Optimization of Location Aware Routing Protocols for Wireless Adhoc Tactical Networks

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Declaration

I certify that this research work titled *"Optimization of Location Aware Routing Protocols for Wireless Adhoc Tactical Networks"* is my own work. The work has not been presented elsewhere for assessment. The material that has been used from other sources it has been properly acknowledged / referred.

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Language Correctness Certificate

This thesis has been read by an English expert and is free of typing, syntax, semantic, grammatical and spelling mistakes. Thesis is also according to the format given by the university.

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Copyright Statement

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Abstract

Mobile Adhoc Network (MANET) is a wireless technique which does not require any pre-existing infrastructure to function. It only requires wireless devices with sufficient battery to build the infrastructure dynamically by using any of available Adhoc routing protocols. MANET comprises three types of nodes i.e. source node, destination node and forwarding nodes also called routing nodes. Routes between source and destination are established as and when needed using on demand approach i.e. reactive approach. Therefore when a route is needed source node broadcasts "send request" packet to the destination node with the help of intermediate nodes called forwarding nodes and when a route is found/established, source node sends data via intermediate/forwarding nodes to this destination node. But due to high node mobility and frequent change in routes, data transmission may break often hence routes are recreated and updated accordingly by using any of the Adhoc routing protocol. There are many MANET approaches available e.g. DSDV, DSR, OLSR, AODV, ABR, ZRP but these protocols are used depending on the nature of situation. Protocol we have used in our thesis is Adhoc on Demand Distance Vector Routing (AODV) which is a reactive protocol i.e. it creates routes as and when required. AODV protocol was developed by Nokia Research Center, University of California, Santa Barbara and University of Cincinnati by C. Perkins, E. Belding-Royer and C. Das. Algorithm of AODV states that when source node needs route to destination it broadcasts send request packet to all the nodes present in given geographic region and broadcasting method used is expanding ring search. Even when route breaks or invalidates, AODV first checks route buffer to see if existing route could be used or not. If either existing route is stale or to-

pography is changed due to mobility then again AODV uses broadcasting to discover the requested route. That means each time, when route is needed, the route request packet is broadcasted to all nodes which unnecessarily uses the bandwidth and processing at each node causing power bottleneck to arise. Therefore our thesis is focused on the optimization of AODV protocol by restricting packet broadcasting to conserve power of nodes. For this purpose, we have used Global Positioning System. By knowing coordinates of the nodes, our algorithm targets only that subset of nodes which are directly participating in route establishment. This modified algorithm limits route request packets which results drastic reduction in packet broadcasting and conserves power. Hence control packets are reduced whereas data transmission increases which also increases performance. To simulate the algorithm we have used NS2 in Linux based platform. NS2 is basically mixture of TCL and C++ whereas OTCL provides linkage between TCL and C++. Backend code is implemented in C++ language whereas TCL language is used to create front end layout by defining number of nodes, their traffic pattern and their parameters e.g. transmission range, battery power etc. In the end, results of modified AODV are compared with traditional AODV and DSR.

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ABBREVIATIONS

MANET: Mobile Adhoc Network
AODV: Adhoc On Demand Distance Vector
HELLO: Keep Alive Packet
RREQ: Route Request
RREP: Route Reply
RERR: Route Error
IEEE: Institute of Electrical and Electronics Engineers
TCP: Transmission Control Protocol
TCL: Tool Command Language
IDE: Integerated Development Environment
NS2: Network Simulator 2
OTCL: Object Command Tool Language
OAODV: Optimized Adhoc on Demand Distance Vector
GPS: Global Positioning System
LAR: Location Aided Routing
TTL: Time to Live
DSR: Dynamic Source Routing

Chapter 1

Introduction

1.1 Background

Mobile Adhoc networks or MANET is a widely used field in world today because of the need for rapid deployment of networks in situations like natural disaster, war or any emergency where we cannot bear any delay in establishing communication due to the sensitivity of situation [4].

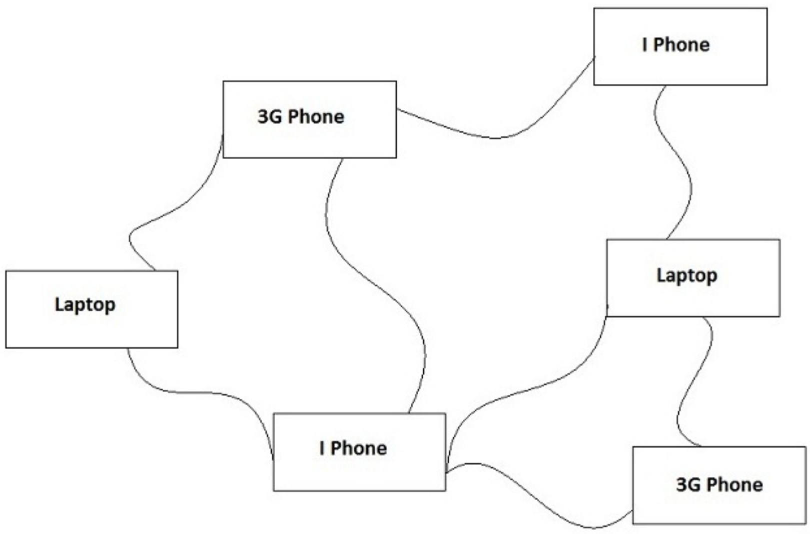

Figure 1.1: Overview of Adhoc Networks

MANET do not require any prerequisite infrastructure to work because protocols developed for adhoc networks are on demand. It means that route is created/established when it is required by the node to transmit data and when data transmission finishes; the route is invalidated and finally removed after some timeout period. Because in most situations nodes are not stationary but rather mobile therefore physical location of the node is changing continuously hence the distance between nodes in a given geographic region is also changing accordingly.
In adhoc networks every node may act as source, destination or a router and in most cases a router node acts like a forwarder node i.e. it is helping source node to send its data to the destination node by using it as a next hop.

There are two types of MANET approaches reactive and proactive approach [1] [4] [17]. In proactive approach routes are saved in cache and are reused later but this approach is normally used in situation where nodes are stationary or where there is very less movement. In this case it is feasible to store the routes in tables/linked lists format. Whereas, in case of reactive approach nodes are highly dynamic due to which routes break quite often. Therefore in this scenario routes are created on demand i.e. when data transmission is required then route is created and finally these routes are removed from cache after some timeout period.
Mobile Adhoc networks are used for warfare/tactical networks to help army to communicate in deserts or places where there is no pre-existing infrastructure for communication and all is to depend on reactive approach i.e. to create routes on demand for communication. There are different reactive routing protocols but Adhoc on Demand Distance Vector routing protocol (AODV) is mostly used

1.2 Literature Review

Lot of work has already been done on Location Aided Routing (LAR) or on demand approach using GPS. In LAR, global position system (GPS) for nodes is used that means if we already know the coordinates of nodes then we can optimize LAR. Young-Bae Ko and Nitin H. Vaidya of Department of Computer Science, Texas A/M University [3] have worked on LAR. This paper has also been published in international journal. In this paper authors have suggested ways to optimize algorithms by using LAR and reducing flooding of packets. Hence flooding is confined to some specific region which is subset of a bigger geographic region resulting in optimization of battery consumption of nodes. Techniques have also been discussed to convert bigger region into smaller region comprising request zone and expected zone. Now the only nodes present in request zone may receive the broadcast of packets thereby reducing broadcast domain which resulted in performance improvement. Energy Aware Location Aided Routing in Mobile Adhoc Networks is another research paper by Anamika student of Computer Science, Inderprastaha Engineering College [1]. This paper has also been published in International Journal of Scientific and Research Publications in December 2012. In this paper author has designed algorithm for energy Aware Location Aided Routing by reducing size of request zone and limiting flooding by using available bandwidth and battery life efficiently. Line of sight between source and destination has been used for this purpose. Intermediate nodes which are closer to this concept line are used in route creation. There is another paper on Performance Evaluation of AODV protocol in MANET which has also been published in 2nd National Conference on Information and Communication Technology (NCICT) 2011. [9]. In this paper AODV protocol workflow has been discussed in detail along with different packets types i.e. RREQ, RREP and RERR. Algorithms are also discussed that how AODV can be optimized. Another paper titled Energy Efficient Location Aided Routing Protocol for Wireless MANETS by Mohammad A. Mikki [22] which has also been published in International Journal of Computer Science and Information Security. In this paper it is assumed that GPS device is installed in all mobile nodes and circular geographic area is divided into equal regions with a central base station in center of geographic region. Central Base Station has table namely position table which contains geographic positions of all mobile nodes and is continuously updating any change in position at regular interval of time. Now for example if a node has to send data to some other node then it first checks base station where destination node is located and by knowing the location of destination node, it comes to know the region in which destination is located. Now after knowing the location of destination, angle between source and destination is found and then sender broadcasts route request in this direction only for finding valid route. Using this concept, I have applied it in my thesis and created four dynamic regions in a given geographic region after calculating the GPS position of destination. These regions are like four quadrants which are selected depending upon the position of destination node with respect to sender node. There is another paper titled A Reliable Route Selection Algorithm Using global Positioning Systems in Mobile Adhoc Networks by Won-Ik Kim and Dong-Hee Kwon, Young-Joo Suh [23]. In this paper author has described an algorithm for creating a route which is reliable i.e. if there are more than one route from source to destination then most reliable route will be selected. Algorithm works by creating circular regions representing transmission range of node. Each node has two circular zones one is stable zone and other is caution zone. Stable zone is basically reliable zone and is inscribed circle within outer circle and radius of stable zone is calculated by speed of node. Zone between outer circle and inscribed circle is a caution zone which is not reliable and route may break in this zone. Algorithm works by broadcasting RREQ packet from sender node A, which also includes its own GPS coordinates, to all nodes which are in its transmission range. Let's say some intermediate node B received RREQ first compares whether it is in stable zone by comparing its own GPS information with the GPS obtained by node A. If it is not in stable zone then it simply discards but if node B is in stable zone with node A then it accepts RREQ and forwards it to next node with its own GPS coordinates. This concept was also helpful in my thesis because using concept of stable zone and caution zone I have used rectangle method in which there are two zones namely request zone and expected zone. Sender node will broadcast RREQ in geographic region and nodes within rectangle will accept RREQ whereas nodes outside the rectangle will simply ignore it.

