Design and Development of an Intelligent Routing Protocol for Mobile Ad hoc Network :A Review Paper

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Summary
With the increase of portable devices as well as progress in wireless communications, ad hoc networking is gaining importance with the increasing number of widespread applications. Ad hoc networking can be applied in places where there is little or no communication infrastructure or existing infrastructure is expensive or inconvenient to use. In MANETs, nodes do not have a priori knowledge of topology of network around them, they have to discover it. These networks are rapidly deployable community networks, which are the largely hobbyist-led development of interlinked computer networks. MANETs use limited network management and administration, in order to establish communications, dynamically. These algorithms need to keep routing table reasonably small, choose best route for given destination (fastest, most reliable, highest throughput, or cheapest route) and keep table up-to-date when nodes move or join. In this paper, we propose an efficient routing technique with minimum power consumption for Ad hoc networks. A hybrid technique using the Analytical Hierarchy Process (AHP) and Genetic Algorithm (GA) has been adopted by use of key communication parameters to select the optimal nodes / routes. 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 has shown an average throughput gain of 45 to 55% (depending upon power consumption) over traditional minimum hop route selection techniques.

Keywords
Ad hMobile adhoc Networks, Node Density (ND), Power Consumption (PC), Node Status (NS), Traffic Congestion (TC), Throughput, Genetic Algorithms, Analytical Hierarchy Process.

1. Introduction

A mobile ad-hoc network (MANET) is a self-configuring network of mobile routers (and associated hosts) connected by wireless links—the union of which form an arbitrary topology. Nodes that are unable to communicate directly with each other require intermediate nodes to forward packets for them. Each node acts as a router and as a host. 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. Experimenters included Jerry Burchfiel, Robert Kahn, and Ray Tomlinson of later TENEX, Internet and email fame. 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 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) 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

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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. We have used a variable length representation that is expected to allow the GA more flexibility to evolve in response to changes in the network. The fitness of a path is determined from the measurement data returned by an ACK that is received in response to sending a dumb packet along that path. GA's 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 M (0), computing and saving the fitness u (m) for each individual m in t population M (t), defining selection probabilities p (m) for each individual m in M (t) so that p (m) is proportional to u (m), generating M (t+1) by probabilistically selecting individuals from M (t) to produce offspring via genetic operators, repeating the computation for of fitness function for each individual until satisfying solution is obtained. The appeal of GA's 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. GA's 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) 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 de composing 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.

Step 1: - Creating hierarchies to resolve a problem

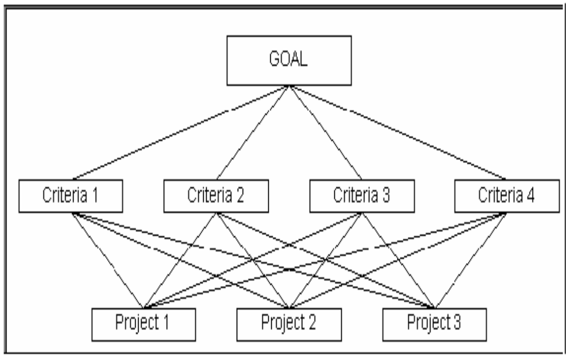

Fig 1: AHP Selection Criteria

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.

A MANET is a type of ad hoc network that can change locations and configure itself on the fly. Because MANETS are mobile, they use wireless connections to connect to various networks. This can be a standard Wi-Fi connection, or another medium, such as a cellular or satellite transmission. Some MANETs are restricted to a local area of wireless devices (such as a group of laptop computers), while others may be connected to the Internet. For example, A VANET (Vehicular Ad Hoc Network) is a type of MANET that allows vehicles to communicate with roadside equipment. While the vehicles may not have a direct Internet connection, the wireless roadside equipment may be connected to the Internet, allowing data from the vehicles to be sent over the Internet. The vehicle data may be used to measure traffic conditions or keep track of trucking fleets. Because of the dynamic nature of MANETs, they are typically not very secure, so it is important to be cautious what data is sent over a MANET. 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 from an application point of view, while minimizing the cost imposed on the network in terms of capacity. Thus, when two nodes travel apart, they may no longer have a direct link between them. Some protocols can be classified like a Best Effort protocols, which minimize the network costs in terms of capacity. 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. Proactive routing protocols, like DSDV and TBRPF, periodically exchange routing information in the whole network so that routes between different nodes are dynamically maintained. DSDV 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 Therefore proactive protocols have low latency and are reliable. Yet they high have overhead since even if there is no data traffic in the network routing messages are exchanged. Thus these protocols cannot scale well in commercial applications. Reactive protocols, such as AODV, DSR and the TORA, exchange the routing information only to establish the routes between the nodes that have the data traffic. So that overhead is lower than proactive routing protocols. Yet in high mobility situations, path is long and link may frequently break, so that the overhead may be high. In contrast to table based protocols, geographic routing protocols like as utilize location to route the information. They do not exchange routing message to establish routes. When a node has data packets to be transmitted to other node, forwarding decision is made based upon the position of destination and the position neighbors of the forwarding node. Thus a geographical routing protocol is a stateless routing protocol. It is scalable and has low overhead. But to determine the physical location, each node must be equipped with global positioning system (GPS). Geographical Positioning Systems (GPS) can detect the physical location of a terminal using universal satellite-transmitters and receivers. Quality of service (QoS) 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. Another scholar presented a ticket-based probing algorithm for QoS routing in ad hoc networks. 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. An approach proposed an adaptive QoS routing scheme based on the prediction of the local performance in ad hoc networks. 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. The use of hybrid routing is an approach that is often used to obtain a better balance between the adaptability to varying network conditions and the routing overhead. For instance, a hybrid routing protocol may benefit from dividing the network into clusters and applying proactive route updates within each cluster and reactive routing across different clusters.

