GENETIC ZONE ROUTING PROTOCOL

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ABSTRACT

Zone Routing Protocol (ZRP) is a most promising and widely accepted and well proved hybrid routing protocol in Mobile Ad-hoc Networks (MANETs) for its performance when compared with table-driven and on-demand protocols. Our study is based on using the concept of genetic algorithms to provide a set of available paths to the destination in order to load balance the network. This gives us the reduction in overhead and better delivery of packets. We call this new routing protocol as Genetic Zone Routing Protocol (GZRP).

Keywords: *Ad hoc Network, MANET, Genetic Algorithm, Table-Driven Protocol, On-Demand Protocol, Hybrid Protocol, ZRP, GZRP*

1. INTRODUCTION

In multihop wireless networks such as ad hoc networks, mobile users need to communicate where there is no fixed networking infrastructure or no time to create such an infrastructure. The idea of ad hoc networking is sometimes also called *infrastructureless networking* [1]. Mobile ad hoc networks (MANETs) are created dynamically. The dynamic nature of MANETs provides special challenges beyond those in standard data networks [2]. In such networks, each mobile node operates not only as a host but also as a router, forwarding packets for other mobile nodes in the network that may not be within direct wireless transmission range of each other. Each node must cooperate dynamically establish routing among themselves. Each node participates in an ad hoc routing protocol that allows it to discover "multi-hop" paths through the network to any other node. Some examples [3],[4] of the possible uses of ad hoc networking include students using laptop computers to participate in an interactive lecture, business associates sharing information during a meeting, soldiers relaying information for situational awareness on the battlefield, and emergency disaster relief personnel coordinating efforts after a hurricane or earthquake.

The shortest path (SP) has to be computed within a very short time. It involves a classical combinatorial optimization problem arising in many design and planning contexts [5]. Since genetic algorithms (GAs) and other evolutionary algorithms [6]-[14] promise solutions to such complicated problems, they have been used successfully in various practical applications. Further, hardware implementations of GAs are extremely fast.

This paper is organized as follows: In Section 2, we provide a discussion on work related to the existing routing protocols, the operation of Zone Routing Protocol (ZRP), and working of genetic algorithm and its features. Section 3 provides proposed new protocol, Genetic Zone Routing Protocol (GZRP) and its working. Section 4 gives the experimental procedure including the evaluation methodology and simulation environment used for the simulation, and in Section 5, we present the results of our simulations. Section 6 gives the conclusions.

2. RELATED WORK

A. *Conventional Routing Protocols*

In recent past, a lot of attention has been shown by the research community to various issues related to ad hoc networks [15],[16]. Many protocols have been proposed for routing in such an environment. These protocols can broadly be classified into two types: *proactive* and *reactive* routing protocols. Proactive or *table-driven* protocols try to maintain routes to all the nodes in the network at all times by broadcasting routing updates in the network. Examples are DSDV[17], TBRPF, OLSR, WRP, STAR, and FSR. On the other hand, reactive or *on-*

demand protocols attempt to find a route to the destination, only when the source has a packet to send to the destination. Examples are DSR[18], AODV, and TORA. Proactive protocols maintain the routing information of one node to the other using routing tables. Whenever there is a need for the route to the destination, it is readily available incurring minimum delay. But, at the same time, they may lead to a lot of wastage of the network resources if a majority of these available routes are never used. Reactive protocols are usually associated with less control traffic in a dynamic network; nodes have to wait until replies to the route queries are received. Also reactive protocols resort to frequent flooding of the network, which may cause network congestion. In between the above two extremes, there are the *hybrid* protocols. The Zone Routing Protocol (ZRP) [19] is a hybrid proactive / reactive protocol. It is a routing framework composed of the proactive Intrazone Routing Protocol (IARP)[20], reactive Interzone Routing Protocol (IERP)[21], and the Bordercast Resolution Protocol (BRP)[22]. ZRP is proved to work well compared to either table-driven protocols or on-demand protocols [23-26],[27-28].