There is a paper namely GPS enhanced AODV routing by Hristo Asenov and Vasil Hnatyshin [24] in which authors have discussed ways to narrow down the given geographic region so that flooding of RREQ packets may be limited to some specific region only for saving power and processing at each node. For this purpose authors have devised a cone based method in which conical region is created from source to destination. Now only nodes present in this conical region may participate as intermediate nodes for route creation whereas nodes outside this region may simply discard route requests. Algorithm says that cone is formed logically by calculating the flooding angle. If coordinates of destination is unknown then flooding angle is at its maximum value which is complete geographic region but if coordinates of destination are known then flooding angle is found using coordinates of source and destination. Intermediate nodes also find their angle by using their coordinates with source node coordinates and see whether this angle is within flooding angle. If it is true then it accepts route request otherwise it just ignores because now it is outside legitimate region. I have also applied concept similar to it in my thesis by using coordinates of source and destination node to create rectangle.

Another paper titled GPS Enabled Energy Efficient Routing for Manet by Divya Sharma and Ashwani Kush in which authors have discussed ways to optimize route to avoid route breaks due to poor Signal to interference ratio (SIR). There is another parameter discussed that is power state in each node and it may vary depending upon usage of node. Therefore, two factors comprising SIR and power make the route optimum causing fewer number of route breaks thereby increasing throughput. We assume that all the nodes are equipped with GPS and certain threshold level for SIR is developed. Nodes above this threshold will participate in route creation whereas nodes below this SIR threshold will not participate in route creation and will simply discard RREQ. Along with SIR, another factor which is to be considered is battery percentage level. Let's say, if node's battery level is below 25 percent then node will ignore RREQ and will not participate in route creation. Therefore only nodes with SIR above threshold and battery level above 25 percent will participate in the route creation process, thereby resulting in a route, which may exist longer than it does in traditional adhoc routing algorithm. In this algorithm authors have assumed that each node knows both SIR and battery level and this information is also shared with other nodes. One drawback in this scenario is initial delay in route creation due to calculations made when route is unknown but in longer run it may improve power parameter and route may also stay longer with lesser breaks.

1.3 Problem Statement

Basic problem in traditional AODV algorithm is that when nodes require to create a link with another node for data transmission then it has to use the concept of flooding, in which source node in form of send request packet asks each node that whether it is a destination node or not [3]. It keeps on flooding until any node replies back that it is the destination node for which source node is searching for. This traditional algorithm is very expensive in terms of processing/battery consumption at each node and we also know that we are short of resources i.e. battery used to provide power to nodes. In this thesis our task is to make the algorithm resource efficient by using GPS which is assumed to be installed at each node. Therefore traditional algorithm needs to be modified to make effective use of GPS coordinates by restricting flooding to some specific region, where source and destination nodes along with enough intermediate nodes lie. We have used the concept of requested and expected region which are created with the help of x and y coordinates, thereby restricting broadcast of packets in this rectangular region only. If there are not enough intermediate nodes present within the rectangular region then we may increase the size of rectangle to include more number of intermediate nodes to create route and send data smoothly.

1.4 Contribution

If we reduce packet processing at each node then it means that we have improved power parameter and achieved the said optimization. This can be done with the help of GPS or LAR because if we already know the GPS coordinates of each node then we also know the position of source node and destination node. Using coordinates of source and destination node, we may create a region which is subset of a bigger region. Now remaining in this region which is subset of bigger geographic region we send route finding packets in the direction of destination node only. This reduces processing of packets at nodes which are not in this region and hence conserves power.

1.4.1 Tactical MANET

Tactical network is required to support military operation because it is independent infrastructure which is not dependent on any existing networking infrastructure [6][28]. When we say that tactical network is self configuring then that means it is Tactical MANET i.e. MANETs supporting military operations.

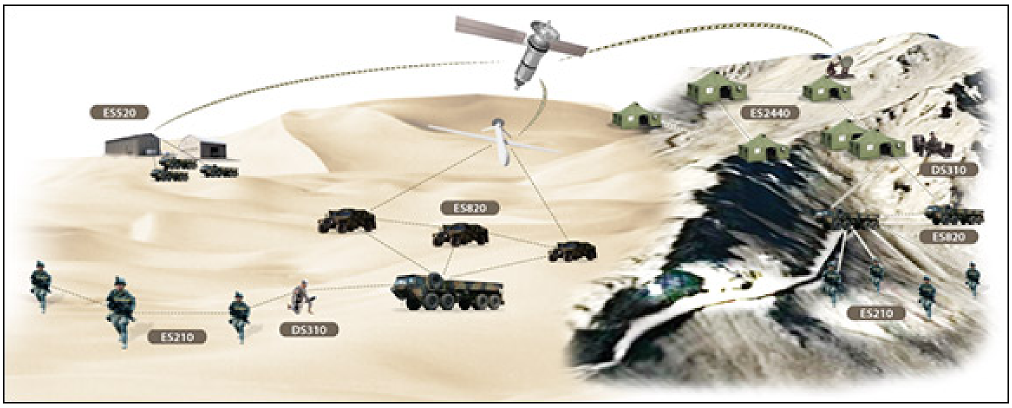

Figure 1.2: Example Tactical MANET [19]

1.4.2 Adhoc on Demand Distance Vector

There are many Ahoc Routing Protocols today out of them our thesis uses / modifies AODV protocol. Traditional AODV works by broadcasting send Request packets to other nodes using process called flooding [9] [10]. All nodes in network receive this request packet until destination node receives this packet, processes it and in return creates a route reply packet. This Route Reply Packet when reaches back to source node then a valid route is created and finally data transmission starts. But this is an expensive solution in terms of battery consumption because due to flooding of route request all the nodes are involved which drains node battery early.

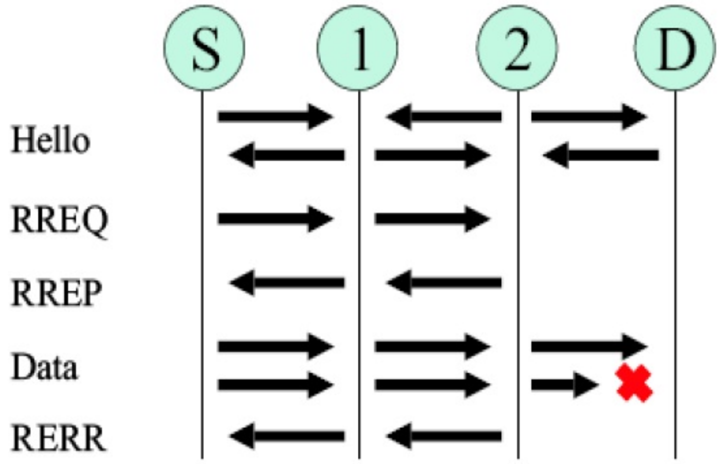

Figure 1.3: Flow of AODV Routing Packets [21]

1.4.3 AODV in Location Aided Routing

Basic theme of the thesis is to optimize the adhoc routing protocol by using LAR for better performance [1] [11]. We have devised an optimized solution to cope the basic problem of flooding that is reducing the generation of route request packets. For this purpose, we have used GPS coordinates and optimized the algorithm by dividing geographic region further into two regions i.e. request region and expected region. AODV optimization through GPS (O-AODV or LAR) in which the send request packet is limited to this rectangular request region only which was initially calculated by using GPS coordinates of source node and destination node. Now whole process of route discovery and data transmission is going to happen in this rectangular region only thereby ignoring any region outside the rectangular region. Whenever source node initiates the route request, it broadcasts route request packet and the nodes which reside inside the rectangular region accept this route request packet whereas nodes residing outside rectangular region simply discard it. After finding the route by afore-mentioned process, data channel is established between source and destination node. During the course of data transmission, coordinates of source and destination node is continuously updated and hence rectangular region is also continuously refreshing.

1.5 Thesis Organization

Chapter 2 presents an overview of general concepts of routing, classification of routing and different types of routing packets. Chapter 3 discusses various techniques for optimization of location aided routing using GPS, which is followed by AODV protocol using LAR in which modified routing packet types which are used for optimization of AODV algorithm are also discussed. Chapter 4 discusses Network Simulation Tool, TCL script and its different types of traffic generation / output files through which we can draw useful information for analysis purpose. AODV performance parameters are also discussed through which we can determine whether algorithm is optimized or not. These performance parameters are then applied on various scenarios to see how modified algorithm behaves. For example when we change no of nodes then how algorithm behaves or when speed is varied or pause time is changed then how algorithm behaves. The results are then plotted in graphical form and compared with traditional AODV and DSR. Finally in chapter 5 we conclude the thesis with a brief description of the possible future work.

Chapter 2

Routing in MANET

MANET is highly dynamic in nature due to the continuous movement of mobile nodes that interfere in consistent route maintenance. Due to this dynamic nature of nodes route may drop quite often resultantly data transmission may stop, generating route failure errors [12] [6] [10]. When route gets down send error messages is generated showing that route is down so we again use mobile Adhoc routing algorithm to find the route and then continue transfer of data from where we left off. When we compare normal wireless networks with MANETs then we find lot of difference between them because wireless is based on preconfigured infrastructure whereas MANET is infrastructure less and configures infrastructure on fly. When we discuss wireless network then we can say that it consists of one common base station covering each cell and this base station within specific cell functions by broadcasting signals directly towards destination nodes thereby creating direct links with destination node and in this process no other node is involved. We can say that now a direct link between base station and node is established and when node moves from one cell to another cell then hand off occurs and link with base station of next cell is established. Whereas in case of MANETs link is established between source and destination by using available intermediate nodes therefore we can say that there is no central control or base station in MANETs and everything is scattered / distributed but it still works in an organized manner by using Adhoc routing protocols.

