Geometric Routing Protocol based on Genetic Algorithm for Delay Minimization in MANETs

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Summary
Mobile Ad hoc Networks are consisting of mobile nodes having limited radio range and bandwidth without having any fixed infrastructure. Thus to deliver the message from source to destination does not only require to establish the shortest route for message delivery to the destination. But also to establish such a route that can deliver the message with minimum delay so that the message can be sent from source to destination with the maximum data rate with minimum delay. To establish such a route with minimum delay we attempt to propose a Genetic based Algorithm for establishing a route with minimum delay in Geometric Routing.

Key words:
Position-based (geomeric) routing ;mobile adhoc netwoks (MANETs); Genetic Algorithm; bandwidth ; delay , simulation.

I. Introduction

A mobile ad hoc (MANET) [1, 2] is an infrastructure less network that is consisting of mobile nodes that communicate with each other via wireless links. Such types of networks are the best suitable for use in the areas where the establishment of the fixed infrastructure is not possible, not trusted, or unreliable. For example a network of notebook computers or Personal Data Assistances in a conference or campus setting, rescue operations and head quarts industries. In infrastructure less networks mobile nodes have to cooperate to provide the network functionality. Thus each node works as a routing node and has to perform the routing to establish the route between the mobile nodes that are not directly within each other's transmission range. Thus the development of efficient routing protocol is a non trivial and a challenging task due to the specific character of a MANET scenario.

- Due to the mobility of the nodes the network topology changes randomly and rapidly.
- The bandwidth availability for the each mobile node is limited and varies due to noise, fading and interference effects.
- Most mobile devises are battery operated thus the energy consumption plays a vital role.

As existing routing algorithms can be broadly classified into two categories [12].

- Topology-based routing protocols
  - Proactive protocols
  - Reactive protocols
- Position-based routing protocols
  - Greedy Routing protocols
  - Geographical Routing protocols

This paper focuses on the *position based routing* (also called the *geometric* or *geographic routing*) .Position-based routing protocols are attractive because they have the lower route discovery overhead as compared to proactive and reactive topology-based protocols ,using flooding. In position based routing each mobile node knows its position and the positions of their neighbor nodes using location service of the GPS modems by the satellite attached with each mobile node. Thus the source node knows the position of the destination node. As the position based routing protocols employ the greedy forwarding as basic routing operation. In Greedy forwarding based protocols we establish a shortest route between source to destination node without checking for the compatibility of the established shortest route for the message size which is to be sent to the destination node, means that either the message can be sent with minimum *delay* or not. Unlike the Greedy forwarding protocols our proposed algorithm is based on Genetic Algorithm to establish a route with minimum delay for the message delivery.
The rest of the paper is organized as follows: Section II introduces the genetic algorithm as an optimization technique Section III deals with the proposed GA based routing algorithm for minimized delay. The simulation environment is described in Section IV. The experimental results are shown in Section V and conclusion is given in Section VI

II. GENETIC ALGORITHM

Genetic Algorithm [2, 14, 15, and 16] was first proposed by John Holland, was adopted from natural evolution of

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new species in the nature. As the natural evaluation has the following feature:

1) The individual characteristics are encoded on a chromosome.

2) Each chromosome has a certain fitness function value according to the environment in which it exists.

3) Individual chromosomes judged stronger are able to survive and produce next generations of strong individual chromosomes.

Thus GA is general purpose optimization tool 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. The Genetic Algorithm keeps a population of randomly selected chromosomes to combine by mutation or crossover techniques and produce the offspring having new characteristics, which in turn replaces the low fitness old chromosomes .This process is repeated until we find a chromosome with best and repeated characteristics for the successive generations of the population. Which finally represent the optimal solution for the problem. There are two mechanisms are used that link a genetic algorithm to the problem it is solving. These mechanisms are:

1) Encoding of the possible solutions to the problem on the chromosomes in the form of the parameters that are desired to optimized for the given problem environment.

