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Genetic Algorithm Based Unipath and Multipath Intelligent Routing for Mobile Ad-hoc Networks

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ABSTRACT

MANET is a self-configuring network of mobile devices connected by wireless links. Each device in a MANET is free to move independently in any direction, and will therefore change its links to other devices frequently. Each node must forward traffic unrelated to its own use, and therefore it acts as a router. In MANETs, unicast routing establishes a multi-hop forwarding path for two nodes beyond the direct wireless communication range. Routing protocols also maintain connectivity when links on these paths break due to effects such as node movement, battery drainage, radio propagation, or wireless interference, hence routing is an important issue in case of MANET.. In this paper Genetic algorithm based intelligent routing protocol for mobile ad-hoc network is proposed. GA technique is required for efficient use of the limited resources while at the same time being adaptable to the changing network conditions such as: network size, traffic density and network partitioning. GA is introduced to provide stability in packet routing to reach the next possible neighboring node in order to avoid resending the packet from the source. GA learns the new routes through crossover and mutation.

Key words : Mobile Ad-hoc Networks (MANETs), Genetic Algorithms(GAs), Ad-hoc On-Demand Distance Vector (AODV), Genetic Algorithm Ad-hoc On-Demand Distance Vector (GAODV), Ad-hoc On-Demand Multipath Distance Vector (AOMDV), Genetic Algorithm Ad-hoc On-Demand Multipath Distance Vector (GAOMDV).

1. INTRODUCTION

MANET is new emerging and has become one of the most important areas of research because of the challenges it pose to the related protocols. It is an infrastructure less network as it allows the users to communicate without using any physical infrastructure regardless of their geographical location. Routing involves transfer of information from a source to a destination in an internetwork. Determining most advantageous routing paths and transferring the packets through an internetwork are the two basic activities performed by routing. The transferring packet through an internetwork is called as packet switching which is straight forward, where as the path determination could be complex. A number of metrics are used by routing protocols as a standard to find the best path for steering of the packets to its destination which could be number of hops, and can be used by routing algorithm to determine the best path for transferring the packet to its destination. The process of path determination involves finding out the suitable routing algorithm and maintain routing tables that contain the complete route information for the packet.

The major requirements of designing an reliable routing protocol in MANETs are as follows:

- Minimum route acquisition
- Route reconfiguration in very short time
- Loop-free routing
- Distributed routing approach
- Minimum control overhead
- Scalability
- QoS provisioning.

The routing protocols in mobile ad-hoc network can be classified in many ways, but most of the classification is done depending on routing strategy and network structure. The routing protocols can be categorized as flat routing; hierarchical routing and geographic position assisted routing based on the network structure.

The classification of routing protocols is as below:

1. **Flat Routing Protocols** In a flat structure, all nodes participating in the network are at the same level and perform the same routing functions. Flat routing protocols are divided mainly into two classes; the first one is proactive routing (table driven) protocols and other is reactive (on-demand) routing protocols.

(a) Table Driven Routing (Pro-Active) Routing Protocols: Proactive routing protocols are also called as table-driven protocols find the routes to all possible destinations ahead of time.

(b) On-Demand (Reactive) Routing Protocols: On-Demand routing protocols are also called as Reactive protocols. These protocols will find the route when it is required in the sense when a node wants to communicate with another node at that moment of time the route will be discovered between the respective source destination pair, and that route will be used for communication. This situation is exactly opposite to previous case of routing where routes will be found ahead of time.

2. **Hierarchical Routing Protocols** The flat routing protocols may produce too much overhead for the MANET as the size of the network increases. In this case a hierarchical routing can be used as solution.

3. **Geographical Routing Protocols** There are two approaches to geographic mobile ad hoc networks :

(a) Actual geographic coordinates (as obtained through GPS – the Global Positioning System).

(b) Reference points in some fixed coordinate system.

2. GENETIC ALGORITHM

GA was invented to mimic some of the processes observed in natural evolution. The idea is to use this power of evolution to solve optimization problems. John Holland was the father of the original GA who invented it in the early 1970's. The basic techniques of the GAs are designed to simulate processes in natural systems necessary for evolution; especially those follow the principles first laid down by Charles Darwin of "survival of the fittest". In nature, in the competition among individuals for scanty resources results the fittest individuals dominates over the weaker ones. GA simulates the survival of the fittest among individuals over consecutive generations for solving a problem. Each generation consists of a population of character strings that are similar to the chromosome that we see in our DNA. Each individual represents a point in a search space and a possible solution. The individuals in the population are then made to go through a process of evolution.