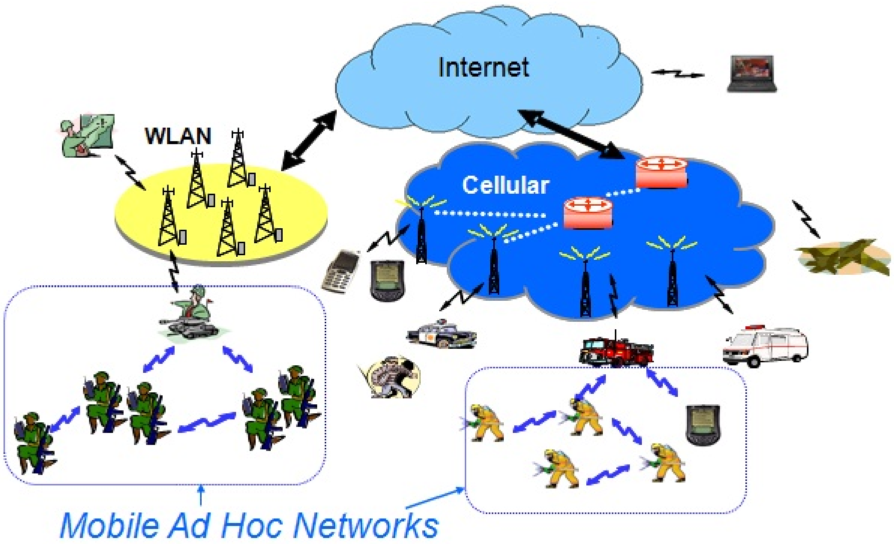

Figure 2.1: Cellular Vs MANET [19]

2.1 General Concept of Routing

Routing is defined as movement of packets from source to destination and for this purpose it uses various metric values for selection of routes. Metric values may be number of hops or link quality etc. Routing consists of two phases, in first phase we select routing path and in second phase we transfer the data through this route by using one intermediate node at minimum as a routing node [17][26]. During this process packets are forwarded so it is like packet switching but normally finding routes in it could be very difficult and complex job.

Until now various routing algorithms have been developed which determine optimum route and also keep that route in routing table for some period of time for future use. Routing tables normally consist of IP-address of destination, next hop value and sequence number etc. Sequence number represents freshness of route and help avoiding loops which may cause routing infinite loop errors[10]. There are two types of routing static or dynamic. In static routing, humans i.e. network administrator enter the routing decisions in routing tables where as in dynamic routing there is no need of human intervention and routing protocols themselves configure routing table depending upon the network and its traffic.

2.2 Classification of Routing

Routing protocols are classified as flat, hierarchical or location aided routing protocols depending on the type of routing strategy used and network layout [12][26]. We define routing protocols that may be either table driven or on demand. Several Adhoc routing protocols are as follows.

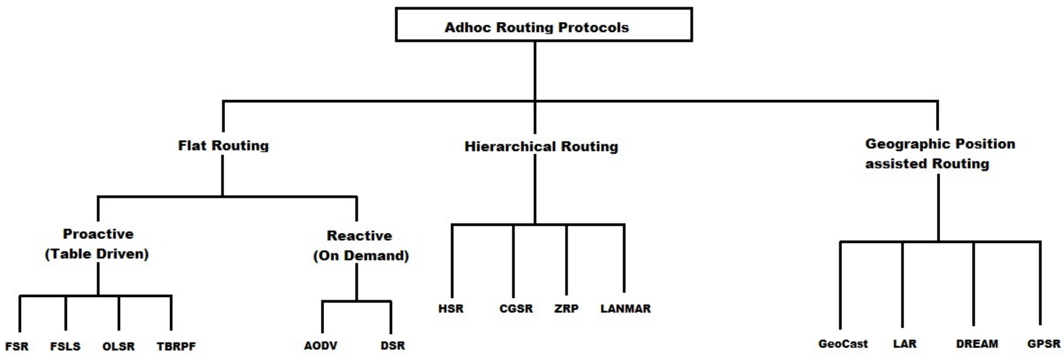

Figure 2.2: Adhoc Routing Protocols

2.2.1 Flat Routing Protocols

There are two types of flat routing protocols. One is proactive routing protocol which may also be called as table driven because routing tables are maintained in form of tables and are constantly updated. Second type is called reactive routing protocol in which route may be created on demand. We can further classify them depending on their structure i.e. proactive routing is link state whereas reactive routing is distance vector.

Proactive or Table Driven Routing Protocols

In proactive routing protocol complete picture of network is kept in form of routing tables and is constantly updated for any change occurring in any route at any time. That is why we may say that proactive protocols are used for time critical applications. Therefore fresh route is always available when there is any type of data transfer[4]. There is also a disadvantage of proactive approach because routes are constantly created/maintained causing unnecessary consumption of bandwidth which leads to battery consumption at each node and hence power bottleneck arises. Routes which are never used in data transfer are also created in proactive approach which is kind of overhead. These never used routes become stale after sometimes and are refreshed again after regular interval of time and this aggravates when the size of network is huge. In other words, control traffic becomes more than the original (data) traffic and is a very costly solution in terms of power consumption. Essence of MANET is to provide service in disaster recovery operations and in these situations we cannot bear power bottleneck. Therefore proactive approach is used in scenarios when there is very less movement of nodes and hence less control traffic is generated to maintain routes. Some of Proactive Routing Protocols are as follows[12].

- Optimized Link State Routing (OLSR).
- Fish eye State Routing (FSR).
- Destination Sequenced Distance Vector (DSDV).
- Custer-head Gateway Switch Routing (CGSR)

Reactive/On Demand Protocols

There are situations when mobility of nodes is very high and unpredictable due to which keeping the routes updated is difficult. In such situation we use reactive approach which works in on demand manner. Which means that route is created only when there is a need of data transfer[9]. Control packets used in this protocol are RREQ, RREP or RERR. Prior to creating route control packet RREQ is broadcasted in geographic region containing all the nodes. When RREQ packet reaches the destination node then it means that destination node has been found. Destination node in turn generates a RREP packet back to source node traversing back the cached path from where RREQ reached destination. In this way route is established and remain in active state until data transfer completes. Various reactive routing protocols are as follows.

- Adhoc on Demand Distance Vector
- Dynamic Source Routing Protocol
- Temporally Ordered Routing Algorithm
- Associativity Based Routing
- Signal Stability Based Adaptive Routing
- Location Aided Routing Protocol

2.2.2 Hybrid Routing Protocols

Depending on the situation we can make use of hybrid protocols which is a combination of both proactive and reactive approach. For example geographic region can be divided into small regions and reactive approach is used in small regions whereas to find nodes outside those small regions proactive approach is used. Some common hybrid protocols are as follows:

- Zone Routing Protocol
- Wireless Adhoc Routing Protocol

2.2.3 Hierarchical Routing Protocols

Hierarchical Routing Protocols are used to make routing tables management easy/robust because in this type of routing, routes are stored in hierarchical manner [12]. We can easily understand hierarchical routing if we consider an example of static routing in an enterprise. In this scenario we usually have core layer, distribution layer and edge layer. Different LANs are connected to make one bigger LAN/enterprise whereas routing tables are divided into core layer and distribution layer in a hierarchical manner. Smaller LANs get there routes from distribution layer to access other LANs whereas to access bigger LANs it has to get the routes from core layer. Hierarchical routing is also used in Adhoc networks in which we have proactive and reactive approach depending on the hierarchy level. For example in one hierarchy we may use proactive approach whereas deeper in next hierarchical level we may use reactive approach for finding the routes. Some Adhoc routing protocols are as follows:

- Cluster Based Routing Protocol
- Fisheye State Routing Protocol

2.2.4 Geographical Routing Protocols

Geographical Routing Protocols are used to make the route searches more optimized by considering GPS coordinates of each node [16]. Now we know the position of each node so we send route request packets in that specific direction only. In this way control packet broadcast is reduced to fewer number of control packets which are required to establish a route. This increases efficiency and throughput but the only drawback is that we need GPS equipment installed at each node and it should be quicker than movement of nodes so that accurate position of node is known at time of establishment of route. Some common geographical routing protocols are as follows:

- Geocast (Geographical Addressing and Routing)
- DREAM (Distance Routing Effect Algorithm for Mobility)
- GPSR (Greedy Perimeter Stateless Routing)

2.3 AODV Routing Protocol

AODV protocol works by broadcasting route request packets to neighboring nodes. These neighboring nodes after receiving route request packets process to determine that whether they are destination node or if they have valid route to destination nodes. If any condition is true then route reply is sent back to source traversing the reverse path. But if none of the case exists then it is further rebroadcasted to find the destination node until either route request times out or complete network is traversed. Different types of Control packets used in AODV are as follows: -

2.3.1 Route Request Packet (RREQ)

When a node needs a route to destination it broadcasts route request packet using a specific TTL with unique RREQ ID and route request timeout [9][29][30]. When intermediate node receives RREQ it checks to see whether it is destination node or it has route to destination available. If any of the conditions gets true it stops broadcasting RREQ to next hop. If condition is not true then it will broadcast it further to other nodes and these nodes repeat the same process until destination is reached or route request timeouts.

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|     Type      |J|R|G|D|U|   Reserved          |   Hop Count   |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                            RREQ ID                            |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                    Destination IP Address                     |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                  Destination Sequence Number                  |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                    Originator IP Address                      |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                  Originator Sequence Number                   |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 2.3: Route Request Packet [2]

During this entire route request process reverse route is stored by each node traversed to reach back to source node. RREQ Packet structure is shown in figure 2.3

2.3.2 Route Reply Packet (RREP)

When destination receives RREQ packet then it does not broadcast it further and send route reply (RREP) packet back to source node using reverse route that was stored during RREQ process. [1][29][30]. RREP packet structure is shown in figure 2.4.

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|     Type      |R|A|    Reserved     |Prefix Sz|   Hop Count   |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                     Destination IP address                    |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                  Destination Sequence Number                  |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                    Originator IP address                      |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                           Lifetime                            |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 2.4: Route Reply Packet [2]

2.3.3 Route Error Packet (RERR)

Route error packets are used to send the error to neighboring nodes to show link failure.

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|     Type      |N|          Reserved           |   DestCount   |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|            Unreachable Destination IP Address (1)             |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|         Unreachable Destination Sequence Number (1)           |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-|
|  Additional Unreachable Destination IP Addresses (if needed)  |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|Additional Unreachable Destination Sequence Numbers (if needed)|
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 2.5: Route Error Packet [2]

That means link between source and destination are broken [9] [29] [30]. RERR packet structure is shown in figure 2.5

2.4 DSR Routing Protocol

DSR is basically source routing in which sender knows the complete route from source to destination. Complete routes are stored in node's route cache. During transmission data packets carry source route in their header. But if a node does not has route to destination then it uses the method similar to AODV in which a route request packet is broadcasted and when RREQ packet reaches destination node then it generates RREP back to source node. This complete route from source to destination is saved in route cache of source. Along with that any node which lies in between source and destination also save route in its route cache. Unlike AODV, there is no concept of sequence no. therefore multiple routes may exist from source to destination and if one route breaks then node may use the alternate route available. Moreover, there is no concept of timer in DSR protocol for expiry of route. Therefore when route error occurs due to failure in link to destination then source node removes the route from its cache and send message to other nodes to remove the route from route cache. After that it again initiates the route discovery process.

