area that needs to be given emphasis.

3 Chapter Three: Related Work

Recently, the issue of reducing the routing overhead associated with route discovery and maintenance in on demand routing protocols has attracted increasing attention. This helps to improve the performance of the network.

As it is discussed in the previous chapters, MANET is a type of network which has no fixed infrastructure i.e. there is no central base station which controls the devices in the network. As a result devices are free to move in any direction to join or leave the network. Due to the infra-structure less nature of the network nodes have limited battery power, bandwidth and other important resources. Thus to optimize the performance of the network, designing efficient routing protocol is important. In route discovery phase the dissemination of RREQ packets plays a vital role to improve performance of the routing protocol. When using blind flooding of RREQ packets, redundant and unnecessary RREQ packets will be exchanged in the network which creates overhead. This overhead causes inefficient utilization of bandwidth. To reduce this problemseveral works have been proposed for MANET Routing protocols and improve the performance of routingprotocols. This is done by using different ways to broadcast RREQ packets. Some of the works which are done on AODV routing protocol are presented below.

Gaurav Sharma et al,[23] modified AODV routing algorithm to obtain a better performance. This algorithm applies two changes to route discovery process of original AODV.

The first change is the use of location information in route discovery process to restrict the broadcast of RREQ packets in the direction of sink. As the location of Sink is already known to all nodes, all the nodes which lie away from sink nodes, compared to sender node do not broadcast the RREQ packet thus limiting the number of broadcast queries. For this, an extra parameter in RREQ packet called distance_val is used. This distance_val is sent with RREQ packet which is the scaled value computed from distance of sender to sink and a dist_factor which maintains a fixed value to increase or decrease distance based on network characteristics.

The second change is that, a busyness_factor and busyness_threshold values have been used to check busyness of nodes. Busyness of a node is defined as the total packets in queue of a node divided by total limit of packet queue in node. This helps in reducing the packet drop rate as well as reducing the number of RREQ request packets. Any node receiving this RREQ packet check its packet queue and decides whether it has to forward /process RREQ packet or discard it, on the basis of the busyness threshold value. In this way, already busy nodes ignore the RREQ and do not participate in route discovery procedure, which otherwise could result in packet drops increasing the packet drop rate and affecting delivery ratio. Both busyness_th and scalability_factor depends on size and characteristics of the network. Busyness_th depends on network load and scalability_factor depends on size of network. However, unlike scalability_factor, busyness_th can be modified frequently based on needs of network. For this purpose separate broadcast control packets can be used. These values can also be predefined in the nodes.

In this work using additional control packets to be broadcasted to check and modify the busyness of nodes creates additional overhead in the network, which decreases performance. Besides, considering node degree helps to cover more nodes in single broadcasting of RREQ packet and minimizes redundant and unnecessary sending of RREQ packet.

Mahesh Kumar Yadavet al, [24] proposed novel approach of dynamically adjusted flooding for AODV to yield higher performance in term of reachability and save rebroadcast. This work contributes to minimize the Broadcast storm problem and a new approach is proposed which is A novel probabilistic approaches based on distance based selective flooding. In Distance based probabilistic broadcasting approach the distance of a node is used to estimate forwarding probability and adjust the rebroadcast probability. According to this work if a mobile node is located in the area closer to sender, its rebroadcast probability will be set lower. On the other hand, if a mobile node is located in the area far from sender, its rebroadcast probability will be set higher, because rebroadcast through this node can cover much extra area. The distance between sender and receiver can be estimated by signal strength or global positional system. The proposed schemes keep up the reachability of blind flooding while maintaining the simplicity of probability based schemes. When comparing this work with the original AODV routing protocol Simulation results show that the approaches can improve the average performance of broadcasting in various network scenarios.

The rebroadcast probability should be set differently for one node to another in order to alleviate the number of rebroadcasting RREQ control packets and increase the efficiency of the network. Upon the selection of the value of forwarding P, the algorithm generates a random number between the interval [0, 1], compares it with the value of P, and decides to rebroadcast or drop the RREQ packet

This work has its own advantages but it selects an intermediate node to forward RREQ packet based on the closeness of nodes to sender. According to this work, the node that is close to the sender is given less probabilityto rebroadcasting RREQ packet and those nodes which are far from sender is given higher probability of rebroadcasting RREQ packet. But the closer nodes can have much more neighbors to be covered than those located far. This creates a situation for more nodes to rebroadcast RREQ packets. Thus considering node connectivitycontributes for the minimization of RREQ packet dissemination.

David Espes et al, [25] proposed AODV based routing algorithm that reduces control packets by using a backbone network. In the proposed algorithm the area (zone) is reduced during RREQ broadcast decreases the number of control packets and prevents some nodes from hearing the request. The destination location is given by GPS and transmitted to the source by the backbone network. This routing algorithm limits the route search to zones smaller than those used by the original AODV protocol, thus reducing the number of control packets.

The algorithm consists of two routing levels: one to find destination locations and another to select routes. As mentioned in the paper, “location routes” is used to talk about routes composed of backbone nodes and used to find node locations, and “data routes” is used to talk about regular routes used to exchange data between mobile nodes. Data routes are determined and maintained by AODV protocol. The network considered is composed of BN (Backbone nodes) and regular nodes. The numbers of broadcast control packets are limited to save the ad hoc network bandwidth. To limit the zone where data route creation packets are transmitted, nodes have to know the destination location. However, it is important that finding the destination location should not increase the number of control packets. In fact, the network structure used by this protocol is a mobile backbone network. Two frequencies are used by the backbone network to send packets. The first is used by the backbone nodes and the other by the regular nodes.

Consequently, when nodes find the destination location, they use the backbone network. Indeed, the use of the backbone network avoids disturbing the regular nodes. Each backbone node knows the list of nodes which are associated with it.