Figure 1 illustrates the four stages of the process using biologically inspired GAs terminology. In each cycle, a new generation of the candidate solutions for a given problem is produced. At the first stage, an initial population of the potential solutions is created as a starting point for the search. Each element of the population is encoded into a string chromosome, to be manipulated by the genetic operators.

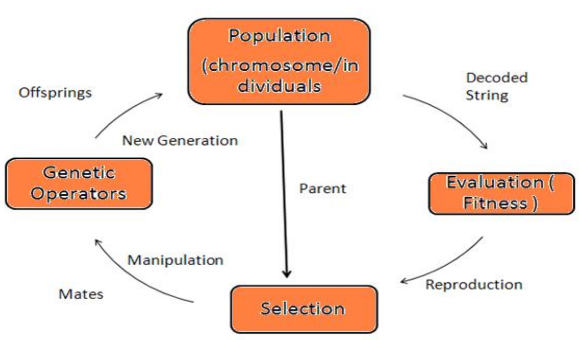

Figure 1. Genetic Algorithm Cycle

In the next stage the performance (fitness) of each individual of the population is evaluated, with respect to the constraint imposed by the problem. A selection mechanism chooses "characteristics" for the genetic manipulation process based on each individual's fitness. The selection mechanism is responsible for assuring survival of the best fitted individuals.

2.1 Genetic Operators

Genetic operators mimic the process of heredity of genes to generate new offspring at each generation and play a very significant role in genetic algorithm Based on Natural Selection Once an initial population is randomly generated, the algorithm evolves through three operators:

1. **Selection:** This equates to survival of the fittest.

• It gives preference to better individuals, allowing them to pass on their genes to the next generation.

2. **Crossover:** This represents mating between individuals.

• Prime distinguished factor of GA from other optimization techniques

• Two individuals are chosen from the population using the selection operator

3. **Mutation:** This introduces random modifications.

• With some low probability, a portion of the new individuals will have some of their bits flipped.

• Its purpose is to maintain diversity within the population and inhibit premature convergence.

• Mutation alone induces a random walk through the search space

• Mutation and selection (without crossover) create a parallel, noise tolerant, hill-climbing algorithm.

3. ROLE OF GENETIC ALGORITHM IN MANET

Existing applications of genetic algorithms is to have not only optimized network topology, but also a total solution to ad-hoc network design using a genetic algorithm approach. Because of this topology optimization, reliability of the network is improved as it checks for nodes whose failure would break the network into two or more pieces.

The optimization process then redesigns the links to improve reliability. Such a reliability requirement dictates that two non-identical paths connect every two nodes in the network. This gives rise to a ad-hoc network, which interconnects adjacent nodes. Our topology optimization process adopts a depth-first search to test network bi-connectivity. A depth-first search visits every node and checks every link in the network systematically.

A genetic algorithm poses the potential solution of a problem as a set of parameters encoded as a string of binary bits. These parameters are like the genes of a chromosome, and they change order from generation to generation, much like genes in an actual chromosome. Standard genetic algorithm manipulations, such as crossover and mutation, mix and recombine the genes of a parent population (mating pool) to form offspring for the next generation.

Genetic algorithm approach breaks the problem of network design into three optimization processes—for topology, routing, and capacity—and applies the genetic algorithm technique to each. In the optimization processes, a fitness function is calculated which may recognize the connection cost in the network.

GA belong to the class of evolutionary algorithm (EA), which generate solutions to optimization problems using techniques inspired by natural evolution, such as inheritance, mutation, selection and crossover.GA is developed by John Holland, University of Michigan a fitness function to evaluate the solution domain.

A routing path contains of sequence of nodes in network. The genetic algorithm is applied to paths that is been obtained from the route discovery phase. A routing path is encoded by a string of positive integers that indicating the IDs of the nodes in the network. The length of the string should not be more than the number of nodes present in the network.

1. **Initial population**

In GA each chromosome represents a potential solution and this can contain more than one solution initially. The paths obtained from route discovery phase are considered as initial chromosomes.