DSR protocol uses the concept of promiscuous listening in which when a node overhears a packet then it sees whether it has a shorter route available for the packet. If it is true then it sends gratuitous RREP to source node to tell that it has a fresh shorter route to destination. Another benefit of promiscuous mode is helping node learning new routes without directly involving in routing process.

2.5 Summary

In this chapter, various Adhoc routing protocols are discussed. These Adhoc routing protocols are used in various scenarios depending upon situation of usage and exhibit different performance parameters. Adhoc protocols are broadly classified as either reactive or table driven. In reactive approach, route is created whenever it is required to send data and is used in situation where there is a dense node count. Whereas, table driven approach is used when number of nodes is less. This is fast approach as compared to reactive approach because there is no delay in route establishment since any change in topology leads to updating of routing tables even when there is no need for data transmission. In this thesis Adhoc approach of our interest is AODV, which is reactive approach i.e. route is established on demand. In AODV protocol various control packets including route request (RREQ) and route reply (RREP) which are used for route establishment.

Chapter 3

Optimization of AODV Protocol

As we discussed earlier that AODV protocol consists of RREQ and RREP packets. We also know that AODV works by broadcasting RREQ packets in all directions of given geographic region but this is costly solution in terms of power consumption. It would be much better if we send RREQ only in direction where destination is most probably located. This could only be possible if we have coordinates of destination node available which could be retrieved through GPS device. This process of creating region based on GPS coordinates and then finding route from source to destination is called Location Aided Routing. If we use this approach for tactical networks then we call it tactical MANETS using GPS. Location Aided routing (LAR) is basically an optimized algorithm to reach the destination node [3]. Using LAR, we know the coordinates of source and destination node and based on these coordinates we make a rectangular region which is a subset of bigger geographic region. Now send request is done in this rectangular region only whereas nodes outside this rectangular region ignore it.

3.1 Location Aided Routing

3.1.1 Flooding

Flooding is a node searching process in which a token is circulated through all the nodes and the required node (destination) responds back to the source node which initiated the search process [3]. When we talk about AODV then token is actually a route request packet that is broadcasted by the source node in hop by hop fashion to find a destination node. Algorithm used by source node S is spreading ring search algorithm in which if destination is not found then TTL value is incremented by one each time before a new broadcast of RREQ packet. DSR and AODV are on demand routing algorithms that use flooding method to find destination node. To better understand the flooding process let us say we have source node S and destination node D with intermediate node I. Node S needs to find a route to node D therefore it will disseminate the route request packet in all directions in form of spreading ring pattern. Assume some intermediate node I, which receives the route request packet, will first verify whether it has received a route request packet before by checking RREQ ID. If node I has already received the route request packet then it will just discard the new RREQ packet. But if node I has not received the route request before then it will check whether it is destination node or not. If it is a destination node then it will send the route reply back to source node S otherwise if it is not destination node then it will first save the route back to source node and then forward the route request. If source node S did not find route within some route request timeout then Source node S will generate a route request packet again after some specified time period and it will repeat this whole process for number equal to route request retries. After that it assumes that either destination node is not within wireless range or it does not exist physically. Flooding process is accurate because it traverses all nodes in the geographic region but this requires processing at each node and hence consumes energy. Energy or power is the most important factor in MANET when we are in middle of desert and we don't have any alternate power source avaiable. Flooding is shown in figure 3.1.

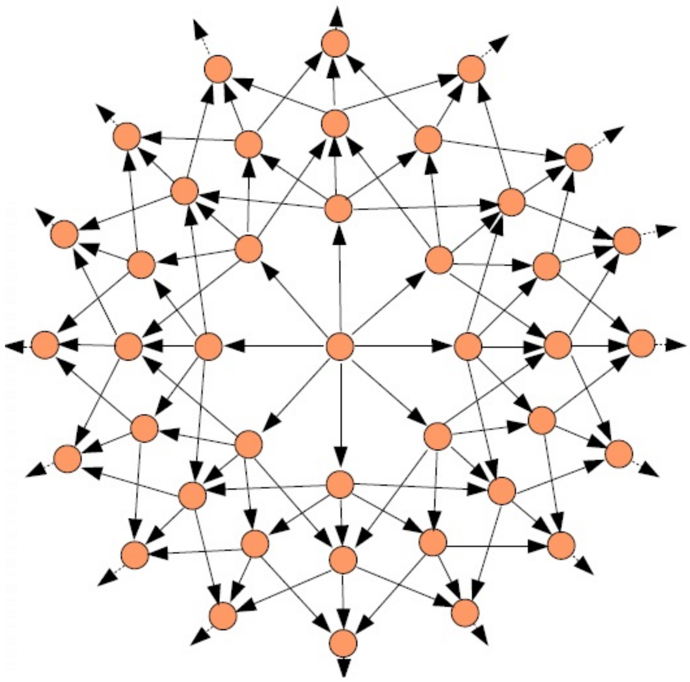

Figure 3.1: Flooding [20]

3.1.2 Function of LAR

Flooding is a route searching process that helps finding the destination node by traversing the whole geographic region and gives accurate result given there is no break in the routing path [5] [16]. But flooding has drawback that it consumes bandwidth and processing at each node which creates power limitation problem because if we assume that our required destination node is in north direction and we are flooding send request packet in all directions which is useless and wastage of energy at each node. It would be better if we send the route request packet in north direction only where destination node exists. We know that if we are dealing with directions then we have to make use of Global Positioning System which provides the position of each node. Now we know position of destination node therefore we can send the packets in specific direction with the help of intermediate or forwarding nodes. As we already know that routing algorithm that uses position of node is called LAR and for Adhoc networks different location aided routing algorithms have been developed out of which two algorithms are described below.

3.1.3 Type I LAR

This is a region based routing in which we define a new smaller region out of the original bigger region by knowing coordinates of source and destination node [3]. Route request packets are now broadcasted in the smaller region which we know is subset of a bigger geographic region. By using this technique nodes within the smaller region are accepting the route request packets whereas the nodes outside of this region are simply discarding the route request packets. In this way the broadcast domain of route request packets is limited which conserves energy. For Location Aided Routing algorithm to work we divide the smaller region further into two parts called "requested region" and "expected region" which is shown in figure 3.2.

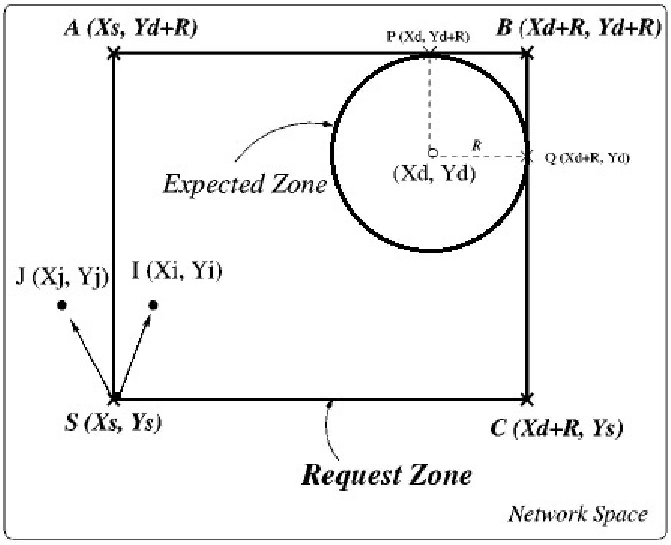

Figure 3.2: Type I LAR

Expected Region

Expected region contains destination node which is found using coordinates (x,y) and average speed v of the destination node. Expected region is basically a two dimensional space in which destination node is expected to be found for next time say 't'. Now we can find the expected position of destination node in expected region by using the formula S=v/t [3]. If S is multiplied by 2, then we found the diameter of circular region around the destination node which means that for next t seconds destination is expected to be in this circle. We may further refine the situation by taking into consideration the direction of movement of node. Let us say if it is moving in north direction then we may consider half of the circle and hence expected region is reduced to further half.

Requested Region

As the name of requested region indicates that it is the region in which send request packets are broadcasted to find the route. This region is calculated based on the parameters i.e. destination node coordinates, expected region and source node coordinates [3]. We may form the rectangle by using these parameters which is subset of bigger geographic region and also contains expected region. This rectangular region contains the nodes which are ready to accept send request packets but outside this rectangle the nodes ignore send request packets because destination node is not outside but present inside the rectangle. Therefore by using above mentioned divide and conquer strategy we conserve power.

3.1.4 Type II LAR

This type of routing utilizes GPS information at each node [3] [5] therefore before broadcasting send request, source node calculates its distance from destination node by using distance formula which is explained in detail as below.

Source node broadcasts send request packet after inserting its calculated distance (from destination node)in it. Intermediate nodes which accept this route request packet first checks whether it is destination node or not. Assuming it is a destination node then it sends route reply back to source node. If this is not destination node then it calculates its distance from destination node by using distance formula and compares it with the distance in send request packet which was received from previous node. If calculated distance of current node is more than the distance of previous node then it means that we are moving away from the destination node and destination node does not exist in this direction so current node will discard the packet and no more packets will be broadcasted further in this direction. But if distance of current node is less than the distance of previous node then this means that we are going in right direction and we are getting closer to destination node. Now the send request along with this fresh distance will be broadcasted to other nodes in this direction and same procedure is repeated until destination is reached. This is shown in figure 3.4. In Type II LAR we have to calculate distance at each node which requires processing and is time consuming whereas in Type I LAR we have to calculate the region in beginning then after that we proceed as usual and does not require processing at each node for distance calculation. Whereas in Type I LAR we have to apply certain checks to see if there is any intermediate node present in request region or if there is no intermediate node and destination node is also out of direct transmission range of source node then we can never reach destination node. In this situation we have to use some alternate method to reach destination.