2) Evaluation function that returns a fitness value of a chromosome in the context of the problem. Thus the evaluation function is environment in natural evaluation.

In order to use Genetic Algorithms for networking applications, the chromosome consists of the network parameters as the genes of the chromosomes. A possible chromosome would be a string consisting of the various mobile nodes parameters for the wireless network. The fitness function assigns the fitness value to each chromosome that is assigned according to the objective of the design problem. If the objective is to minimize the route delay between source and destination, then the fitness function will compute the route delays of all possible paths between source to destination and return the minimum delay path among the all possible paths between source to destination

III. THE PROPOSED TECHNIQUE

The proposed Genetic based algorithms for the route discovery with minimized delay in geometric routing are as follows:

Genetic Algorithm for the Delay Minimization

Step1: *Let each node have route table with delay, distance, bandwidth and mobility characteristics for each node.*

Step2: *Categorize the ranks of routes according to the number of hopes (node).*

Step3: *Now for each group apply the Genetic Algorithm with number of chromosomes equal to the number of nodes.*

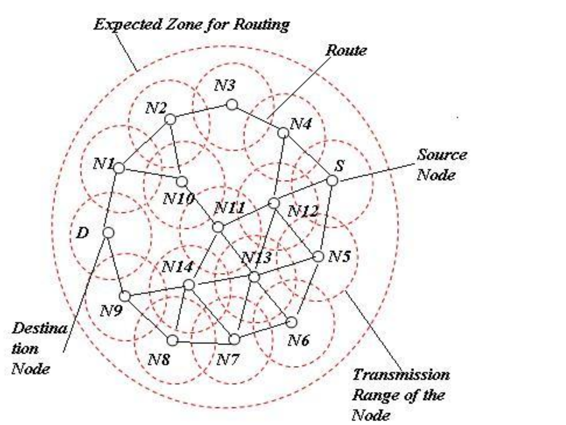
Step4: *Now for each chromosome set minimize the fitness function.*

$$= \sum_{i=1}^{N}(Di) + \sum_{i=1}^{N}(DISTi) + Max\left(\frac{1}{(BWi)}\right) + Max((MOVi))$$

Step5: *Repeat the algorithm for all groups and form the final route table by storing the best route from all groups (of different hop counts).*

Step6: *Select the route with minimum fitness value from this final route table.*

Step7: *If more than one route having the same minimum value then randomly select any one route of them*



In Geometric Routing each node is attached with a GPS Modem thus Source Node is aware of the Destination Node location. Thus the routing is performed in the Expected Zone consisting of the mobile nodes by which the message can be sent to the destination node. The Source Node S is having a Route table (***Table-2***) consisting of all the possible routes by which the message can be sent to the destination node.

Symbol	Definitions
Di	Processing Delays at Nodes
DISTi	Distance to the next Node
BWi	Bandwidth available at the Node
MOVi	Mobility Ratio of the Node
N	Hop Count for the Route