2. **Fitness function**

For an obtained solution, it should be able to evaluate its quality accurately which can be done with the help of fitness function. Our goal of using this GA is to find a path for better throughput between source and destination and the larger buffer size that the path can have in case of route failure.

It is important to obtain the shortest path and lowest delay time as the primary concern then we can choose according to the buffer size. The fitness of each chromosome can be calculated as:

$$f\,(Ch_i) = \left[\sum l\epsilon p\,(s,r)\; C_l + C_d\right]$$

The Ch represents the chromosome fitness value and Cd the delay time taken by each chromosome where Cl represents the cost of the path. The above fitness function is been maximized and involves only shortest path and delay constraint, the buffer size for every path is been checked in the evolutionary process.

3. **Selection scheme, crossover and mutation**

Selection plays a key role in improving the quality of population of chromosomes. The selection of chromosome is purely done on the result of fitness function. Crossover is done to find the better solution from current one. Since chromosome are been used as path structure, every time we choose two chromosomes Chi and Chj for crossover. Chi and Chj should have at least one common node mentioned as v. Now we have two paths Chi(s→ r) and Chj(s→r). Now we have v in both paths can be mentioned as Chi(s→v) and Chi (v→r), Chj(s→v) and Chj(v→r). Now we exchange the sub path Chi (v→r) and Chj(v→r). The population will undergo mutation after the crossover had been performed. Both crossover and mutation may produce infeasible solution so we need to check it for its acyclic nature.

Great deals of successful research in the field of Mobile Ad-hoc Networks have been inspired by Genetic Algorithms. Yet, we believe that genetically inspired mobile ad-hoc networking still has a better solution in routing. In particular, there are great opportunities in exploring a new approach. GA is general purpose optimization technique based on the natural selection of the fittest individual for the production of the new generation. In Genetic Algorithm the solution of the problem is encoded on a string of bits that is comparable with the chromosome of the biological system analogy.

4. GENETIC ALGORITHM BASED UNIPATH ROUTING

As per the request (demand) the routes are developed in unipath on-demand routing protocol. Here only one path will be used during communication between source and estination if the link failure occurs other path will be selected for communication. The working is as follows. When a node wants to communicate with another node, it initiates a route discovery process to find a route.

The following are the two main phases of communication.

1. Route discovery: The process of finding a route between two nodes.
2. Route maintenance: The process of repairing a broken route or finding a new route in the presence of a route failure.

Mobile Ad-hoc Networks which do not have fixed topology use AODV which is an efficient and effective routing protocol. This algorithm was motivated by the limited bandwidth that is available in the media that are used for wireless communications.

AODV is an on demand routing protocol, which builds routes between nodes only as desired by source nodes. These routes are maintained as long as they are needed by the sources. There by making it an on-demand routing protocol.

In AODV, each node maintains at most one route per destination and as a result, the destination replies only once to the first arriving request during a route discovery. Being a Unipath protocol, it had to invoke a new route discovery whenever the only path from the source to the destination fails. As topology changes frequently, route discovery needs to be initiated often which can be very inefficient since route discovery flood is associated with significant latency and overhead.

Genetic Algorithm can be used successfully for complex problems. Many parameters can be manipulated efficiently at the same time using genetic algorithms.

The use of parallelism enables them to produce multiple equally good solutions to the same problem. To address the mentioned problem by looking at the strength of GA, propose a reliable routing protocol which bases on the route life – time that is obtained using mobility information and residue energyand low latency. In on-demand protocols, AODV is found to be the most energy efficient routing protocol, therefore most have the studies concentrate on making AODV routing protocol more energy efficient by applying genetic algorithm To present a genetic algorithmic approach, variable length chromosomes and their genes have been used for encoding the problem, the crossover operation exchanges partial chromosomes at appositionally independent crossing site and mutation operation maintained the genetic diversity of the population. The objective of a GA in this work is to assist in the routing by doing some processing in the information. The algorithm which proposes GA based AODV in an efficient way so that the Ad- hoc network has a greater life time and energy consumption across the nodes is reduced.

4.1 Working Principle GAODV Routing

Genetic Algorithm Based Ad-hoc On-demand Distance Vector (GAODV) algorithm is altered such that the Route Request (RREQ) and Route Reply (RREP) packets sent during route discovery and route reply contain fields that provide a measure of the transmitted power and node capacity.