When a node receives a data route creation request, it buffers this request. To find a destination location, the algorithm principle is simple. When a source needs a destination location, it broadcasts a request on the backbone network. When a backbone node finds the destination in its list of associated nodes, it asks the destination to send its location to the source. In the network, two source and destination types exist: backbone nodes and regular nodes. Procedures are different according to the source and destination type.

When a source, which is a regular node, needs the location of a destination, it sends a Location Request (LReq) to its backbone node. When a source, which is a backbone node, needs the location of a destination, it directly broadcasts aLReq packet on the backbone network.

In this work even if the area (zone) is minimized to reduce the RREQ packet broadcasting, the localization phase adds some overhead to the traditional AODV route selection, and the use of GPS is required to locate the destination in the network, which is expensive.

Zygmunt J. Haas et al, [27] proposed a gossiping-based approach, where each node forwards a message with some probability, to reduce the overhead of the routing protocols. Gossiping exhibits bimodal behavior in sufficiently large networks: in some executions, the gossip dies out quickly and hardly any node gets the message; in the remaining executions, a substantial fraction of the nodes gets the message. The fraction of executions in which most nodes get the message depends on the gossiping probability and the topology of the network. In the networks that are considered in this work, using gossiping probability between 0.6 and 0.8 suffices to ensure that almost every node gets the message in almost every execution. For large networks, this simple gossiping protocol uses up to 35% fewer messages than flooding, with improved performance.

This basic gossiping protocol is simple. A source sends the route request with probability 1. When a node first receives a route request, with probability p it broadcasts the request to its neighbors and with probability 1 − p it discards the request; if the node receives the same route request again, it is discarded. Thus, a node broadcasts a given route request at most once. This simple protocol is called GOSSIP1(p). GOSSIP1 has a slight problem with initial conditions. If the source has relatively few neighbors, there is a chance that none of them will gossip, and the gossip will die. To make sure this does not happen, they gossip with probability 1 for the first khops before continuing to gossip with probability p. This is modified protocol GOSSIP1(p, k).The performance of GOSSIP1(p, k) clearly depends on the choice of p and k. Clearly, GOSSIP1(1,1) is equivalent to flooding.

What happens in general depends in part on the topology of the network (particularly the average degree of the network nodes), the gossip probability p, and the initial conditions (as determined by k). If it's thought gossiping as spreading a disease in an epidemic, this simply says that the likelihood of an epidemic spreading depends in part on how many people each person can infect (the degree), the likelihood of the infection spreading (the gossip probability), and how many people are initially infected.

MueenUddinet al, [28] a protocolcalled Tactical AODV (TAODV) is proposed. It is a modification of the Ad-hoc On-demand Distance Vector (AODV) routing protocol.In the proposed technique, location information is used to determine the proximity of an intermediate router to the destination node. Once determined, if an intermediate node is closer to the destination node than the node that passed the route request packet, forwards the packet to its neighbors. The packet is dropped if the intermediate node is found to be further away.

Route localization technique used in TAODV is an optimization of the flooding technique used by on-demand algorithms. If available, the location information of the destination node is used to determine if an intermediate node (acting as a possible router) should rebroadcast a route request packet. It will only rebroadcast the packet if it is deemed to be closer to the destination than the node from which it received the route request packet. This method aims to prevent route request packets from traversing to unnecessary sections of the network i.e., going to nodes that are not in vicinity of the path between the source and destination pair. Preventing route request packets from reaching such areas will result in a reduced protocol routing overhead.

The dissemination of a node's location data occurs in an on-demand manner. There is no periodic transmission of the location data, thus it is not necessary to change the basic routing mechanism of the protocol to accommodate the route localization algorithm. Other nodes in the network will only know about new nodes whereabouts if they have communicated with it, or acted as a router for any of its routes. The location information of a source and destination node is piggy-backed with each route request and route reply packet respectively. The route localization is implemented in such a way that when the route request is generated for the destination node, the source node inspects its location cache to see if it has a location entry for the destination. This is likely if it has either communicated with the destination previously or acted as router for it. If the location entry is found, the positional information of the destination (its *x* and *y* coordinates) is used to calculate the distance to it. The intermediate node then calculates the distance from the source to the destinationusing its information for the destination and the location information of the source from the route request packet.

Despite the works explained earlier, our proposed approach uses node degree to rebroadcast RREQ packet. When an intermediate node with maximum node degree rebroadcasts a RREQ packet most neighbors will be covered. This prevents other nodes from rebroadcasting the packet redundantly and reduces many number of RREQ packets from being exchanged unnecessarily. Our algorithm uses the hello packetto exchange node degree information with neighbors.

The following table shows the summary of the related works that are explained earlier.

Table 3.1Summary of related works

Author	Title	Method used to rebroadcast RREQ packet
Gaurav Sharma, Manoj Singh, Prashant Sharma	Modifying AODV to Reduce Load in MANETs	1. Use of location information 2. Use of busyness_factor and busyness_threshold
Mahesh Kumar Yadav	Broadcasting in AODV Routing Protocol of MANETs: A NovelApproach	1. Distance between sender and receiver estimated by signal strength or GPS

		2. Probability assigned based on closeness to sender
David Espes and CédricTeyssié	Approach for Reducing Control Packets in AODV-based MANETs	1. Area (zone) reduction during RREQ broadcasting 2. Use of GPS is required
Zygmunt J. Haas and Joseph Y. Halpern Li Li	Gossip-Based Ad Hoc Routing	Gossiping probability between 0.6 and 0.8 is used
MueenUddin and Azizah Abdul Rahman	Improving performance of mobile ad hoc networks using Efficient tactical on demand distance vector (TAODV) routing Algorithm	1. Use of location information to determine the proximity of an intermediate node to the destination node. 2. Intermediate node closer to the destination node forwards the packet to its neighbors