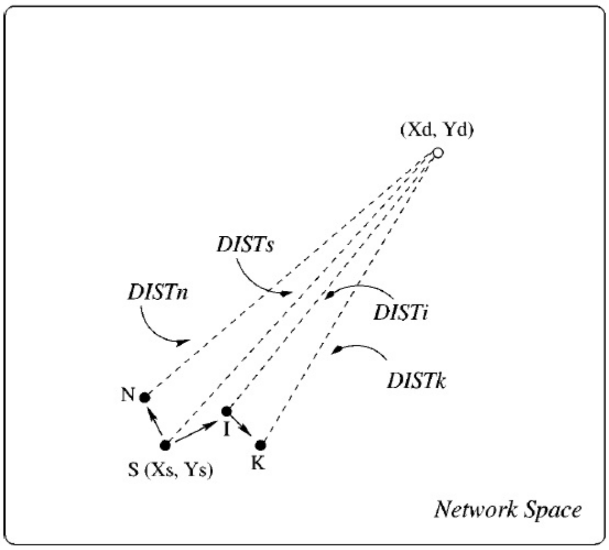

Figure 3.3: Type II LAR [3]

One method is to increase size of rectangle to include more no. of intermediate nodes because if we have more number of intermediate nodes then we have more flexibility to create optimum routes from source to destination.

3.2 LAR Based AODV Protocol

As explained earlier AODV protocol can be optimized by reducing the number of control packet. We use GPS for purpose of reducing the control packet broadcast and hence reduce energy consumption resulting in optimization of AODV protocol. Using GPS we can form rectangular region with source node at one corner of rectangle and destination node at other corner of rectangle making a diagonal form and control packets will broadcast in this rectangle only.
We have used linked list to create GPS table whose data fields are given below.

- Node x-coordinate.
- Node y-coordinate.
- Node Velocity.
- GPS Expire.

3.2.1 GPS Table in AODV Protocol

We have added an additional GPS table in Optimized AODV Protocol to store GPS coordinates of nodes. We also set expiry timeout after which GPS coordinates will be removed. Since nodes are highly mobile so coordinates may change often. GPS table is useful if a link between source and destination breaks then source will consult GPS table and if GPS is not expired then it will get GPS coordinates of destination from GPS table and process it further. But if the GPS coordinates are expired then it has to fetch fresh coordinates of required node.

3.2.2 General Flow of O-AODV

When it is needed to transmit data packets and there is no available route in cache to reach the destination node then source broadcasts send Request packet [13]. For this purpose sendrequest() function is called at source node and recvrequest() function is called at receiving node. recvRequest() first checks whether it is destination node or not. If it is destination node then it calls sendReply() function which sends route reply packet along with GPS coordinates back to source node which further calls recvReply() function and saves GPS coordinates in GPS table by setting appropriate timeouts. Based on GPS coordinates rectangular region is formed which contains expected region and request region. But if current node is not destination node then reverse route to source is saved and forward() function is called which forwards send request packet further to other nodes and forwarding continues until destination node is reached which is followed by sendreply() at destination and recvreply() at source node. Final route received is saved in routing table after setting timeout appropriately. Numerous other helper functions are used for calculations or for timing to trigger the events. There are some other functions for handling different types of tables including routing tables or precursors etc.

3.2.3 Optimized Route Request Message

How route request works in the scenario of optimize AODV. This is in fact two stage process. One stage is send request and other stage is receiving request. Source node will broadcast route request to all nodes but only nodes present in request region will receive route request message. Whereas nodes outside the request region just discard it and do not process it.

3.2.4 Optimized Route Reply Message

When destination node receives the route request message it generates route reply message traversing the reverse path which contains two extra parameters along with it. One is fresh coordinates of destination to source node whereas other one is velocity of destination. These two parameters are used to create expected region and request region as shown in figure 3.5.

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|     Type      |R|A|    Reserved     |Prefix Sz|   Hop Count   |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                     Destination IP address                    |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                  Destination Sequence Number                  |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                    Originator IP address                      |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                           Lifetime                            |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                         X-coordinate                          |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                         Y-coordinate                          |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                          V-velocity                           |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 3.4: Optimized Route Reply

3.2.5 Variable Size of Rectangle for Request Region and Expected Region

It is possible that there are not enough intermediate nodes to transfer data from source to destination then algorithm will sense the problem and automatically increase size of rectangle accordingly. It will go on increasing rectangle size until there are enough intermediate nodes to send the data from source to destination.

3.3 Summary

In this chapter, we discussed LAR in detail along with changes which we made in AODV protocol to optimize it. One of the major changes is inclusion of GPS table which keeps track of source and destination node coordinates for certain time period. Some extra fields are added in route request and route reply packets to share important information with other nodes.

Chapter 4

Simulation Results and Discussions

In this chapter, simulation results are analyzed and briefly discussed for AODV, DSR and O-AODV. As mentioned earlier that O-AODV uses RREQ and RREP control packets therefore some extra fields are added in RREQ and RREP to handle GPS values.
Using various performance parameters O-AODV can be compared with traditional AODV or DSR. Most useful parameters to judge performance of algorithm include packet end to end delay, packet delivery ratio, routing packet count etc.

4.1 Network Simulator

For simulation purpose we have used Network Simulator 2. AODV protocol is already built into Network Simulator therefore we changed the already available AODV code for optimization. After that we compared these results with original AODV and DSR. Researchers in Berkley did intensive working and research for Network Simulator 2 It is discrete type of Simulator which is used in research for various protocols including TCP, UDP etc [7] [8]. Coding in Network Simulator is done by using C++ language. For front end interfacing OTCL scripting is used to define interface characteristics or parameters e.g number of nodes, type of traffic, source node, destination node etc. After setting the parameters code is simulated in NS2 that generates two output files. One file is trust with .tr extension whereas other one is nam file with .nam extension. Nam file is used to run simulation in visualized form whereas .tr file is used to collect important information for analysis of performance parameters e.g. packet delivery ratio, end to end delay, total routing packets etc.

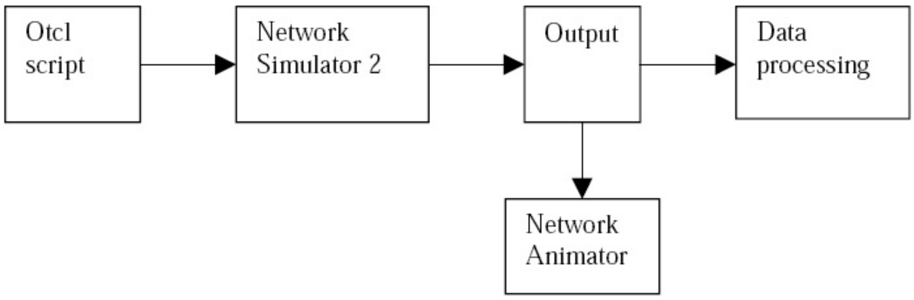

Figure 4.1: Network Simulator 2 [7]

4.2 Simulation trace/NAM files

Simulation in ns normally includes mobility extension therefore input files are as follows [8].
Communication file that defines the pattern of movement of nodes.
Trace file that defines different events e.g. when data is trasferred or when route is broken etc.
Communication file can be created using available scripts which generate random movement pattern over a given period of time. This file is linked in the TCL script whereas OTCL provides linkage between TCL and C++ which after simulation generates trace output file. Using trace file important information is collected and then different performance parameters are analyzed. These parameters are then plotted in form of graphs for understanding and comparison.

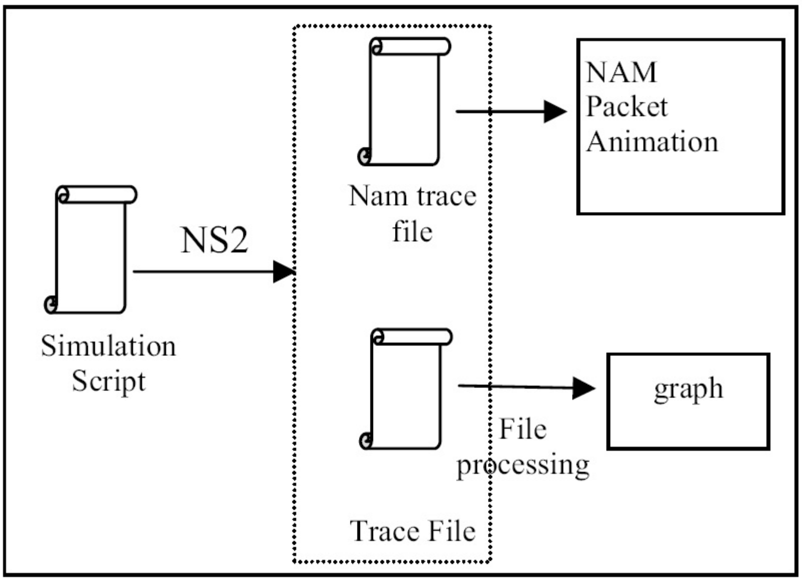

Figure 4.2: Simulation Flow [7]

4.3 TCL Script and Traffic Generation

TCL Script is used to define the parameters of nodes like source node and sink or destination node etc. TCL script also provides option to select protocol to use e.g. in our case optimized AODV [7]. Communication file or movement of nodes is generated through setdest command which is built into NS2. Setdest command has arguments which can be no. of nodes, speed of nodes, total simulation time, pause time, x coordinate or y coordinate etc. After appropriately setting the arguments, output file is generated containing pattern for random movement of nodes encompassing simulation time. This output file is finally imported into TCL script.

4.4 Performance Parameters

Various performance parameters [9] are as follows:

4.4.1 Throughput

Throughput defines how fast packets are transferred from source to destination divided by time when last packet is received.

4.4.2 Packets Dropped

It gives a measure of traffic generated and congestion because packets are dropped during congestion and effects overall packet transfer count.

4.4.3 Packet Delivery Ratio

This gives ratio of how many packets were sent divided by number of packets received by receiver.

4.4.4 Routing Overhead

This means that overall how many routing packets have been used for transfer of data packets. Because initially when there is no route and route has to be build using routing packets. Routing packets are also used when there is break in route.

4.4.5 End-to-end Delay

End to end delay is the time between when packet leaves source and reaches destination. When we add end to end delay of all packets and divide it by total time then it provides average end to end delay. Possible causes of delays are buffering when route discovery is going on, transmission delay at MAC layer etc.