Route Table Entries are as follows:

- Destination IP Address
- Destination Sequence Number
- Valid Destination Sequence Number flag
- Other state and routing flags (e.g., valid, invalid)
- Network Interface
- Hop Count
- Next Hop
- List of Precursors
- Lifetime (expiration or deletion time of the route)
- Maximum Remaining Energy Capacity

During route discovery from the source to the destination the energy values along the route are accumulated in the RREQ packets. At the destination or intermediate node (which has a fresh enough route to the destination) these values are copied into the RREP packet which is transmitted back to the source. The algorithm once designed is to be evaluated using the performance metrics average energy consumed, routing overhead, throughput and packet delivery ratio etc. The way GA works is by combining existing routes which share a common node and destination in order to generate new routes and selecting the routes which are more efficient in terms of achieving the goal. This processing is done only at the source node. Here the figure 2 represents the design model of the work.

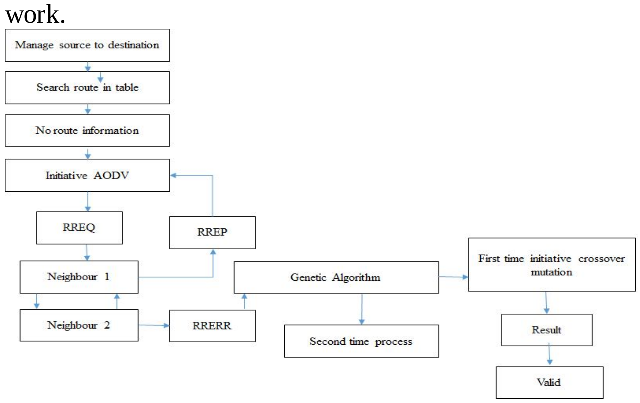

Figure 2. Design model of a GA based Intelligent unipath Routing

The proposed genetic based unipath routing algorithm is shown below.

When a source node wants to transmit some data to a destination node, it needs an active route from itself to the destination. If the source node has no active routing information regarding the destination, it initiates the route discovery process. When a source node needs a route to a destination node and there is no valid route in the routing table, the source node broadcasts a route request packet (RREQ) to the destination node. When each node receives the RREQ, it creates or updates a reverse route to the source node in the routing table. If it does not have a valid route to the destination node in the routing table, it rebroadcasts the RREQ.

In this protocol, each RREQ packet records information of all links-status and nodes along traversed path. Link-status information is delivered from the source node to the destination node along with energy values. The destination node may receive link-status information from different RREQ packets; it means that there are different feasible paths. Finally, required computation for route selection is accomplished at the destination node and result is backward to the source node in order to decide route.

5. GENETIC ALGORITHM BASED MULTIPATH ROUTING

Multipath routing consists of finding multiple routes between a source and destination node. These multiple paths between source and destination node pairs can be used to compensate for the dynamic and unpredictable nature of ad-hoc networks. The general use of multipath routing is related to co-operative working and balancing loads. Unlike unipath, in multipath routing, the data flow is divided among a number of paths which leads to a better balancing of load. In this work Ad-hoc On-demand Multipath Distance Vector (AOMDV) is considered. In MANET many traditional routing protocols are associated with unipath routing feature. In unipath routing the optimal route is maintained in only the source nodes routing table even though multiple routes will be detected during a routing discovery process. AODV is one of the examples of unipath routing protocol. In contrast with unipath, multipath protocols maintain all routes that can be detected during a route discovery process in the source node routing table. All detected routes can be used sequentially (e.g. as backup routes) or co-operatively (e.g. for load balancing) for data transmission process between a source and destination nodes. In multipath protocols, a source can select the optimal route among multiple available routes, which enhance the route availability and ultimately minimizes

frequent re-establishing of route discovery process.

Multipath routing is considered as advantage due to easy recovery from a route failure and because of this multipath protocols are considered more reliable and robust. Along with easy recovery from route failure, multipath routing also can save energy, reduce frequent routing update, enhance data transmission rates and increase wireless network bandwidth. In a broad sense, multipath routing enables route reliability and facilitates load balancing. These two advantages are commonly used in several applications.