4 Chapter Four: Proposed Solution

MANETs, unlike a conventional networks (infrastructure based networks), disseminate messages in absence infrastructure, i.e., intermediate nodes relay message until message reach destination node [29]. In other words, the absence of dedicated communication infrastructure makes the nodes that constitute MANETs to act as router and host. As a result, the dissemination of messages is significantly affected by node mobility. For instance, nodes leave and join the networks randomly which in turn makes links to appear and disappear spontaneously. Due to this reason, route discovery is a common phenomenon in MANETs. During a route discovery process a significant number of control message, namely, Route Request (RREQ) packets are generated. Its impact on the performance of MANETs' routing protocols becomes high as the number of nodes and their mobility are increased. So, the main goal in MANETs routing protocols is to design routing protocol taking into account the bandwidth constrain and nodes mobility of infrastructure networks.

To handle node mobility, blind flooding based message propagation is an ideal solution for dynamic networks. It is an ideal solution because its convergence is fast (i.e., high reachability). In blind flooding nodes that receive control message (RREQ) simply rebroadcast it with no father processing. Since blind flooding technique allows nodes to rebroadcast message (RREQ packets) with no restriction, the number of unnecessary and redundant RREQ packets especially in large size networks consumes high bandwidth which can't be affordable by bandwidth constraint networks. There are several routing protocols proposed so far to optimize blind flooding. One of the protocols designed for this proposes is Adhoc On-demand Distance Vector (AODV). The goal of AODV is to reduce the impact of routing overhead. To achieve the goal, AODV allows nodes to launch route discovery on demand (i.e., the source node launch only when the required route is not available in routing table). Compared to proactive routing protocols (which use blind finding) AODV is able to reduce routing overhead (RREQ packets) generated during route discovery. Generation of RREQ packets on demand makes AODV scalable routing protocol compared to proactive routing protocols. Though AODV generates RREQ packets on demand, still AODV routing protocol uses flooding technique (controlled flooding, i.e., flooding is limited by hop count (timeout)) during route discovery. In other words, the performance of AODV is still affected by the size of the networks, i.e., AODV's scalability issue is manifested as the size of network increase.

This situation is a reason for the further optimization of AODV. In other words, a further reduction of control message (RREQ packets) makes AODV more adaptable to changing topology scenarios. Hence, to optimize AODV by reducing unnecessary and redundant RREQ packets during route discovery, we proposed message dissemination (control message, i.e., RREQ packets) through nodes having maximum node degree in their local topology as described in the following section.

4.1 Overview of the proposed work

The main goal of the proposed work is to improve AODV by integrating non-flooding technique during route discovery. As it is discussed earlier, AODV uses flooding technique, i.e., every node that receives RREQ packet rebroadcast RREQ packet as long as RREQ packet is fresh (i.e., within timeout). But in our work, we design an algorithm that identifies nodes which are responsible to rebroadcast RREQ packets. In other words, our algorithm identifies subset of nodes to rebroadcast RREQ packets. This technique allows the modified AODV to reduce redundant routing overhead compared to AODV. Nodes that are selected to rebroadcast RREQ packets (in the proposed work) are based on their node degree. In each local topology nodes with maximum node degree (i.e., with maximum neighbor nodes) have a capability to disseminate RREQ packets sufficiently than the other nodes. So, to achieve desirable reduction of routing overhead (i.e., without affecting the dissemination of RREQ packets) only nodes with maximum node degree are allowed to participate in the propagation of RREQ packets. This technique significantly reduces routing overhead (which is a required feature in MANETs).

4.2 Improved Ad hoc On demand Distance Vector (IAODV) algorithm

Our non-flooding technique is a simple method in which nodes with maximum number of node degree rebroadcasts a RREQ packet. Under this proposed protocol the dissemination of control packet (RREQ packet) is changed from flooding to non-flooding technique. In this protocol each node that receives RREQ packets will not rebroadcast it further. From nodes within the same transmission range node with maximum node degree is chosen to rebroadcasts it.

Though IAODV uses non-flooding message propagation technique during route discovery, IAODV maintains fresh routes the same way as AODV does.Nodes discover their neighbor node information through the periodic HELLO message [41], [42] and [43]. In the proposed work, the node degree of neighbor nodes is appended in the HELLO packets. In other words, nodes are made to maintain their neighbor nodes node degree in their routing table. Which enable nodes to make a forwarding decision based on node degree. For example, upon receiving RREQ packet a node will not simply rebroadcast it. First it compares its node degree with its neighbor's node degree. If the node degree of the node is maximum then it rebroadcasts the RREQ packet for its neighbors. Otherwise it discards the packet. This technique minimizes the dissemination of redundant and unnecessary RREQ packets.

The main aim of our work is to decrease the overhead that occur during route discovery process by reducing the RREQ messages, which are flooded into the whole network. Our algorithmis given below.

Input:

Intermediate nodes received RREQ read their neighbor nodes node degree(ND) from their routing table (RT).

Output:

Intermediate nodes that received RREQ packets make decision whether to forward or discard the received RREQ packet.

Method:

(1) **each** intermediate node $\mathbf{N_i}$ that received RREQ packet compare its node degree with their neighbor node $\mathbf{N_j}$ node degree in their respective local topology.

