An Efficient Routing Technique for Mobile Ad-hoc Wireless Networks

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ABSTRACT

In this paper, a novel GA and AHP based route optimization algorithm for MANETs (not used by packet technology till date) has been presented. It uses node selection and route determination as a design criterion in order to ensure the integrity of network services, traffic congestion and various other adverse conditions. The topologies of high speed networks have become sparser (not dense) due to the increased capacity of communication media and cost considerations. Here in this work, GA and AHP together have been used for the optimal selection of the routes as well as the node selection parameters. Simulations and testing of the developed algorithms on a considered 802.11b MANET (IEEE specification) has shown an average throughput gain of 50 to 70% (depending upon network density) over traditional minimum hop route selection techniques.

1. INTRODUCTION

A mobile ad-hoc network (MANET)[4] is a self-configuring network of mobile routers (and associated hosts) connected by wireless links—the union of which form an arbitrary topology. The routers are free to move randomly and organize themselves arbitrarily; thus, the network's wireless topology may change rapidly and unpredictably. Such a network may operate in a standalone fashion, or may be connected to the larger Internet. Minimal configuration and quick deployment make ad hoc networks suitable for emergency situations like natural or human-induced disasters, military conflicts, emergency medical situations etc. The earliest MANETs were called "packet radio" networks, and were sponsored by DARPA in the early 1970s.

The popular IEEE 802.11 ("Wi-Fi") wireless protocol incorporates an ad-hoc networking system when no wireless access points are present, although it would be considered a very low-grade ad-hoc protocol by specialists in the field. An Ad hoc routing protocol [4] is a convention or standard that controls how nodes come to agree which way to route packets between computing devices in a mobile ad-hoc network (MANET). In ad hoc networks, nodes do not have a priori knowledge of topology of network around them, they have to discover it. Some ad-hoc network routing protocols are - Pro-active (Table-driven), Reactive (On-demand), Hybrid (Pro-active/Reactive), Hierarchical, Geographical, Power Aware, Multicast Geographical Multicast (Geocasting). Routing protocols select paths dynamically while the packets are being forwarded, or statically (in advance) as in source routing from a source node to a destination. For instance, routing in the Internet is typically based on prior agreements between "autonomous systems" (AS) to carry each others traffic based on economic considerations. On the other hand, routing within each AS is generally based on the selection of a "shortest path" or the "smallest number of hops" from source to destination.

A Genetic Algorithm (GA) [5,7] is a learning algorithm which operates by simulating evolution. Key features that distinguish a GA from other search methods include - a population of individuals where each individual represents a potential solution to the problem to be solved. Individuals are typically binary strings, but in the context of routing we will take them to be sequences of nodes. The terms individual, solution, and genome will be used interchangeably to refer to one potential solution in a GA population. A fitness function which evaluates the utility of each individual as a solution, a selection function which selects individuals for reproduction based on their fitness, a selection function which exploits useful information currently existing in a population. The GA population will consist of individuals who represent paths between the source node and potential destination nodes.

Genetic Algorithms were introduced as a computational analogy of adaptive systems. They are modeled loosely on the principles of the evolution via natural selection, employing a population of individuals that undergo selection in the presence of variation-inducing operators such as mutation and recombination (crossover). The Algorithms include randomly generating an initial population, computing and saving the fitness for each individual in the current population, defining selection probabilities for each individual so that it is proportional to generating by probabilistically selecting individuals from population to produce offspring via genetic operators, repeating the computation for of fitness function for each individual until satisfying solution is obtained. The appeal of GAs comes from their simplicity and elegance as robust search algorithms as well as from their power to discover good solutions rapidly for difficult high-dimensional problems. GAs are useful and efficient when - the search space is large, complex or poorly understood, domain knowledge is scarce.
or expert knowledge is difficult to encode to narrow the search space, no mathematical analysis is available, traditional search methods fail.

Analytical Hierarchy Process (AHP) [6] is a method for comparing a list of objectives or alternatives. When used in the systems engineering process, AHP can be a powerful tool for comparing alternative design concepts. AHP is a comprehensive, logical and structured framework. It allows improving the understanding of complex decisions by decomposing the problem in a hierarchical structure. The incorporation of all relevant decision criteria, and their pair-wise comparison allows the decision maker to determine the trade-offs among objectives. This procedure recognizes and incorporates the knowledge and expertise of the participants. It makes use of their subjective judgments, which is a particularly important feature for decisions to be made on a poor information base. The AHP is based on three principles: Decomposition of the decision problem, Comparative judgment of the elements, Synthesis of the priorities and the corresponding steps involved are-

- Step 1: Creating hierarchies to resolve a problem
- Step 2: Comparison of the alternatives and the criteria.
- Step 3: Synthesize the comparisons to get the priorities of the alternatives with respect to each criterion and the weights of each criterion with respect to the goal. Local priorities are then multiplied by the weights of the respective criterion the results are summed up to get the overall priority of each alternative.