5.1 Implementation

AOMDV uses, the AODV route construction process. In this case, however, some extensions are made to create multiple loop-free, link-disjoint paths. The main idea in AOMDV is to compute multiple paths during route discovery. It consists of two components:

• A route update rule to establish and maintain multiple loop-free paths at each node.

• A distributed protocol to find link-disjoint paths.

5.2 Sequence Numbers and Loop Freedom

1. Every node maintains a monotonically increasing sequence number for itself.
2. It also maintains the highest known sequence numbers for each destination in the routing table (called “destination sequence numbers”).
3. Destination sequence numbers are tagged on all routing messages, thus providing a mechanism to determine the relative freshness of two pieces of routing information generated by two different nodes for the same destination.
4. The AODV protocol maintains an invariant that destination sequence numbers monotonically increase along a valid route, thus preventing routing loops.
5. A node can receive a routing update via a RREQ or RREP packet either forming or updating a reverse or forward path.
6. It refers to such routing updates received via a RREQ or RREP as “route advertisements.”
7. Represents the sequence number at node i for the destination.
8.Rrepresents the hopcount to the destination d from node i .
9. For any two successive nodes i and j on a valid path to the destination, j being the nexthop from i To d , the route update rule enforces that
10. The tuples along any valid route are in a lexicographic total order, which in turn implies loop freedom.

5.3 Computing Multiple Loopfree Paths

1. The advertised hopcount of a node i for a destination d represents the “maximum” hopcount of the multiple paths for d available at i .
2. The protocol only allows accepting alternate routes with lower hopcounts.
3. This invariance is necessary to guarantee loop freedom.
4. In AOMDV, advertised_hopcount replaces hopcount in AODV.
5. A route_list replaces the nexthop, and essentially defines multiple next hops with respective hopcounts.
6. A node i updates its advertised_hopcount for a destination d whenever it sends a route advertisement for d .
7. A key observation here is that similar to AODV the following condition holds good for two successive nodes i and j on any valid route to destination d.

5.4 Finding Link-disjoint Paths

• Maintain last hop info in routing table.

• Ensure that next hops and last hops before destination are unique.

• This requires route request and replies to carry first hop info.

5.5 Route Maintenance

• If a node does not receive a confirmation from the next node that the packet was successfully forwarded, initiates a Route Error message back to the source

• The data packet will be transmitted over another existing path (if multipath) or a new route discovery could be initiated.

6. **SIMULATION AND RESULT ANALYSIS**

6.1 Network Simulator-2 (NS2)

The NS2 or Network Simulator is discrete event network simulator. NS is popularly used in the simulation of routing and multicast protocols, and is heavily used in ad-hoc networking research. NS is an object oriented simulator, written in C++, with an OTcl interpreter as a frontend. Some of the list of simulator commands commonly use in simulation scripts:

1. To create an instance of the simulator object and working with instance.
2. Creating a node and working with nodes
3. Creating Links between the nodes
4. Queue Management
5. Attaching Agents

6.2 Performance Evaluation Metrics

The performance metrics are considered for evaluation of these routing protocols areas follows:

1. **Throughput:** Throughput is the measure of how fast we can actually send packets through network. The number of packets delivered to the receiver provides the throughput of the network. The throughput is defined as the total amount of data a receiver actually receives from the sender divided by the time it takes for receiver to get the last packet .