Case 1: only $\mathbf{N_i}$node has maximum node degree among its neighbor nodes.

if $\mathbf{N_i}$(node degree) >$\mathbf{N_j}$(node degree)

$\mathbf{N_i}$_withMaximumNodeDegree_forward (RREQ)

$\mathbf{N_j}$_discard (RREQ)

end if

Case 2: some$\mathbf{N_j}$nodes may have equalmaximum node degree compared to node degree of $\mathbf{N_i}$

if $\mathbf{\Sigma N_j}$(node degree) >$\mathbf{N_i}$(node degree)

$\mathbf{\Sigma\ N_j}$_withMaximumNodeDegree_ forward(RREQ)

$\mathbf{N_i}$_discard(RREQ)

end if

Case 3: All$\mathbf{N_j}$nodes may have equalmaximum node degree compared to node degree of $\mathbf{N_i}$

if $\forall$ $\mathbf{N_j}$(node degree) >$\mathbf{N_i}$(node degree)

$\forall$ $\mathbf{N_j}$_withMaximumNodeDegree_ forward(RREQ)

$\mathbf{N_i}$_discard(RREQ)

end if

Figure 4.1Pseudo-code of the proposed route discovery process

As shown in Figure 4.1,IAODV uses non-flooding methods to disseminate RREQ packet during route discovery process.

In other words, unlike AODV, IAODV allows nodes having maximum node degree in their local topology to disseminate RREQ packet during route discovery. For instance, when a source node ***S*** broadcasts RREQ packets, only intermediate nodes with maximum node degree (in their respective local topology) are responsible to rebroadcast the received RREQ packets. To perform this, each node received RREQ packet cross check its node degree against its neighbor node degree in its routing table and the node with maximum node degree forwards the received RREQ packet.

So to achieve this, we modified HELLO packets to hold additional information, namely, node degree. Hence, neighbor nodes exchange their node degree during HELLO packet exchange.

In this work additional tasks are included in the original AODV route discovery phase to achieve the goal. This process takes additional computational time when compared with AODV since the additional tasks are performed before the RREQ is distributed to neighbor nodes. But in case of AODV source simply initiates RREQ packet and flood it to neighbor nodes without any pre condition.

In the given algorithm given above, different cases are discussed. $\mathbf{N_i}$and $\mathbf{N_j}$ are two sets of neighbor nodes and for all the cases given when nodes receive RREQ packet, first they compare their node degree. The first case addresses about only N_i node that has maximum node degree when compared with other $N_j$neighbors. In this case the node (N_i) with maximum node degree forwards the RREQ packet and the others (N_j) nodes discard it. The second case addresses about some nodes (some $N_j$nodes from the local topology) with equal maximum node degree. In this case by comparing N_i and $N_j$neighbor nodes, if some of N_j nodes have equal maximum node degree then they forward the RREQ packet and the others, including N_i nodes, discard the RREQ packet. The last case addresses about all nodes (all $N_j$nodes compared with N_i neighbor nodes) with equal maximum node degree. In this case if all $N_j$nodes have equal maximum node degree when compared with other (N_i) neighbor nodes, then all nodes that have equal node degree forward the RREQ packet and the others (N_i) discard it.

5 Chapter Five: Implementation and Performance Evaluation

This chapter first discusses the performance metrics used to evaluate and compares the performance if IAODV with the original AODV. The performance of IAODV is also evaluated by varying the size of the network (i.e., by varying the number of nodes without varying the size of simulation area).

To simulate and compare our modified routing protocol with the existing one we use a simulation environment because it is difficult to apply this task in a real network.

There are many simulation tools provided for researchers to evaluate their work. Some of the simulators are: NS, OPNET, OMNET++, OPNET, QUALNET, and others [45], [46].

To evaluate the performance of our proposed protocol, we used Network Simulator version 2.35 (NS-2.35). This simulator allows us to observe and measure the performance of the proposed protocol under various conditions.

NS-2 is an event-driven simulation tool that can be used to study the nature of communication networks [47]. It has the following features: it is an open source, Scheduling, routing and congestion control, Wired networks: P2P links, LAN, Wireless networks and Emulation and trace. It is used by many researchers in ad hoc simulation and supports different network components, protocols like TCP, UDP, FTP and traffic sources like CBR etc.

By using NS2 we simulate our improved protocol and the existing one. In order to evaluate the performance of improved IAODV routing protocol, we used constant bit rate traffic (CBR). To simulate a certain network scenario a simulation script is required and it is called Tcl. After writing this script it is saved in .tcl format. A Tcl script is written in NS2 for simulation of network model. When this Tcl script is executed it creates two files trace file and Nam file.

NAM (Network Animator)file extensions of NAM that shows the visualize / animation of the simulated network, whereas ***trace file*** which is found with .tr file extensions, is used to store different events statistics such as each individual packets arrival time, departs or is dropped, information about protocol agent, traffic agent , source and destination nodes address etc. This information then can be used to measure a protocols' performance.

To extract and do the analysis of data from the trace file, different tools are available. Some of the tools are: Awk, Perl, sed and grep [48]. From the ways listed to extract data from a trace file, Awk script is used in this work.