2. CASE STUDY: - MANET’s

In case of MANETs, a routing protocol is the mechanism by which user traffic is directed and transported through the network from a source node to a destination node. The objectives include maximizing network performance (throughput) from an application point of view; while minimizing the cost imposed on the network. Quality of Service (QoS) routing is an essential part of QoS architecture. It is a routing mechanism under which paths for flows are determined on the basis of some knowledge of the resources available in the network as well as on the QoS requirements of the flows or connections. Internet and wireless networks are based on the best effort principle, which consists of using links among computers in an optimal way, even if this involves additional delays in data transmission. This principle is problematic for new applications, which require a QoS such as multimedia, IP telephony and networked gaming. Routing packets in ad hoc networks is a challenge because of the constantly changing topology of the networks triggered by node mobility. Thus, when two nodes travel apart, they may no longer have a direct link between them. Figure 1 shows a region for which the path of nodes is being selected along a particular route.

![Figure 1: Area of node selection in MANET](image-url)

Some protocols can be classified like a Best Effort protocols, which minimize the network costs. Best effort protocols can be divided into two classes: proactive and reactive protocols. Proactive protocols keep track of routes for all destinations in the network. These protocols have the advantage that communications with arbitrary destinations experience minimal initial delays. Reactive protocols acquire routing information only when it is needed.

Destination Sequenced Distance Vector (DSDV)[1] is a best effort protocol designed specially for MANETs. It belongs to the class of proactive protocols and uses a version of the Bellman–Ford distributed algorithm adapted to ad hoc networks. Each mobile station maintains a routing table, which contains routing information for each node in the network. Ad hoc On Demand Vector (AODV)[2] represents an improvement of DSDV. In fact, in nutshell, it takes the advantages of DSDV while limiting bandwidth consumption. It functions on demand, i.e., it builds a route to a destination only if a source node needs to reach it. Johnson and Maltz proposed a Dynamic Source Routing (DSR)[3] protocol for ad hoc wireless networks. To send a packet to another host, the sender constructs a source route in the packet's header, with the address of each host in the network through which
Quality of service (QoS) [4] consists of a collection of characteristics or constraints between a source and a destination that a connection must guarantee during the communication to meet the requirements of an application. QoS routing is a procedure that identifies the routes, between a source node and its destination node, which obey the constraints required by the source application and selects between these routes the one to be used. The idea is to provide QoS in a closely-knit two-step process: first, the routing protocol detects the routes that can fulfill the desired QoS, and, second, it reserves these routes. Furthermore, it is necessary to integrate route maintenance in a QoS routing protocol so that it can deal with route breakdowns during communication. The idea is to use tickets to limit the number of candidate paths. When a source node wants to find QoS paths to a destination, it sends a message that contains a certain number of tickets. It is implemented using a link performance prediction strategy. Lower layer parameters are translated into link state information and used to estimate the integrated QoS performance in each local area. Predicting node location is another feasible way to enhance QoS in mobile networks.

3. PROBLEM FORMULATION

In this paper, we have taken up a MANET and have divided the region into various nodes consisting in each region, so as to standardize input data [Yes, it is the information that the user has to pass] for normalization. After that we have taken up the shortest path as the backbone and assigned it the highest priority. Attributes like node density, traffic congestion, and node status and power consumption have been considered. These attributes are normalized on a scale of 0-10. The cost function is given by equation (1) below, in which various local static constants \( A_1, A_2, A_3 \) and \( A_4 \) are assumed. These depend upon the priority and various attribute indices, which are calculated by applying the AHP model. On obtaining these values, the cost function is optimized using GA, so as to choose the best possible routing path for easy data flow without jamming, and minimum power consumption.

\[
TC = A_1 \lambda_1 + A_2 \lambda_2 + A_3 \lambda_3 + A_4 \lambda_4 \ldots \ldots (1)
\]

Here, \( \lambda_1, \lambda_2, \lambda_3 \) and \( \lambda_4 \) are the attribute indices, calculated using comparison matrix.

A sample value for \( \lambda \) is calculated using comparison matrix as shown by equation (2). Their values depend upon present and initial condition pertaining to node condition. Similarly, other attribute indices are obtained under various operating conditions.

The values of \( \lambda \)s form the basis for node selection for optimal route in MANET. These values of \( \lambda \) as obtained by AHP are basically taken at different time slots in a particular region. Genetic algorithm [5,7] is used to perform two functions viz., firstly to obtain two best values of \( \lambda \)s (taken as parent chromosomes participating in crossover), and secondly to generate offspring value of \( \lambda \), which is optimal in comparison to other attribute indices in the initial population. Binary encoding is used in this work. This helps in preventing network congestion and improper utilization of all the available resources. Table 1 below, gives numerical rating considered in this work for verbal judgement of preferences