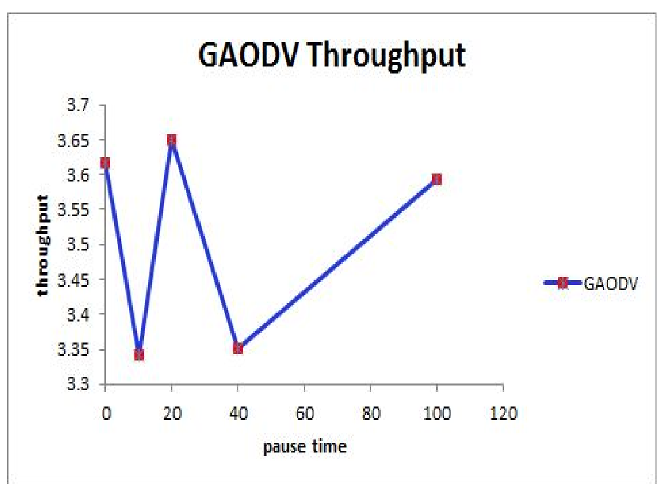

Figure 3. GAODV Throughput

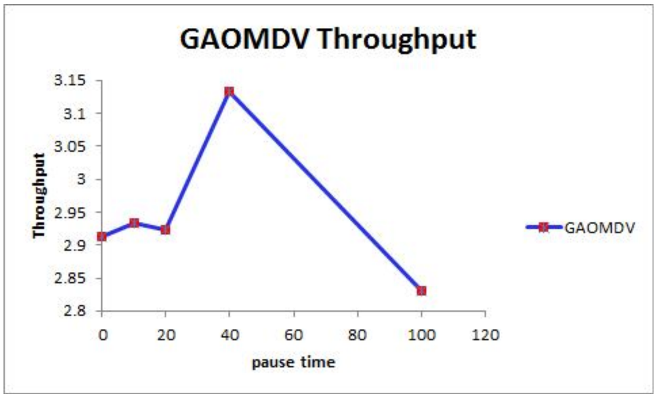

Figure 4. GAOMDV Throughput

2. **Packets Dropped:** Some of the packets generated by the source will get dropped in the network due to high mobility of the nodes, congestion of the network.

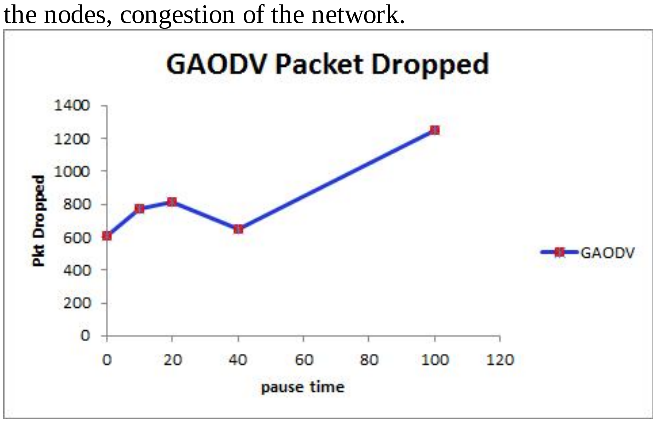

Figure 5. GAODV Packet Dropped

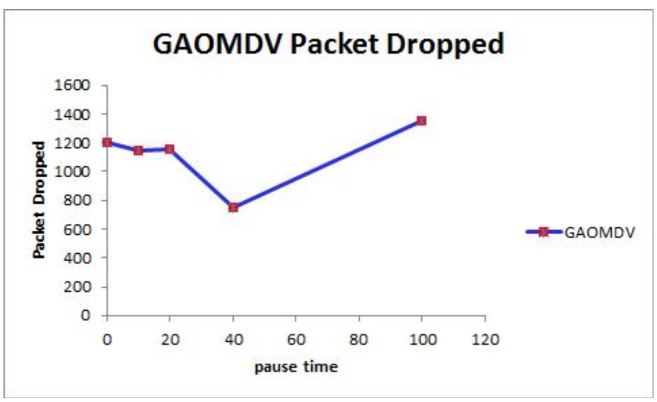

Figure 6. GAOMDV Packet Dropped

3. **Packet Delivery Ratio:** The ratio of the data packets delivered to the destinations to those generated by the CBR sources. It is the fraction of packets sent by the application that are received by the receivers .