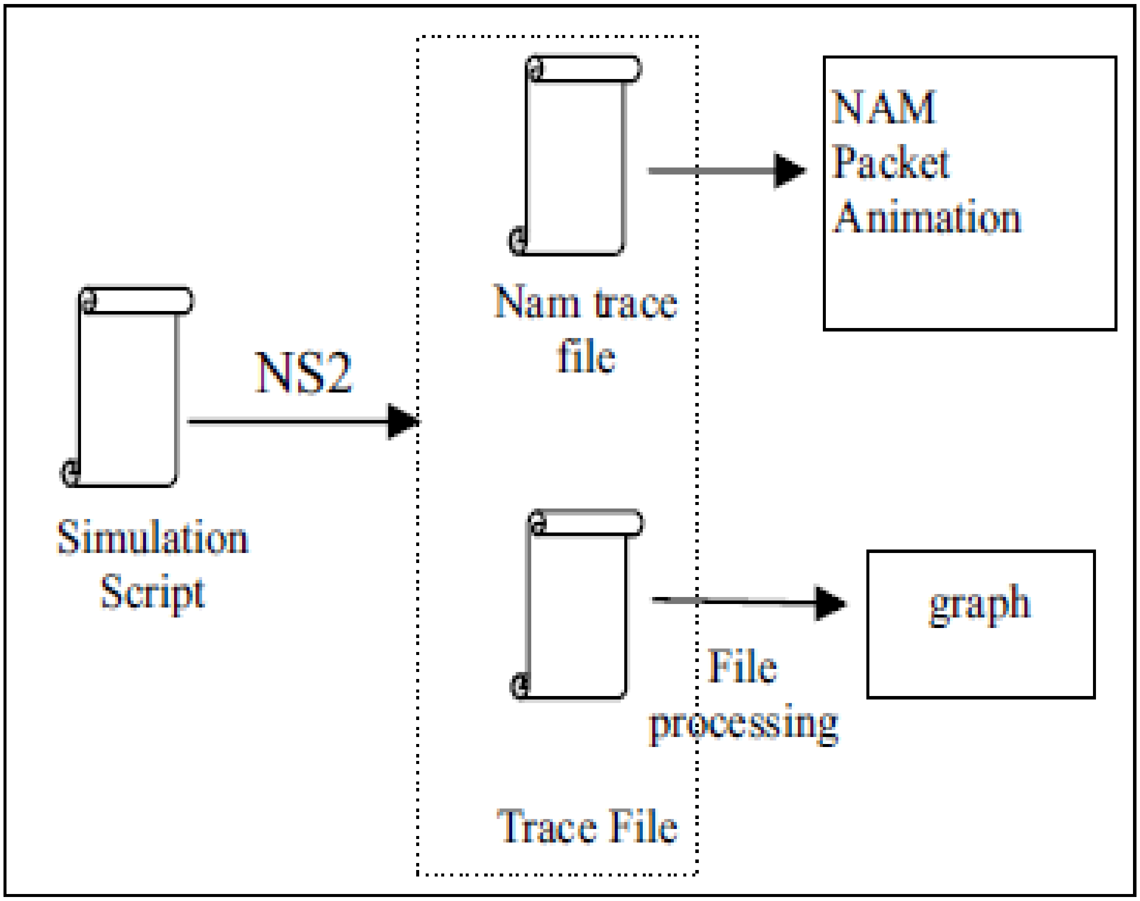

Figure 5.1Simulation process flow for NS2 [49]

5.1 Simulation setup and Assumption

i. Simulation parameters

In the simulation, the Simulation area used in our experiment is 800m by 800m. To test the performance of IAODV in dynamic topology scenarios number of nodes is varying from 20 to 100 and node mobility is also set to 20 m/s. The remaining parameters land their corresponding values are stated in Table 5.1.

Table 5.1General Simulation Parameters for Performance Evaluation

LIST OFPARAMETERS	VALUE
Simulator	NS2
Channel Type	Wireless
Radio-Propagation Model	Two ray ground
Network Interface Type	Phy/Wirelessphy
MAC Type	802_11
Interface Queue Type	Queue/Droptail/Priqueue
Antenna Model	OmniAntenna
Max Packet In Ifq	50
Number Of Nodes	20, 40, 60, 80, 100
Speed	20m/s

ii. Assumption

During our simulation it is assumed that the RREQ packet that is sent by a sender node reaches the intended destination node.

5.2 Evaluation Metrics

The performance of IAOD is evaluated in terms of routing overhead, packet delivery ratio, and end-to-end delay. As discussed earlier, the goal of the proposed work is to come up with bandwidth efficient route discovery technique (i.e., generate less redundant packets). So, to ensure whether the proposed technique is achieved a desirable reduction of routing overhead, we have evaluated the performance of IADOV in terms of packet delivery ratio and end-to-end delay. The three evaluation metrics used for evaluation described as follows:

1. Routing overhead: This is the total number of routing packets divided by total number of delivered data packets. This performance metric is a good indicator whether the proposed work is able to reduce the unnecessary and redundant packets compared to the original AODV.

2. Packet delivery ratio: - is the ratio of the number of packets transmitted by a traffic source and the number of packets received by a traffic sink. It measures the loss rate as

seen by transport protocols and as such it characterizes both the correctness and efficiency of ad hoc routing protocols. This is an indicator whether we are achieved desirable reduction of routing overhead.

3. End-to-end delay: This is the time from the generation of the packet by the sender up to its reception at the destination's application layer and it is measured in seconds. In our case the shortest path may not be selected always as it is the case in the original AODV.

5.3 Simulation result and Analysis

In this section, the simulation result of the proposed work, namely, IAODV is analyzed and discussed. The performance result of IAODV is compared with the performance of original AODV. As mentioned earlier, three performance metrics, namely, routing overhead, packet delivery ratio, and end-to-end delay are used to evaluate the performance of IAODV vs. AODV. Sample Tcl script to create network environment is presented in Appendix A.