Table-1

Group-A (Chromosomes) for Route Hop Count N = 4									
D	N9	N14	N11	N12	S				
D	N1	N10	N11	N12	S				
D	N9	N14	N13	N12	S				
D	N9	N14	N13	N5	S				
D	N1	N2	N3	N4	S				
Group-B (Chromosomes) for Route Hop Count N= 5									
D	N9	N8	N14	N11	N12	S			
D	N9	N14	N13	N11	N12	S			
D	N9	N8	N7	N13	N12	S			
D	N9	N14	N7	N13	N12	S			
D	N1	N10	N11	N13	N12	S			
D	N9	N14	N13	N5	N12	S			
D	N9	N14	N11	N12	N5	S			
D	N9	N8	N7	N6	N5	S			
D	N9	N14	N7	N6	N5	S			
D	N1	N10	N13	N6	N5	S			
D	N1	N10	N11	N13	N5	S			
D	N1	N10	N2	N3	N4	S			
D	N9	N14	N11	N12	N4	S			
Group-C (Chromosomes) for Route Hop Count N= 6									
D	N9	N8	N7	N6	N13	N12	S		
D	N9	N8	N7	N6	N5	N12	S		
D	N9	N8	N7	N13	N5	N12	S		
D	N9	N14	N7	N13	N5	N12	S		
D	N9	N8	N7	N14	N11	N12	S		
D	N1	N2	N10	N11	N13	N5	S		
D	N1	N10	N11	N14	N13	N5	S		
D	N1	N2	N10	N13	N6	N5	S		
D	N1	N2	N10	N11	N12	N5	S		
Group-D (Chromosomes) for Route Hop Count N= 7									
D	N9	N14	N11	N10	N2	N3	N4	S	
D	N9	N8	N7	N13	N11	N12	N4	S	
D	N9	N8	N7	N6	N5	N12	N4	S	
D	N1	N2	N10	N11	N13	N6	N5	S	
D	N9	N8	N7	N6	N13	N12	N5	S	
D	N9	N8	N7	N14	N11	N12	N5	S	
D	N9	N8	N14	N7	N6	N5	N12	S	
Group-E (Chromosomes) for Route Hop Count N= 8									
D	N9	N8	N7	N6	N13	N11	N12	N5	S
D	N9	N14	N11	N10	N2	N3	N4	N12	S

Route table of all possible routes of different Hop Counts from Source to Destination

Table-2

But the Source Node can't decide about the route with the minimum delay among all the possible routes in the route table thus the GA based algorithm helps the source node to find out the route with minimum delay.

The detailed description of the Genetic Algorithm for Delay Minimization is as follows:

Step1: In this step of the algorithm initially all the nodes in the network have a route table with delay, distance, bandwidth and mobility characteristics for each node as shown in the ***Table-3.***

N9	Processing Delay (D9)
	Distance to Next Hope (DIST9)
	Bandwidth (BW9)
	Mobility Ratio (MOV9)
N14	Processing Delay (D14)
	Distance to Next Hope (DIST14)
	Bandwidth (BW14)
	Mobility Ratio (MOV14)
N11	Processing Delay (D11)
	Distance to Next Hope (DIST11)
	Bandwidth (BW11)
	Mobility Ratio (MOV11)
N12	Processing Delay (D12)
	Distance to Next Hope (DIST12)
	Bandwidth (BW12)
	Mobility Ratio (MOV12)

Structure of the Group-A Chromosome (route table entry) for the route with hop count (N=4) (N9, N14, N11, N12)

Table-3

Similarly other chromosomes of the different hop count groups have the same structure for the chromosomes but having only difference in the hop counts which decides the number of genes in a chromosome as shown in ***Table-4.***

Groups	***No of Genes (N*4)***
Group-A (Chromosomes) for Route Hop Count N = 4	*16*
Group-B (Chromosomes) for Route Hop Count N= 5	*20*
Group-C (Chromosomes) for Route Hop Count N= 6	*24*
Group-D (Chromosomes) for Route Hop Count N= 7	*28*
Group-E (Chromosomes) for Route Hop Count N= 8	*32*

Table-4

Step2: In this step the grouping of routes (chromosomes) is done according to the numbers of hop counts as shown ***Table-2.***

Step3: Now for each group apply the genetic algorithm with number of routes (chromosomes) each having the equal number of nodes.

Step4: Now for each chromosome set of a group apply the fitness function

$$= \sum_{i=1}^{N}(Di) + \sum_{i=1}^{N}(DISTi) + Max\left(\frac{1}{(BWi)}\right) + Max((MOVi))$$

For example for the Group-A chromosome with hop count (*N=4*) (*N9, N14, N11, N12*) for which the chromosome structure is given in ***Table-3.***The fitness function value will be evaluated as follows:

$$= \sum_{i=1}^{N=4} Di + \sum_{i=1}^{N=4} DISTi + Max\left(\frac{1}{BWi}\right) + Max\,(MOVi)$$

=(D9+D14+D11+D12)+(DIST9+DIST14+DIST11+D12) + (1/BW11) + (MOV14)

Similarly the fineness function value is evaluated for the other chromosomes of different hop count groups.