4.4.6 Energy Consumed

Energy consumed is the total amount of energy used by all the nodes during the total simulation time. It is a good parameter to calculate energy.

4.5 Simulation Results

Simulation Results are collected / analyzed by creating three different scenarios which are discussed below:

4.5.1 Number of Nodes

Number of nodes is varied keeping pause time to 0s and velocity at 10m/s then it is plotted against the performance parameters i.e. packet delivery ratio, end to end delay, energy consumed, throughput and router drop etc. It is done firstly with optimized AODV and then repeated again with AODV and DSR for comparison purpose. Comparison graphs for 20,30,40,50 and 60 number of nodes are as follows.

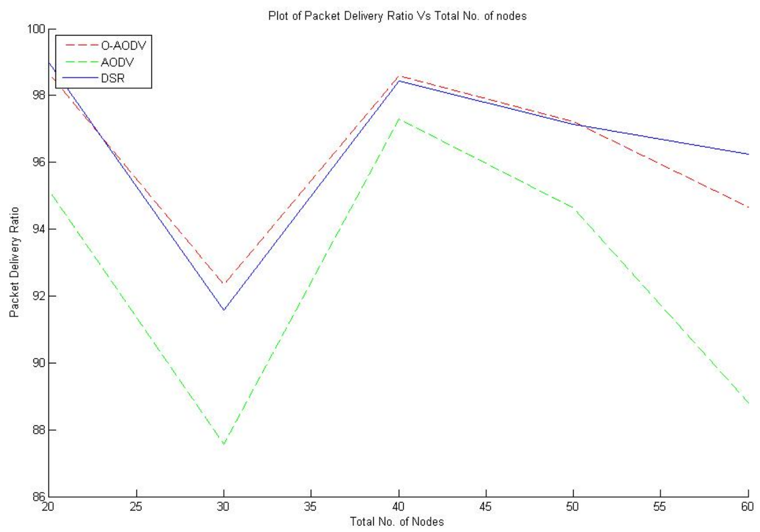

Figure 4.3: Graph of PDR (for varying no. of nodes)

We can see from graph in figure 4.3 that packet delivery ratio is more in O-AODV as compared to AODV or DSR and as we increase number of nodes O-AODV outperforms AODV.

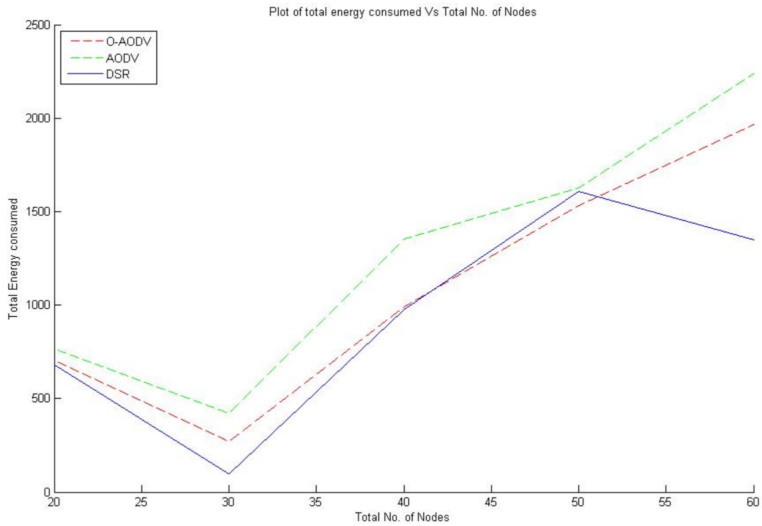

Figure 4.4: Graph of Energy consumed (for varying no of nodes)

Total energy consumed is less in O-AODV as compared to AODV because send request and send reply packets are lesser in O-AODV as evident from figure 4.4 where DSR is further better than O-AODV.

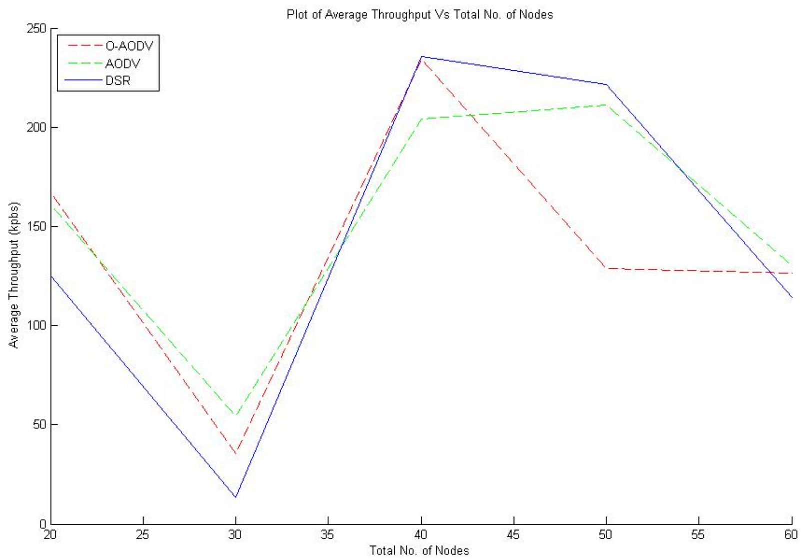

Figure 4.5: Graph of Throughput (for varying no. of nodes)

Average Throughput remains same up to 40 no of nodes and then increases a bit before going down in AODV whereas in O-AODV and DSR it goes down after 40 no of nodes as shown by graph in figure 4.5.

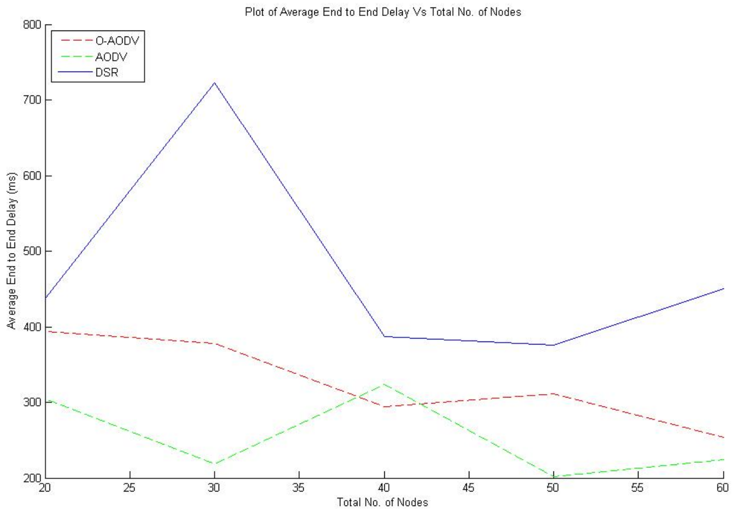

Figure 4.6: Graph of Av. End to End Delay (for varying no. of nodes)

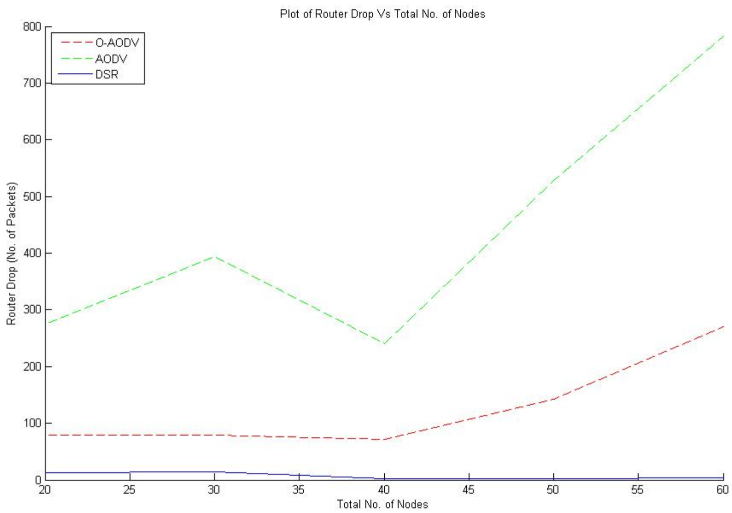

Figure 4.7: Graph of Router Drop (for varying no. of nodes)

End to end delay is less in O-AODV in beginning which becomes more at

40 number of nodes and reduces again after that whereas end to end delay in AODV is lesser than O-AODV and end to end delay of DSR is greater than O-AODV as shown by graph in figure 4.6.

But as evident from figure 4.7 router Drop which is lesser in O-AODV as compared to AODV whereas router drop is very less in DSR.

In table 4.1, we can see that for different number of nodes we can compare total Route Request Packets of O-AODV with AODV. Whereas next coluumn shows comparison of O-AODV Route Received Packets with AODV.

		Route Request		Route Received	
S. No.	Nodes	O-AODV	AODV	O-AODV	AODV
1	20	368	1750	1416	6369
2	30	936	3001	5342	15205
3	40	501	1183	3947	8327
4	50	1893	5383	16856	50163
5	60	5871	12674	59854	123461

Table 4.1: Route Request/received packets for varying no. of nodes

Table 4.2 is the comparison of AODV and O-AODV data send/received: -

		Data Sent		Data Received	
S. No.	Nodes	O-AODV	AODV	O-AODV	AODV
1	20	6693	5143	6604	4894
2	30	1360	2085	1256	1826
3	40	6742	5598	6647	5446
4	50	6323	6634	6147	6278
5	60	5910	4698	5595	4172

Table 4.2: Data packets sent/received for varying no. of nodes

For Performance, we can see from table 4.3 that how router drop has been reduced in O-AODV case when compared with AODV: -

S. No.	Nodes	O-AODV Route Drop	AODV Route Drop
1	20	79	274
2	30	79	394
3	40	72	241
4	50	142	528
5	60	270	782

Table 4.3: Router Drop packets for varying no. of nodes

4.5.2 Speed of Nodes

In this case speed of nodes is varied whereas number of nodes and pause time is kept constant. Again performance parameters i.e packet delivery ratio, end to end delay, energy consumed, throughput and router drop are plotted. In graph both optimized AODV and AODV are plotted together for comparison. Keeping number of nodes to 50 and speed to 25 m/s comparison graph for speed 10, 20, 30, 40 and 50 m/s is as follows: -