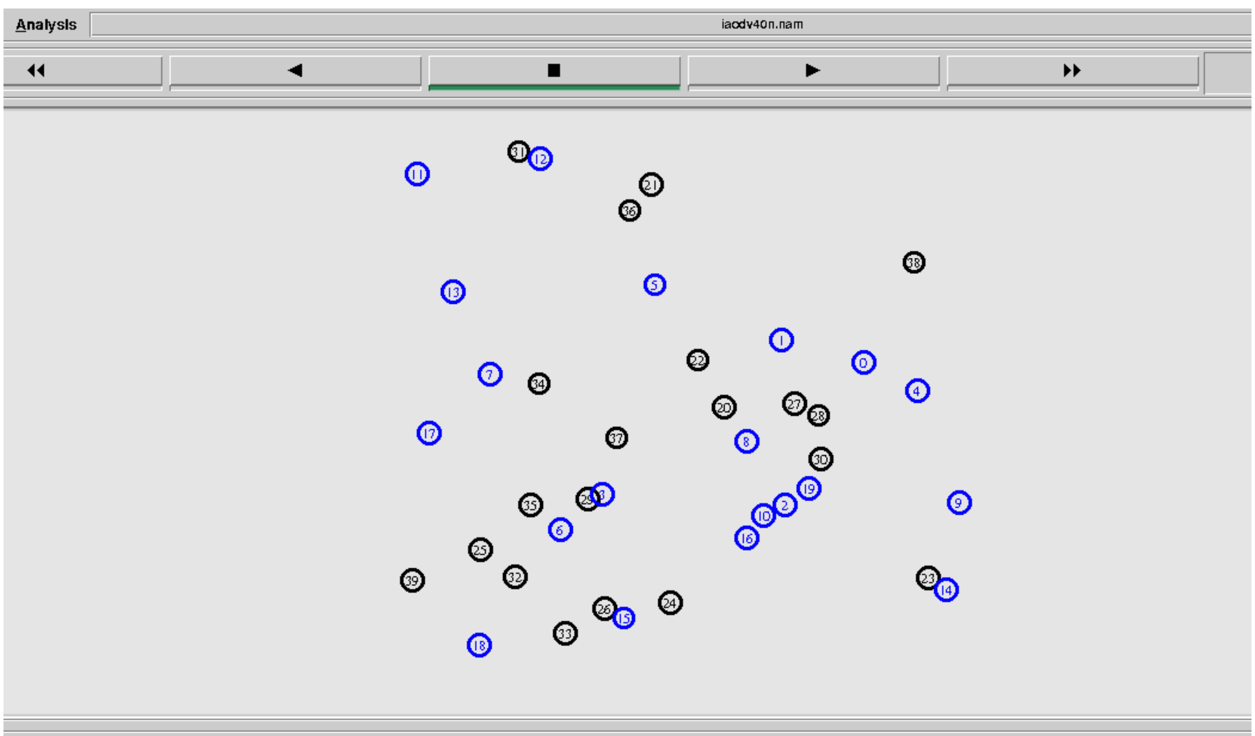

Figure 5.2Simulation scenario Screen shot

5.3.1 Routing overhead

The following graph shows the result of routing overhead for the two routing algorithms.

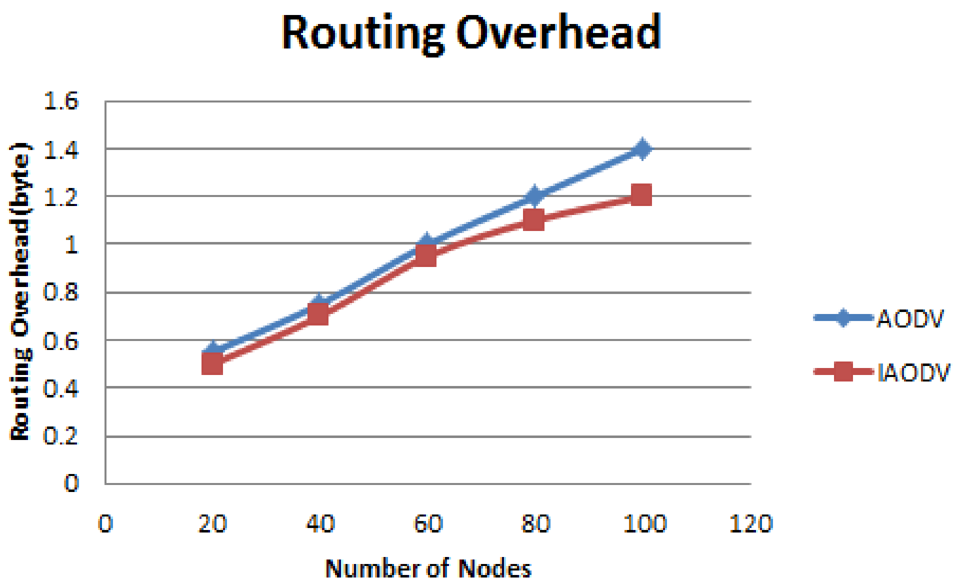

Figure 5.3Routing Overhead in terms of number of nodes

When the number of nodes increases routing overhead also increase.But our proposed work (IAODV) less routing overhead when compared with AODV relatively. This is due to the minimization of redundant RREQ packet transmission. Our work minimizes considerable amount of RREQ packet transmission thus helping in reduction of control packet that are used during route discovery. This minimizes the routing overhead that occurs in the network as a result of control packet exchange (RREQ packets).

5.3.2 Packet delivery ratio

The following graph shows the result of packet delivery ratio for both routing protocols.