$\sum_{i=1}^{N=4} Di$	Denotes the sum of all the processing delays for a route(chromosomes) i.e. for (N=4) (N9, N14, N11, N12)
$\sum_{i=1}^{N=4} DISTi$	Denotes the sum of all the geographic distances for a route (chromosome) i.e. for (N=4) (N9, N14, N11, N12)
$Max(1/(BWi))$	Denotes the Maximum Bandwidth available for the route (chromosome) while the (BWi) will be the minimum bandwidth of the *node i* in the route
Max(MOVi)	Denotes the Maximum Mobility Ratio *(Nf/N)* of the route while the *(MOVi)* will be the maximum mobility of the *node i* in the route. Where *Nf* is the failure attempts for which the node goes down or moved out from transmission rang. and *N* is total attempts for which data was attempted to transfer.

Table-5

Table-5 gives the detail explanation on the fitness function value evolution based on the processing delay, next hope distance, bandwidth and mobility of the nodes in the route (chromosome).

Step5: Repeat the above algorithm for all the groups each having the routes (chromosomes) of different hop counts and forming the final route table by storing the best routes (chromosomes) from all the groups of different hop counts.

Step6: Select the route with minimum fitness value from this final route table.

Step7: If more than one route (chromosome) having the same minimum value then randomly select any one route (chromosome) of them. In case if the existing route (chromosome) with minimum delay fails then we have available the second minimum route (chromosome) without interrupting in the data transmission.

IV. SIMULATION ENVIRONMENT

OPNET Modeler [2, 17, 18, and 19] is used as a simulation tool that accelerates the R&D process for analyzing and designing communication networks, devices, protocols, and applications. Users can analyze simulated networks to compare the impact of different technology designs on end-to-end behavior. Modeler incorporates a broad suite of protocols and technologies, and includes a development environment to enable modeling of all network types and technologies including: VoIP, TCP, OSPFv3, MPLS, IPv6, Others. Key Features of OPNET Modeler are as follows[17]:

- Fastest discrete event simulation engine among leading industry solutions
- Hundreds of protocol and vendor device models with source code (complete OPNET Model Library)
- Object-oriented modeling
- Hierarchical modeling environment
- Discrete Event, Hybrid, and optional Analytical simulation
- 32-bit and 64-bit fully parallel simulation kernel
- Grid computing support for distributed simulation
- Optional System-in-the-Loop to interface simulations with live systems
- Realistic Application Modeling and Analysis
- Open interface for integrating external object files, libraries, and other simulators
- Integrated, GUI-based debugging and analysis

Mobile Ad hoc Networks (MANETs) refer to a family of routing protocols developed to route traffic through mobile wireless networks. These networks place special requirements on routing protocols due the unpredictable nature of the radio links and changing network topology due to node mobility. OPNET provides several MANET routing protocol models that are integrated with the IP and wireless LAN models. In addition, a MANET framework is available for rapid development of new MANET protocol models. OPNET developed the MANET model in close collaboration with over 150 MANET protocol modeling experts from the government, industry, and academia.

OPNET Modeler provides the largest, most comprehensive library of open source, discrete event simulation models for the information technology industry. Most modeling capabilities are included in OPNET's Standard Model Library, which is included with OPNET's Network R&D and network planning solutions. The capabilities of the model library are not limited as it is possible to develop any type of protocol or device model with OPNET process and node editors.