B. ZRP Overview

In this paper, we have taken ZRP is taken as the source protocol. The work does not make any changes to IARP part in ZRP. However, we have applied genetic algorithm to the IERP, and BRP. The ZRP, on one hand, limits the scope of the proactive procedure only to the node's local neighborhood, minimizing the waste associated with the purely proactive schemes. On the other hand, the search throughout the network, although it is global, is performed by efficiently querying selected nodes in the network as opposed to querying all the network nodes. Proactive routing uses excess bandwidth to maintain routing information, while reactive routing involves long route request delays. The ZRP aims to address the problems by combining the best properties of both approaches. The ZRP reduces the proactive scope to zone centered on each node. In a limited zone, the maintenance of routing information is easier. Further, the amount of routing information that is never used is minimized. Still, nodes farther away can be reached with reactive routing. Still all nodes proactively store local routing information, route requests can be more efficiently performed without querying all the network nodes. As its name implies, the Zone Routing Protocol is based on the concept of zones. Each node is defined with a separate routing zone and zones of neighboring nodes overlap. The routing zone has a radius, ***r***, expressed in hops. The zone thus includes those nodes whose distance is at most ***r*** hops from the center node. It should however be noted that the zone is defined in hops, not as physical distance.

The nodes of a zone are divided into peripheral nodes and interior nodes.

- *Peripheral nodes* are nodes whose minimum distance to the central node is exactly equal to the zone radius ***r***.
- *Interior nodes* are nodes whose minimum distance is less than ***r***.

The construction of a routing zone requires a node to first know who its *neighbors* are. A neighbor is defined as a node that can communicate directly with the node which is one hop away. Identification of a node's neighbors may be provided directly by the Media Access Control (MAC) protocols. In other cases, neighbor discovery may be implemented through a MAC-level *Neighbor Discovery Protocol (NDP).* Such a protocol typically operates through the periodic broadcasting of "hello" beacons. The reception (or quality of reception) of a "hello" beacon can be used to indicate the status of a connection to the beaconing neighbor.

The ZRP refers to the locally proactive routing component as the IntrA-zone Routing Protocol (IARP). The globally reactive routing component is named IntEr-zone Routing Protocol (IERP). IERP and IARP are not specific routing protocols. Instead, IARP is a family of limited-depth, proactive link-state routing protocols. IARP maintains routing information for nodes that are within the routing zone of the node. Correspondingly, IERP is a family of reactive routing protocols that offer enhanced route discovery and route maintenance services based on local connectivity monitored by IARP.

The fact that the topology of the local zone of each node is known can be used to reduce traffic when global route discovery is needed. Instead of broadcasting packets, ZRP uses a concept called *bordercasting.* Bordercasting utilizes the topology information provided by IARP to direct query request to the border of the zone. The bordercast packet delivery service is provided by the Bordercast Resolution Protocol (BRP). Route updates are triggered by NDP, which notifies IARP when the neighbor table is updated. IERP uses the routing table of IARP to respond to route queries.

IERP forwards queries with BRP. BRP uses the routing table of IARP to guide route queries away from the query source.

C. Genetic Algorithmic Approach

Genetic Algorithms [5] perform much better with rugged landscapes because of their population based approach spreading "probes" throughout the search space. In our work we preferred genetic algorithm as the optimization algorithm because of the confidence that it would work due to its robustness. Note that one other big advantage of genetic algorithms is the ability to parallelize them on a large scale by spreading the evaluations across different machines. A large amount of work has been done on the application of genetic algorithms or evolutionary algorithms to communications networks. Investigators have applied GAs to the shortest path routing problem [6], multicast routing problem [7-9]. In [10], the authors have tried to investigate the used of genetic algorithms for automated selection of parameters like heartbeat interval, heartbeat points, score history size, up score threshold, down score threshold, routing algorithm and traffic max attempts for ad hoc networks. The authors of [11] have presented a genetic algorithmic approach to the shortest path routing problem. [12] investigates using a genetic algorithm to create routing tables for an under water ad hoc networks. [13] examines the application of genetic algorithms to dynamically optimize routing in MANETs. [14] looks at how to use a genetic algorithm to cluster network nodes into sub-networks. A simple genetic algorithm consists of the following steps:

1. **[Initial Population]** Generate random population of *n* chromosomes (suitable solutions for the problem)
2. **[Fitness]** Evaluate the fitness *f(x)* of each chromosome *x* in the population
3. **[New population]** Create a new population by repeating following steps until the new population is complete
   a. **[Selection]** Select two parent chromosomes from a population according to their fitness (the better fitness, the bigger chance to be selected)
   b. **[Crossover]** With a crossover probability cross over the parents to form a new offspring (children). If no crossover was performed, offspring is an exact copy of parents.
   c. **[Mutation]** With a mutation probability mutate new offspring at each locus (position in chromosome).
   d. **[Accepting]** Place new offspring in a new population
4. **[Replace]** Use new generated population for a further run of algorithm
5. **[Test]** If the end condition is satisfied, **stop**, and return the best solution in current population
6. **[Loop]** Go to step **2**

3. GENETIC ZONE ROUTING PROTOCOL

In this paper we propose a new protocol called Genetic Zone Routing Protocol (GZRP) which uses simple genetic algorithm for finding multiple shortest (near shortest some times) paths to provide load balancing and tolerance. Any on-demand routing protocol uses Route Discovery and Route maintenance procedures for finding the path to the destination which in tern return a single shortest path to the destination. In any case, if that route fails and/or congestion occurs and that route leads to the delays or packet losses, then rediscovery of the new SP is required. This causes unnecessary wastage of network resources and also wastage of time. ZRP is hybrid protocol which has the hands on routes if the destination is within the routing zone. However, the actual problem comes when the destination is outside the zone. In this case, it makes use of Route Discovery with IERP and BRP. This route discovery goes with border nodes between the zones. At this point, we implemented genetic algorithm. Each border node will implement GA to find multiple shortest or near shortest paths. Instead of rediscovering the path to the destination every time on failure of the existing path, the border node will make use of the available shortest or near shortest paths.

A. Encoding Method

A chromosome of the GA consists of sequences of positive integers that represent the IDs of *border* nodes through which a route path passes. Each locus of the chromosome represents an order of a *border* node (indicated by the gene of the locus) in a routing path. The gene of the first locus is always reserved for the source node. It never needs more than N number of nodes in a network to form a routing path. Hence, the maximum size of a chromosome length can be N. A chromosome (routing path) encodes the problem by listing up *border* node IDs from its source node to destination node based on topological information (routing table) of the network.

S	*B1*	*B2*	…	B_{k-1}	B_k	*D*

B. Initial Population

One of the issues in selecting the initial population is its size. A larger population is quite useful but it demands excessive costs in terms of both memory and time. The population size is needed to increase exponentially with the complexity of the problem (i.e. length of the chromosome) in order to generate good solution. Recent studies have shown, however, that satisfactory results can be obtained with a much smaller population size. In this paper throughout, we used the population size as twice the number of nodes in the network. Further, the literature suggested that random initialization method can be adopted in order to generate the new population.

C. Fitness Function

The fitness function of GAs generally the objective function that requires to be optimized. The fitness function has a higher value when the fitness characteristic of the chromosome is better than others. The fitness function in the SP routing problem is obvious because the SP computation amounts to finding the minimal cost path.

The underlying topology of multihop networks can be specified by the directed graph G=(N,A), where N is a set of nodes (vertices), and A is a set of its links (arcs and edges). There is a cost C_{ij} associated with each link (I,j). The costs are specified by the cost matrix $C=[C_{ij}]$, where C_{ij} denotes a cost of transmitting a packet on link (I,j). Source and destination nodes are denoted by S and D, respectively. Each link has the link connection indicator denoted by I_{ij}, which plays the role of a chromosome map (masking) providing information on whether the link from node i to node j is included in a routing path or not.