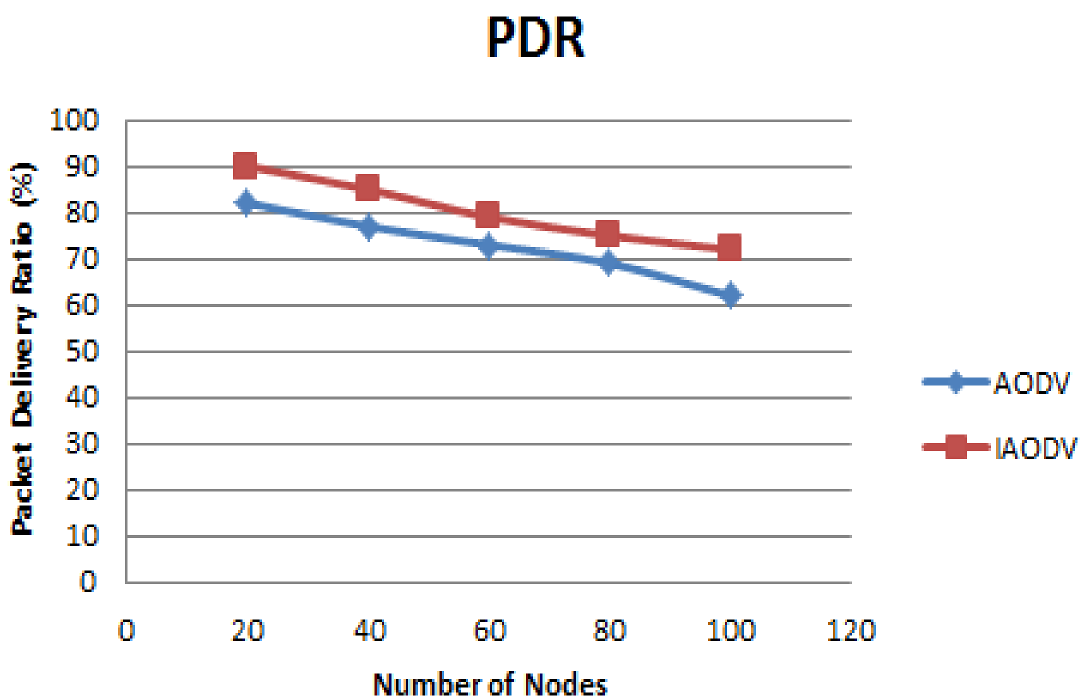

Figure 5.4Packet delivery ratio in terms of number of nodes

For packet delivery ratio our proposed routing protocol shows an improvement. When number of nodes increase packet delivery ratio decreases. But when comparing IAODV and AODV, the packet delivery ratio is improved relatively. Network becomes crowded when there is a huge amount of control packet (RREQ packet) exchange and in route discovery phase these packets are transmitted redundantly and unnecessarily. This makes bandwidth busy and packets will not be delivered to the intended destination. But in our work the redundant transmission of RREQ packets is reduced by using non-flooding technique in route discovery phase. Therefore packet delivery ratio is improved.

5.3.3 Packet end to end delay

In Figure 5.5 the result for packet end to end delay is presented.

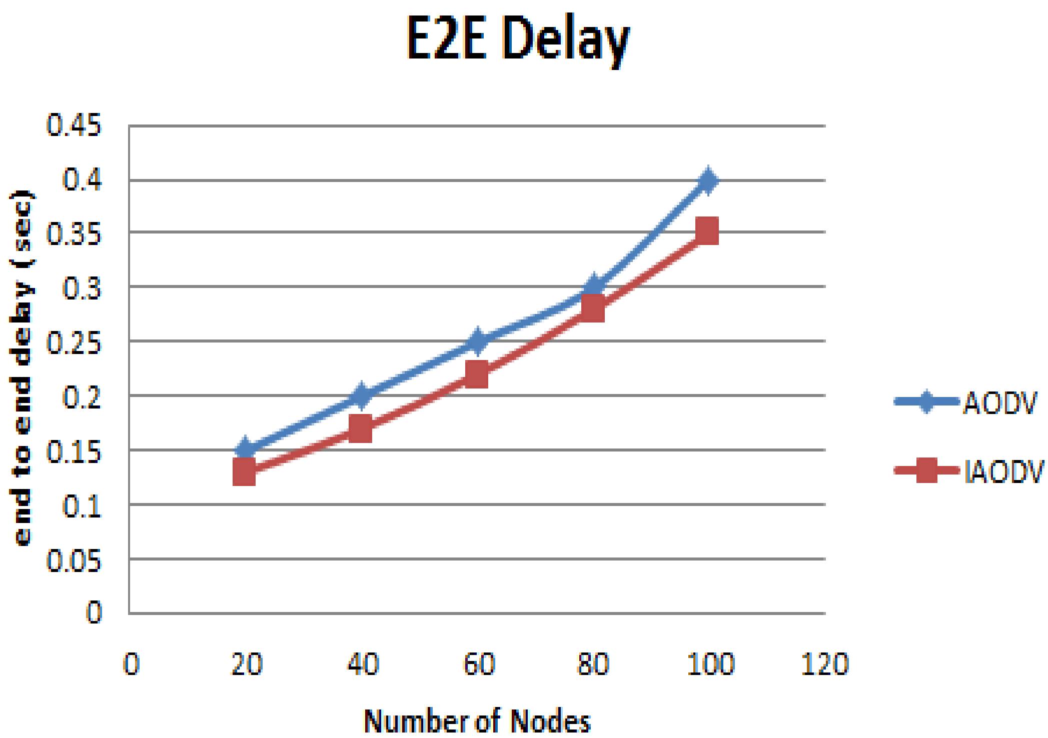

Figure 5.5End to End delay in terms of number of nodes

As shown in the abovefigure, average end to end delay increases when the number of nodes increases. Our improved routing protocol has less end to end delay when compared to the original AODV. This is due to the reduction in redundant RREQ packet transmission. When redundant RREQ packet transmission is reduced, bandwidth utilization will be efficient in the network. This avoids business of bandwidth and the time taken for transmission of packets will decrease.

6 Chapter Six: Conclusion and Recommendation

6.1 Conclusion

MANETs routing protocols use flooding technique to propagate control messages in route discovery phase. This method is applied in AODV routing protocol. To improve the performance of AODV we have used non-flooding technique to disseminate control message (RREQ packet) to discover route. In our IAODV the improvement was made in terms of Routing overhead, Packet delivery ratio and End to end delay. Using non-flooding technique to disseminate control packet helps to minimize redundant and unnecessary RREQ packet. This helps to reduce the overhead that occurs as a result of RREQ packet dissemination and there will be an efficient utilization of bandwidth in the network. When bandwidth is used efficiently the performance of the network is improved.