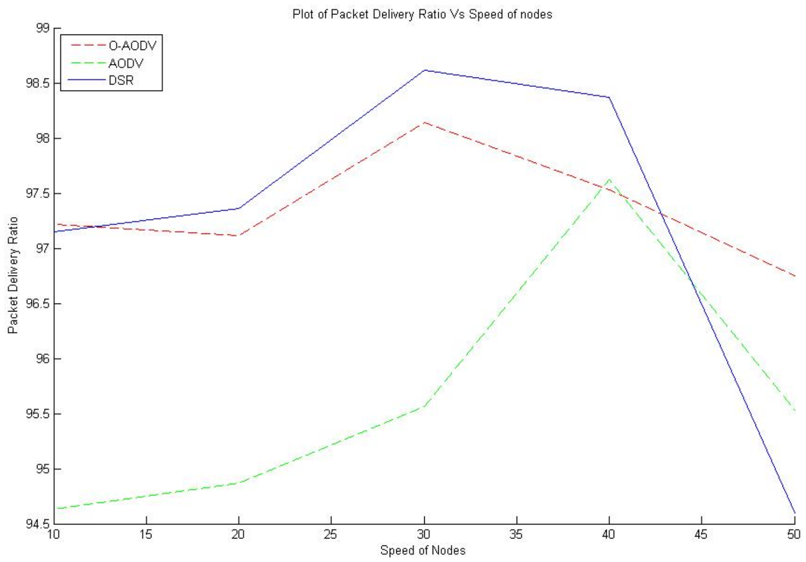

Figure 4.8: Graph of PDR (for varying speeds)

From graph in figure 4.8 we can determine the behaviour of O-AODV when speed of nodes is changed. We can see that Packet delivery ratio is more in O-AODV when compared with AODV whereas DSR is further more than O-AODV.

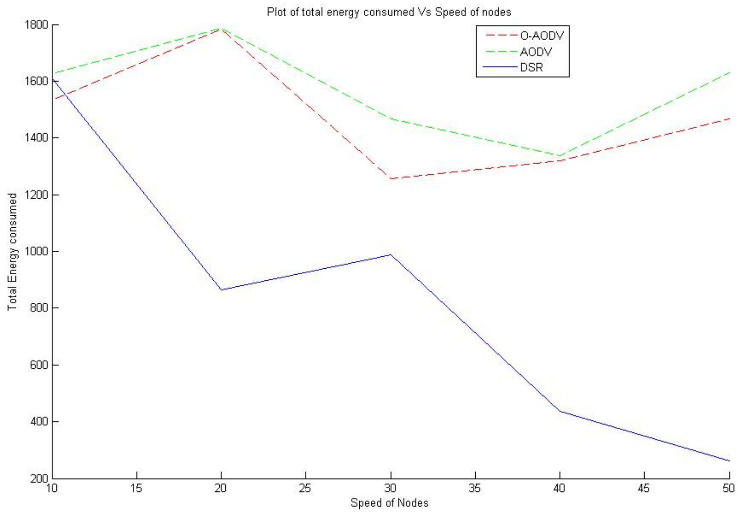

Figure 4.9: Graph of Energy consumed (for varying speeds)

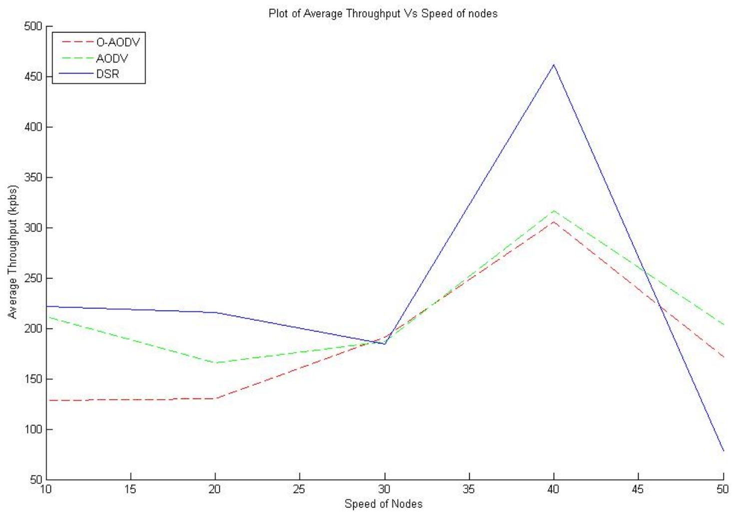

Figure 4.10: Graph of Throughput (for varying speeds)

Total energy consumed in O-AODV is less when compared with AODV

whereas energy consumed by DSR is further less than O-AODV as evident from graph in figure 4.9.
Through put is more in AODV in start but as speed inceases throughput of both AODV and O-AODV becomes almost same whereas throughput of DSR is more than both AODV and O-AODV as shown by graph in figure 4.10.

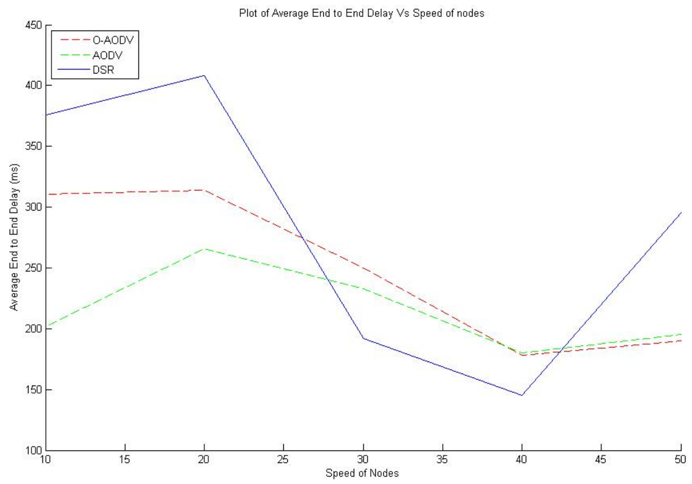

Figure 4.11: Graph of Av. End to End Delay (for varying speeds)

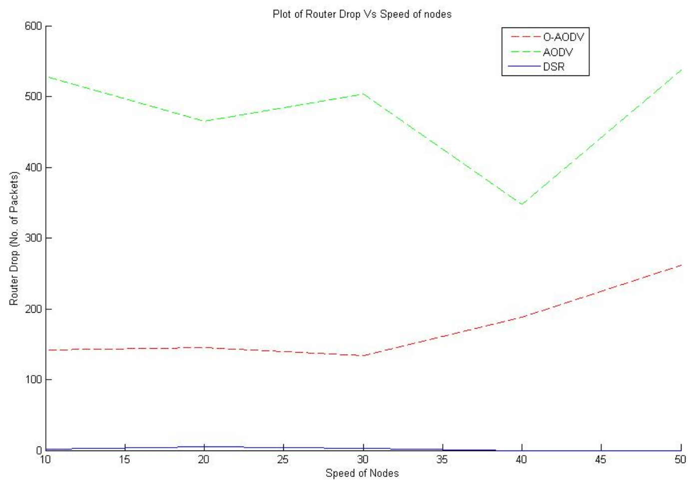

Figure 4.12: Graph of Router Drop (for varying speeds)

We can see from graph in figure 4.11 that End to end delay is less for AODV in start and for higher speeds it becomes almost same for both AODV and O-AODV whereas in DSR it is highest which drastically drops at 20 and again increases at 40..

Router drop is low in O-AODV as compared to AODV wheras DSR is lowest than both AODV and O-AODV as shown by graph in figure 4.12.

For comparison purpose route request and route received packet count of AODV and O-AODV is given in table 4.4.

		Route Request		Route Received	
S. No.	Velocity(m/s)	O-AODV	AODV	O-AODV	AODV
1	10	1893	5383	16856	50163
2	20	2027	3963	17132	30697
3	30	1134	3750	9721	31162
4	40	1413	1412	13028	12283
5	50	2230	5292	19532	43805

Table 4.4: Route Request/received packets for varying speed of nodes

Data sent and Data received of O-AODV and AODV is also shown in table 4.5 for comparison purpose.

		Data Sent		Data Received	
S. No.	Velocity(m/s)	O-AODV	AODV	O-AODV	AODV
1	10	6323	6634	6147	6278
2	20	6105	6064	5929	5753
3	30	8009	6876	7860	6571
4	40	8219	7964	8016	7775
5	50	8362	7297	8090	6971

Table 4.5: Data packets sent/received for varying speed of nodes

Table 4.6 shows how route drop varies in O-AODV and AODV.

S. No.	Velocity(m/s)	O-AODV Route Drop	AODV Route Drop
1	10	142	528
2	20	145	465
3	30	134	503
4	40	188	348
5	50	262	537

Table 4.6: Router Drop packets for varying speed of nodes

4.5.3 Pause Time

Now pause time is varied whereas velocity and number of nodes is kept constant. It is plotted with above mentioned performance parameters. Both O-AODV and AODV are plotted together to get comparison. Pause time is varied with a difference of 2 s i.e. 2,4,6,8,10 whereas number of nodes is kept 50 and v set to 25m/s.

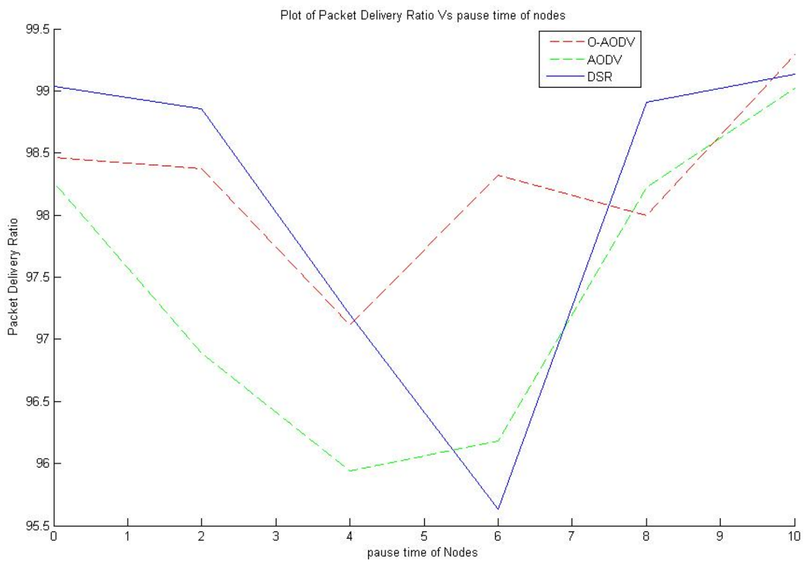

Figure 4.13: Graph of PDR (for varying pause time)

From graph in figure 4.13 we can see packet delivery ratio is more in O-AODV when compared with AODV wheras in DSR it is highest which drops drastically when delay is 2s and at delay of 6s it starts increasing again.