<table>
<thead>
<tr>
<th>Verbal Judgment of Preference</th>
<th>Numerical Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extremely Preferred</td>
<td>9</td>
</tr>
<tr>
<td>Very Strongly to Extremely</td>
<td>8</td>
</tr>
<tr>
<td>Very Strongly Preferred</td>
<td>7</td>
</tr>
<tr>
<td>Strongly to very strongly</td>
<td>6</td>
</tr>
<tr>
<td>Strongly Preferred</td>
<td>5</td>
</tr>
<tr>
<td>Moderately to strongly</td>
<td>4</td>
</tr>
<tr>
<td>Moderately Preferred</td>
<td>3</td>
</tr>
<tr>
<td>Equally to moderately</td>
<td>2</td>
</tr>
<tr>
<td>Equally Preferred</td>
<td>1</td>
</tr>
</tbody>
</table>

| Comparison Matrix For A Particular Time:- |

<table>
<thead>
<tr>
<th>Attributes</th>
<th>Traffic</th>
<th>Node Density</th>
<th>Power Consumption</th>
</tr>
</thead>
<tbody>
<tr>
<td>Verbal Judgment of Preference</td>
<td>Numerical Rating</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Node Status

From the comparison matrix and pair wise comparison scale \( \lambda_1 \) is obtained as given below.

\[ \lambda_1 = \lambda^3 - 4\lambda^3 - 0.5555556 \lambda^2 + 2\lambda \ldots \ldots (2) \]

Solving equation no (2) yields values for \( \lambda_1 \) as 0, 3.7099, 1.4088 and -1.1187

Similarly, different values of \( \lambda_2, \lambda_3, \lambda_4 \) are also obtained. The best two values for each attribute index are selected using GA. Using binary encoding, some other optimized value is selected using another form of mutation and crossover.

4. SIMULATION AND TESTING

Simulation is done in C++. The developed genetic algorithm is tested under various traffic conditions. The traffic conditions refer to the various time zones in a day where the traffic of the signals is different in these time zones. After obtaining the values of various attribute indices, at various period of the day (6.00A.M - 12.00A.M, 12.00P.M - 6.00P.M, 6.00P.M - 12.00AM, 12.00AM - 6.00AM) the optimum value is selected. As shown in figure 2 throughput increases in the region where the node density is less. The region where the node density is less basically refers to the fact that the no of nodes per square meter is less which in turn will reduce the power consumption, thus increasing the throughput. Out of these four values of the cost function in each zone, the lowest one is being represented by lowest power consumed by the node, which being one of the major characteristics of MANET. In Fig 3, the most optimized route is being selected. This route is being selected by considering the four time zones in a day and taking the most optimized values of the attribute indices.

Figure 2: Throughput gain for various \( \lambda \) values for 4 zones.

Figure 3: Optimized route for passing the information

Simulation in C++ of the developed algorithm gives different results of attribute indices. This GA – AHP algorithm exhibits adaptive superiority over other existing reactive routing protocols.

5. RESULTS AND DISCUSSIONS

Simulation results using GA and AHP show an average throughput gain (where throughput gain is the amount of information passing from input to output) of 50% to 70%, depending on network density, over traditional minimum hop route selection in 802.11b networks. If the traffic patterns are not clear in a large network, even an optimal routing
algorithm will achieve low throughput. This is because physically long paths require many hops, which have low path throughput and consume resources all across the network. The definition of realistic mobility models is one of the most critical and, at the same time, difficult aspects of the simulations of applications and systems designed for mobile environments. Currently, there is no publicly available data capturing node movement in real large-scale mobile ad hoc environments. Taken together, for those systems in which mobility is important and for which a synthetic mobility model is an essential ingredient, it would appear to be important to consider the influence of the human-level social network as something that informs likely individual and group mobility patterns.

6. CONCLUSION

What have seen in going through paper of various Ad hoc – MANET routing algorithms, various routing protocols such as (proactive and reactive) by taking into consideration various communication parameters tend to give throughput gain (efficiency) in range of 20%-60%. It has been observed that the route optimization using GA and AHP (First time in packet technology network) results in greater saving of power (taking power consumption as the cost criterion. In this case, AHP is being used for the selection of the performance indices depending on various linguistic variables in different time zones. Once these parameters are being fixed, using GA the optimized values for the same is obtained.

It has been found that using GA, the probability of passing the information through a particular node twice is less than 50 %.( effects of crossover and mutation). The two values after mutation tend to change drastically. Let us consider that the probability of passing information through a node twice, is 33.33% for a certain instance using GA, then we are saving up to 70% the power consumed by that particular node, which resulted in higher throughput.

In this paper, in problem formulation, a particular region (the physical area) is being divided in regions of 4 time related zones Each region is being characterized by four nodes (as evident from the four cost functions) where every node has in turn four parameters (Traffic Congestion, Node density, node status, power consumption), which are key to any communication problem. In this case, the no of nodes have been restricted to 4 (4 cost functions) in a region for simplifying the calculations. This no. can increase to a greater extent depending on the node density per radius and also the respective problem being formed.

The efficiency of the route selection using NS2 [8] simulation tool in the networking domain is less than in comparison to the algorithm using GA and AHP, using more or less the same parameters for communication

This results in the increase in efficiency of 50-70% over the traditional routing protocols. The increase in the no. of parameters in the problem will give more values of the attribute indices which in turn will make the objective function more optimized, thus increasing the efficiency to a greater extent.

7. REFERENCES


8. Baruch Awerbuch, David Holmer, Herbert Rubens “High Throughput Route Selection in Multi Rate Ad Hoc Wireless Networks” computer communication, IEEE Publication, vol. 6, pp 36-402