In our work, to replace the flooding technique of AODV routing protocol by non-flooding we have used maximum node degree of nodes. From the available intermediate nodes, to decide which node rebroadcasts RREQ packet node degree is used. The intermediate node which has maximum node degree is chosen to rebroadcast RREQ packet.

The result of our experiment shows (in Chapter 5) that our improved IAODV shows improvement when compared with AODV in terms of Routing overhead, Packet delivery ratio and End to End delay. These improvements are a result of minimized control packet (RREQ) dissemination. According to our algorithm unlike AODV, when an intermediate node receives RREQ packet first it checks its routing table to check whether it has maximum node degree or not. Node degree information of neighbors is kept in routing table of each node. To exchange this information the periodic hello packet is used. Hello packet is modified in order to hold the node degree information. The node degree information that is taken from hello packet is kept in the routing table, which is used to decide whether a node rebroadcasts RREQ packet or not. Thus when a node receives RREQ packet first it compares its node degree with node degree of its neighbors. If it has maximum node degree it rebroadcasts the RREQ packet and the others discard the packet. If there are some nodes with equal maximum node degree then the nodes with equal maximum node degree forward the RREQ packet and the others discard it. This technique helps to reduce redundant and unnecessary control packets.

We have implemented our work i.e., IAODV using NS2.35 simulator and to evaluate our work the evaluation metrics used are Routing overhead, packet delivery ratio and End to End delay . As the result of our evaluation shows IAODV shows improvement over AODV in terms of the given metrics.

6.2 Recommendation

In this paper, we have proposed an algorithm for AODV that uses non flooding technique in route discovery phase. This is important for improving performance of the routing protocol by reducing number of RREQ packet transmission from source to destination. The non-flooding technique uses maximum node degree as a criterion for intermediate nodes to forward RREQ packet. We have evaluated performance of IAODV and compared them with the original AODV using NS2. In this work there is an assumption in which a RREQ packet that is initiated by source node reaches the destination. But due to nodes frequent movement in the network, there could be link failure between nodes. As a result RREQ packet may not reach to destination. Thus for further improvement in this work we recommend the following direction:

- In the future one can extend this work by studying other methods to improve the performance of AODV by making the assumption stated as a base.

- To extend this work one can change the metrics used to evaluate the performance of the routing protocol and compare it with the original AODV routing protocol.

- As a future study one can apply this algorithm on another routing protocol, in whichrouting overhead is high, and test its performance.

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Appendix A: Tcl script used to simulate IAODV routing Protocol

```
#Simulation script used to simulate 40 nodes for IAODV routing protocol

# Define options
setval(chan)        Channel/WirelessChannel       ;# channel type
setval(prop)        Propagation/TwoRayGround      ;# radio-propagation model
setval(netif)       Phy/WirelessPhy               ;# network interface type
setval(mac)         Mac/802_11                    ;# MAC type
setval(ifq)         Queue/DropTail/PriQueue       ;# interface queue type
setval(ll)          LL                            ;# link layer type
setval(ant)         Antenna/OmniAntenna           ;# antenna model
setval(ifqlen)      50                            ;# max packet in ifq
setval(nn)          40                            ;# number of mobilenodes
setval(rp)          IAODV                         ;# routing protocol
setval(x)           800                           ;# X dimension of topography
setval(y)           800                           ;# Y dimension of topography
setval(stop)        50                            ;# time of simulation end

#Creating simulation:
set ns          [new Simulator]
#Use colors to differentiate the traffics
$ns color 1 Green
#Creatingnam and trace file:
settracefd      [open iaodv40n.tr w]
setnamtrace     [open iaodv40n.nam w]

$ns trace-all $tracefd
$ns namtrace-all-wireless $namtrace $val(x) $val(y)

# set up topography object
settopo     [new Topography]
```

```
$topoload_flatgrid $val(x) $val(y)
set god_ [create-god $val(nn)]

# configure the nodes
        $ns node-config -adhocRouting $val(rp) \
                    -llType $val(ll) \
                    -macType $val(mac) \
                    -ifqType $val(ifq) \
                    -ifqLen $val(ifqlen) \
                    -antType $val(ant) \
                    -propType $val(prop) \
                    -phyType $val(netif) \
                    -channelType $val(chan) \
                    -topoInstance $topo \
                    -agentTrace ON \
                    -routerTrace ON \
                    -macTrace OFF \
                    -movementTrace ON

## Creating node objects..
for {set i 0} {$i < 20 } { incr i } {
set node_($i) [$ns node]
      }
for {set i 0} {$i < 20  } {incr i } {
          $node_($i) color blue
          $ns at 0.0 "$node_($i) color blue"
      }
for {set i 20} {$i < 40 } { incr i } {
set node_($i) [$ns node]
      }
```

```
for {set i 20} {$i < 40  } {incr i } {
          $node_($i) color cyan
          $ns at 1.0 "$node_($i) color cyan"
     }

## Provide initial location of mobilenodes..
for {set i 0} {$i < $val(nn) } { incr i } {
set xx [expr rand()*800]
setyy [expr rand()*800]
               $node_($i) set X_ $xx
        $node_($i) set Y_ $yy
          }
# Define node initial position in nam
for {set i 0} {$i < $val(nn)} { incr i } {
# 30 defines the node size for nam
$ns initial_node_pos $node_($i) 30
}

…

#stop procedure.
$ns at $val(stop) "stop"
proc stop {} {
global ns tracefdnamtrace
   $ns flush-trace
close $tracefd
close $namtrace
execnam iaodv40n.nam &
}

$ns run
```