V. EXPERIMENTAL RESULTS

We conducted experiments to evaluate and compare the performance of the following protocols: Greedy, GRP and the Proposed protocol. In these experiments, we used the discrete event simulator, opnet, which offers high fidelity in mobile ad hoc networks

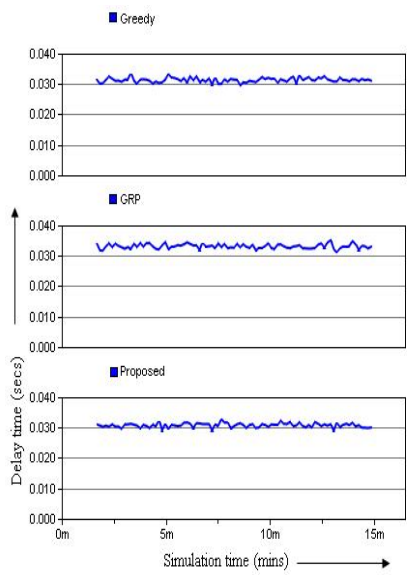


Figure 1. Stacked Statistics for Greedy, GRP and Proposed protocol for delays

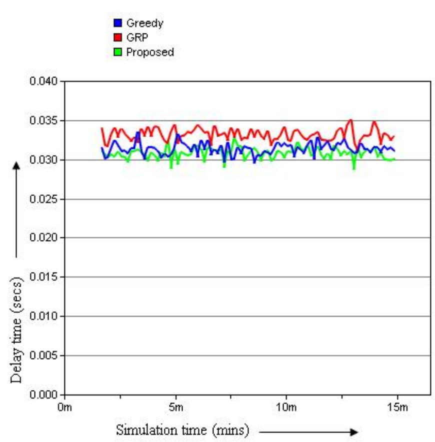


Figure 2: Overlaid Statistics for Delay of Greedy, GRP and Proposed protocols

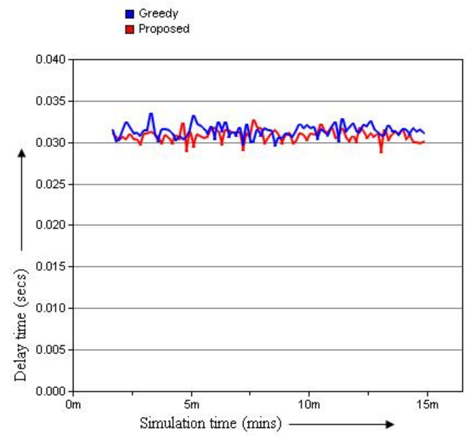


Figure 3: Overlaid Statistics for Delay of Greedy and Proposed protocols

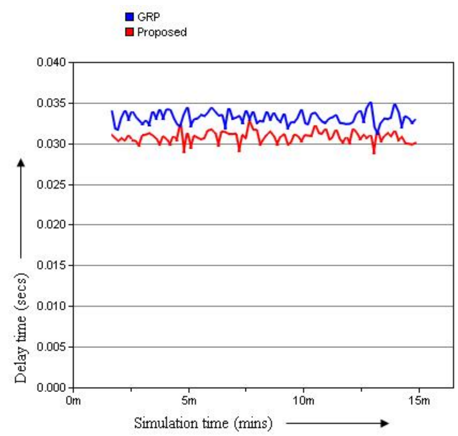


Figure 3: Overlaid Statistics for Delay of GRP and Proposed protocols

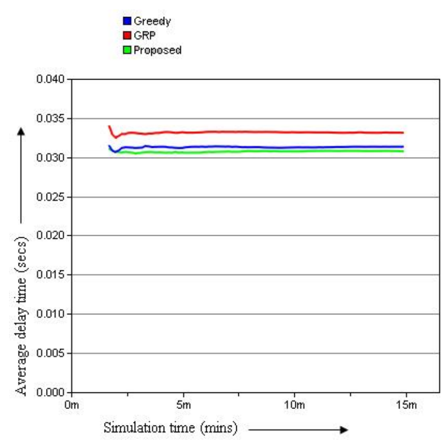


Figure 4: Overlaid Statistics for Average Delay of Greedy, GRP and Proposed protocols

VI. CONCLUSION

In this paper we proposed a genetic algorithm as an optimization technique for minimizing routing delay in geometric routing for MANETs. The results show that, with the genetic algorithmic technique the message routing with proposed protocol is having minimum delay as compared to other protocols for geometric routing.

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