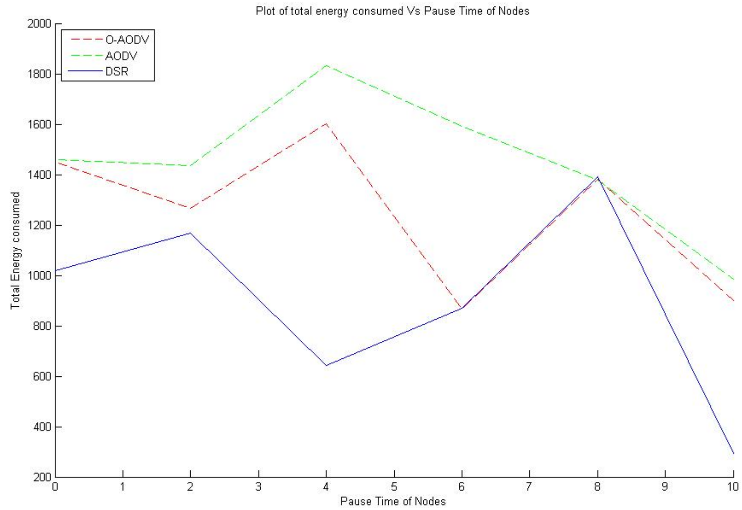

Figure 4.14: Graph of Energy consumed (for varying pause time)

Total energy consumed is less in O-AODV when compared with AODV whereas in DSR it is further less than O-AODV as evident from graph in figure 4.14.

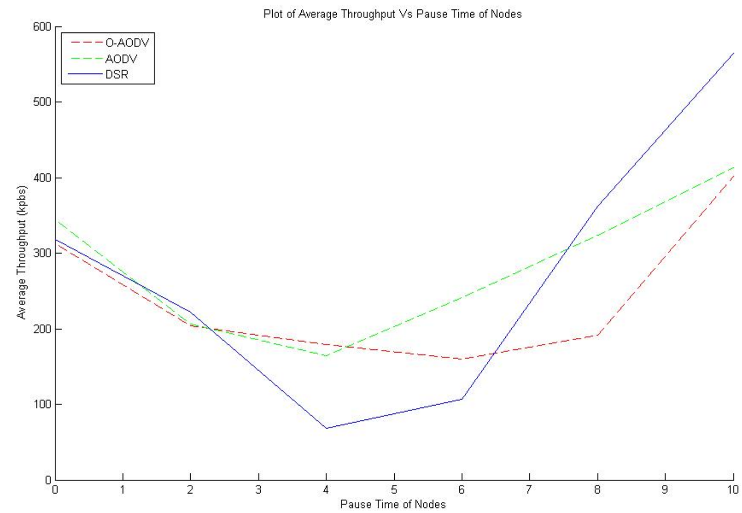

Figure 4.15: Graph of Throughput (for varying pause time)

Average Through put is same in AODV, O-AODV and DSR remain almost same with slight variationas shown in figure 4.15.

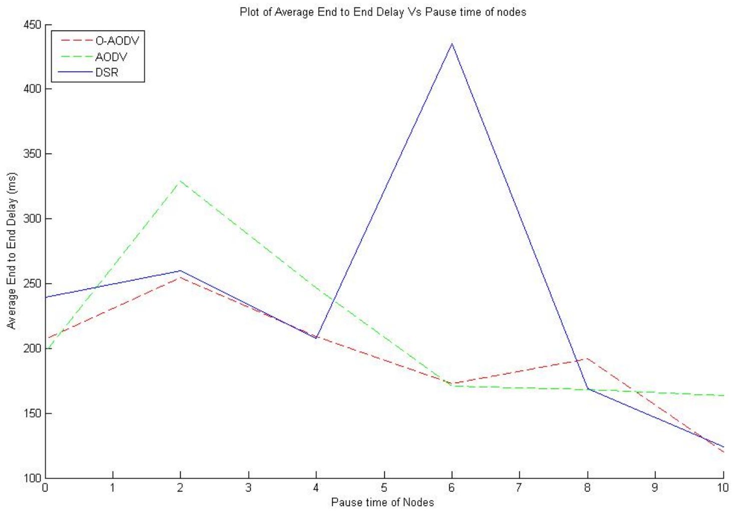

Figure 4.16: Graph of Av. End to End Delay (for varying pause time)

From graph in figure 4.16 we can see that End to end delay in DSR is most least wheras in O-AODV it is even more than AODV.

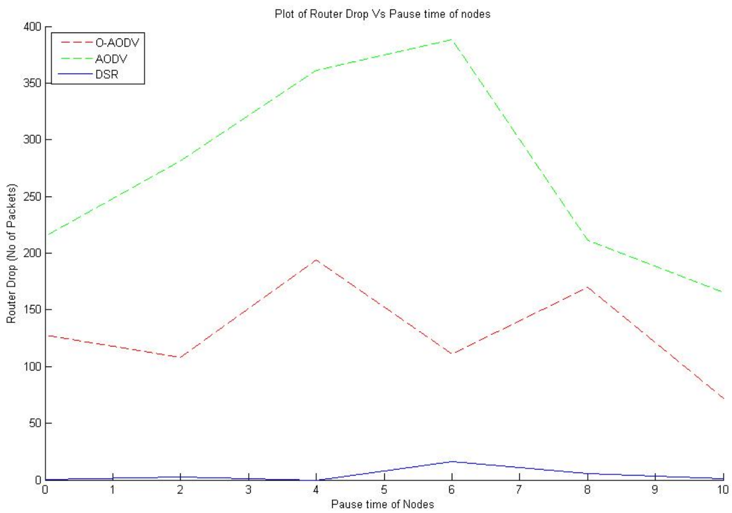

Figure 4.17: Graph of Router Drop (for varying pause time)

Router Drop is less for O-AODV case when compared with AODV as shown in figure 4.17 whereas in DSR it is fruther less than O-AODV.

Comparison of Route request and route received packets for O-AODV and AODV is given in table 4.7.

		Route Request		Route Received	
S. No.	Pause Time(s)	O-AODV	AODV	O-AODV	AODV
1	0	1066	1198	9766	9732
2	2	966	3326	8790	27757
3	4	2445	4766	22075	39491
4	6	1322	4158	11089	33182
5	8	1687	2759	14315	20695
6	10	608	471	5591	3636

Table 4.7: Route Request/received packets for varying pause time of nodes

Data sent and Data received of both AODV and O-AODV is shown in table 4.8.

		Data Sent		Data Received	
S. No.	Pause Time(s)	O-AODV	AODV	O-AODV	AODV
1	0	8580	8535	8448	8387
2	2	7428	6502	7307	6300
3	4	7568	6227	7350	5974
4	6	7804	7150	7673	6877
5	8	8543	8901	8372	8743
6	10	11791	9641	11708	9547

Table 4.8: Data packets sent/received for varying pause time of nodes

Router drop for O-AODV and AODV is compared in table 4.9.

S. No.	Pause Time(s)	O-AODV Route Drop	AODV Route Drop
1	0	128	215
2	2	108	281
3	4	194	361
4	6	111	388
5	8	170	211
6	10	72	165

Table 4.9: Router Drop packets for varying pause time of nodes

Chapter 5

Conclusions

In this thesis, Location Aware Routing Protocols along with tactical MANETs have been discussed in detail. An optimized algorithm has been designed and while evaluating and simulating, it has been observed that this optimized system reduces energy consumption at each node.
An overview of routing protocols are discussed in Chapter 2 explaining the classification of routing. AODV routing protocol is also discussed elaborating how reactive protocol discovers its routes on demand. After which DSR route discovery / maintenance method is discussed. An overview of Optimized AODV Protocol or LAR is discussed in Chapter 3 explaining how existing algorithm of AODV can be modified for optimization. In this chapter general flow of O-AODV is also discussed to provide brief overview of the algorithm. In Chapter 4, results are drawn based on various performance parameters. These performance parameters are then plotted by varying no. of nodes, speed of nodes or pause time of nodes.
Location Aware Routing is basically an enhanced form of wireless MANET but only difference is that it also has GPS information available with it. Therefore to make this information useful, an algorithm has been designed so that broadcast of routing packets is limited to concerned area only i.e. where source and destination lie with enough intermediate nodes in between them. This concerned area is a subset of a bigger region and nodes residing outside this concerned area just ignore send request packets.

Existing AODV protocol has routing table available with it but there is no GPS table available for storing of GPS coordinates which is also required by modified GPS enabled AODV (LAR or O-AODV). Therefore linked list structure has been devised for storing useful GPS information with all the basic functions of add, remove, update, delete and purge etc. If for first time destination GPS is unknown then algorithm generates one full broadcast to all nodes till it reaches desired node and fetches its GPS information and stores in GPS table. It is also necessary to change packet structure to accommodate GPS therefore existing routing packets including route request, route reply etc. have also been modified.
LAR algorithm which we used in this thesis works by creating the rectangle using the GPS of source and destination. This rectangle is subset of bigger geographic region so as to reduce packet broadcast but modified LAR algorithm also checks whether there are enough intermediate nodes in between source and destination so as to create route between them but in case if there are not enough intermediate nodes to create a route then size of rectangle is increased to include more intermediate nodes.

5.1 Future Work

In this thesis, Location Aided Routing is used to optimize MANET. However, some suggestion can be made for giving more room to improving the system.

We have used central GPS to maintain GPS information but it can also be handled in distributed form by adding GPS information with each node after sharing of GPS coordinates. Rectangular region can be reduced to cone shaped region using GPS coordinates in which geographic region is further decreased to a cone instead of rectangle.

In this thesis, communication has been established between single sender and single receiver; it can be further extended to multiple senders/receivers. It is assumed that all nodes are trusted nodes but it is possible to include different security features in algorithm for secure data transfer and to detect intruder nodes.

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