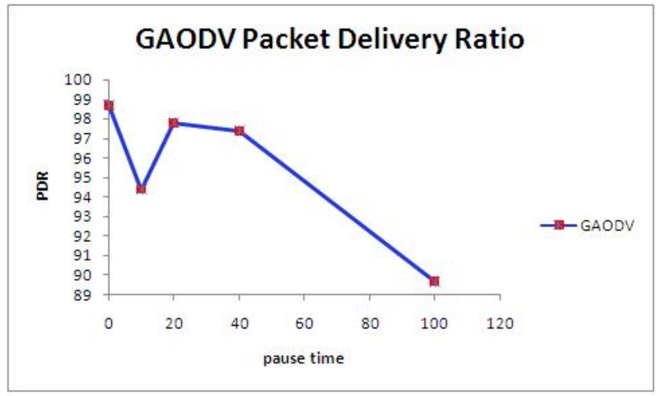

Figure 7. GAODV Packet Delivery Ratio

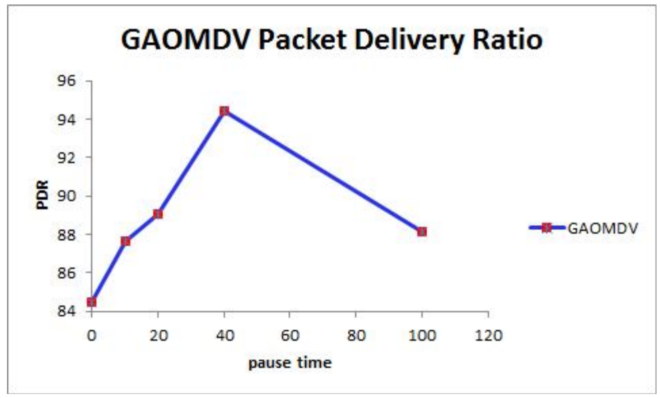

Figure 8. GAOMDV Packet Delivery Ratio

4. **Routing Overhead:** The number of routing packets transmitted per data packet delivered at the destination. Each hop-wise transmission of a routing packet is counted as one transmission. The routing overhead describes how many routing packets for route discovery and route maintenance need to be sent in order to propagate the data packets.

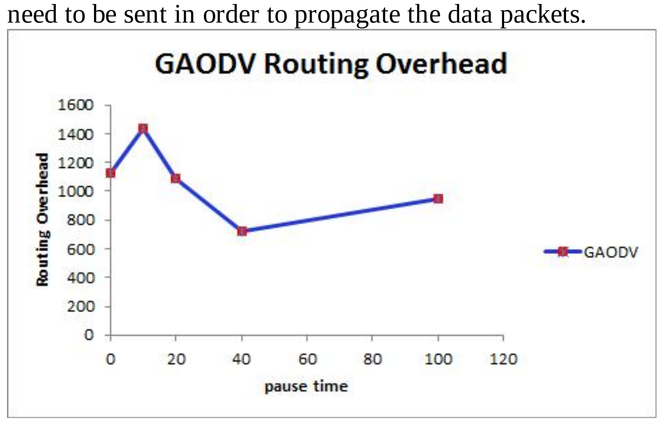

Figure 9. GAODV Routing Overhead

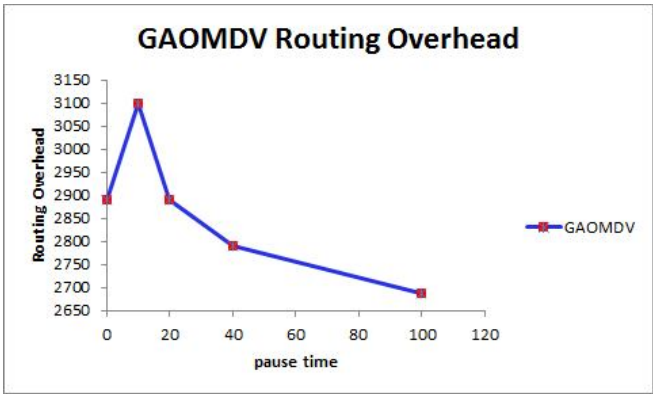

Figure 10. GAOMDV Routing Overhead

7. CONCLUSION

Mobile Ad-hoc Networks (MANETs) have received increasing Research attention in recent years. Mobile ad hoc networks are wireless networks that use multi-hop routing instead of static networks infrastructure to provide network connectivity. MANETs have applications in rapidly deployed and dynamic military and civilian systems. The network topology in MANETs usually changes with time.

We have developed a novel approach called GAODV to improve the performance. In GAODV we have used genetic algorithm search technique which searches for population of solutions and not a single solution. In GAODV when route failure occurs Genetic algorithm is used to find the next path to destination at the node where route error is generated instead of reinitiating route request by the source.

In the second approach we have concentrated on the working of multipath on-demand routing protocol. Here the work is based on AOMDV. In AOMDV we will be having multiple path in between a pair of source and destination if primary path fails secondary will be used which will might again fail because of less energy. In the proposed approach GAOMDV we are using genetic algorithm to select the secondary path by using genetic algorithm whose fitness function is taken as residue energy of the nodes.

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