It can be defined as follows:

$$I_{ij} = \begin{cases} 1, & \text{if the link from node i to node j exists in the routing path} \\ 0, & \text{otherwise.} \end{cases}$$

The objective function can be formulated as:

$$\sum_{i=S}^{D} \sum_{\substack{j=S \\ i \neq i}}^{D} C_{ij} \bullet I_{ij}$$

subject to the condition that the path between a source and destination can have no loops only when:

$$\sum_{\substack{j=S \\ i \neq i}}^{D} I_{ij} - \sum_{\substack{j=S \\ i \neq i}}^{D} I_{ij} = \begin{cases} 1, & \text{if } i = S \\ -1, & \text{if } i = D \\ 0, & \text{otherwise} \end{cases}$$

and

$$\sum_{\substack{j=S \\ i \neq i}}^{D} I_{ij} = \begin{cases} \leq 1, & \text{if } i \neq D \\ 0, & \text{if } i = D \end{cases}$$

D. Selection

The selection (reproduction) operator is intended to improve the average quality of the population by giving the high-quality chromosomes a better chance to get copied into the next generation. There are many techniques like roulette wheel selection, stochastic remainder selection, Tournament selection, and truncation selection for selecting the chromosomes for next generation. However, the proposed GA technique employs the *roulette wheel selection* which is most widely used one. In this technique, two chromosomes are selected based on the probability. However, the same chromosome should not be picked twice as a parent.

E. Crossover

Crossover examines the current solutions in order to find the better ones. Physically, crossover in the SP routing problem plays the role of exchanging each partial route of two chosen chromosomes in such a manner that the offspring produced by the crossover represents only one route. This dictates selection of one-point crossover as a good candidate scheme for the proposed GA. One partial route connects the source node to an intermediate node, and the other partial route connects the intermediate node to the destination node.

But the mechanism of the crossover is not the same as that of the conventional one-point crossover. In the proposed scheme, two chromosomes chosen for crossover should have at least one common gene (node) except for the source and destination nodes, but there is no requirement that they be located at the same locus. That is, the crossover does not dependent on the position of nodes in routing paths.

Before crossover:

S	B1	B2	B4	B5	D

S	B2	B3	B5	B6	B7	D

After crossover:

S	B1	B2	B3	B5	B6	B7	D

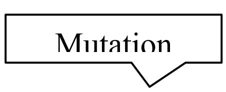
S	B2	B4	B5	D

It is possible that loops are formed during crossover. A simple countermeasure must be taken this regard. Repair and penalty functions are the usual counter measures.

F. Mutation

The population undergoes mutation by an actual change or flipping of one of the genes of the candidate chromosomes, thereby keeping away from local optima. Physically, it generates an alternative partial-route from the mutation node to the destination node in the proposed GA. A topological information database is utilized for the purpose. Of course, mutation may induce a subtle bias. However, the bias can be ignored.

Before mutation:



S	B2	B4	B5	D

After mutation:

S	B2	B1	B3	D

Depending on the mutation point, a gene from the chosen chromosome is selected (node B2). One of the nodes, connected directly to the node at mutation point, is chosen randomly as the first node of the alternative partial route.

G. Repair Function

As mentioned earlier, crossover may generate infeasible chromosomes that violate the constraints of generating loops in the routing paths. It must be noted that none of the chromosomes of the initial population or after the mutation is infeasible because when once a node is chosen, it is excluded from the candidate nodes forming the rest of the path.

4. CONCLUSIONS

This paper proposes a new routing protocol for mobile ad hoc networks called Genetic Zone Routing Protocol which applies the genetic algorithmic approach for finding the multiple shortest paths (near optimal) to the existing Zone Routing Protocol in order to load balance the network in the case of congestion occurrence and provides robustness in the case of route failures. This gives the better delivery of packets to the destination and reduces overhead and delays on the network. The GZRP will be definitely a promising protocol of future.

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