2. Problem Formulation

A MANET consists of mobile platforms (e.g., a router with multiple hosts and wireless communications devices)--herein simply referred to as "nodes"--which are free to move about arbitrarily. The nodes may be located in or on airplanes, ships, trucks, cars, perhaps even on people or very small devices, and there may be multiple hosts per router. A MANET is an autonomous system of mobile nodes. The system may operate in isolation, or may have gateways to and interface with a fixed network. In the latter operational mode, it is typically envisioned to operate as a "stub" network connecting to a fixed internetwork. Stub networks carry traffic originating at and/or destined for internal nodes, but do not permit exogenous traffic to "transit" through the stub network. In this paper we have taken up an adhoc network between two places on a map and have divided the region into various nodes consisting in each region, so as to standardize input data for normalization. After that we have taken up the shortest path as the backbone and assigned it the highest priority. The attributes such as battery power consumption (BPC), node mobility (NB), and Bandwidth requirements (BW) have been considered. These attributes are normalized on a scale of 0-10. The route function is given by equation (1) below, in which various local static constants B1, B2, & B3 are assumed. These depend upon the priority and various attribute indices, which are calculated by applying the AHP model. On obtaining these values, the route function is optimized using GA, so as to choose the best possible routing path for easy data flow without jamming, high node mobility & minimum battery power consumption.

Route Function “RF” = B1 X1 +B2 X2 + B3 X3…(1)

A sample value for X is calculated using comparison matrix. 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 Xs form the basis for section of route in general and node in particular in MANET. These values of X as obtained by AHP are basically taken at different time slots in a particular region. Genetic algorithm is used to perform two functions viz., firstly to obtain the best values of Xs (taken as parent chromosomes participating in crossover), and secondly to generate offspring value of X, which is optimal in comparison to other attribute indices in the initial population. Binary encoding is used in this work. The developed GA is equipped with a clause conditionally prohibiting the selection of the shortest path, every time. 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 judgment of preferences.

Table 1**:** Linguistic parameters used to generate the relational data:

Linguistic Parameter	Numerical Ranking
Extremely Preferred	9
Very Strongly Preferred	8
Strongly Preferred	4
Moderately Preferred	3
Equally Preferred	2
Least Preferred	1

The different values of these indices can be calculated by using comparison matrix as shown in Fig1.

$$\Delta \quad \begin{vmatrix} \alpha/\alpha & \alpha/\beta & \alpha/\gamma \\ \beta/\alpha & \beta/\beta & \beta/\gamma \\ \gamma/\alpha & \gamma/\beta & \gamma/\gamma \end{vmatrix}$$

Fig. 2 : A typical Comparison Matrix
α = NB, β=BPC, γ=BW)

The Eigen values or performance parameters can be calculated by using $[\Delta - xI] = 0$. By solving these equations, using comparison matrix, various values of the performance parameters (each λ) are obtained. These values form the initial solution for the GA and are passed onto it for further optimization so as to obtain the corresponding cost function.

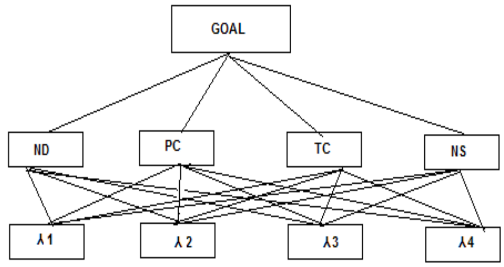

Fig3 AHP parameters

Basic Steps of a Serial Genetic Algorithm:
-Evaluate population- AHP modeling
-Select one set of parents,
-Apply genetic operators to parents to create new offspring.
-Insert new offspring into population, replacing select individuals in population.
As an example we consider numerical ratings for verbal judgment of preferences as detailed below.
$\alpha = 1$, β=2, γ=4
Accordingly, the comparison Matrix for a Particular Time zone: -

Table 2 Comparison Matrix for a Particular Time zone

Attribute	**NB**	**BPC**	**BW**
Node Mobility	1/1	1/2	1/4
BatteryPower Consumption	2/1	2/2	4/2
Bandwidth Requirement	4/1	4/2	4/4

From the comparison matrix and pair wise comparison scale, X1 is obtained as-

$$X_1^{3}-2X_1^{2}+X_1=0 \qquad (2)$$

Solving this equation yields values for X1 as 1, 1, and 2.5143 which are passed on to the GA for further optimization of the cost function. Similarly, different values of X2 & X3 also be obtained by taking different values of attribute parameters in the same time zone.
From the various values of performance indices the best two values for each attribute index are selected using GA. using binary encoding or some other optimized value is selected using another form of mutation and crossover.

3. Simulation and Testing

Simulation is done in C/C++. The developed genetic algorithm is tested under various traffic conditions of considered MANET. The route function here has been calculated for the four standard time zones in the day and the most optimized values of the attribute indices are calculated.

Performance in 1st Time Zone

Precise values of the performance parameters (Xs) as obtained by using AHP modeling and taking the different variation of communication parameters–

α = 1, β=2, γ=4
α = 1, β=5, γ=9
α = 2, β=3, γ=7
α = 3, β=2, γ=5

Table 3:Performance in 1st Time Zone

Performance parameter (X1)	Performance parameter (X2)	Performance parameter (X3)
1	1	0.723
2.51	3.1	3
1	2.4	2

Optimized values of above performance parameters (X_S) using GA are as follows-

Table 4:Optimized Performance parameters in 1st Time Zone

Performance parameter (X1)	Performance parameter (X2)	Performance parameter (X3)
5	4.2	3
5	3.7	2
2	2.4	1.6

The local constants (Weights) A1, A2, & A3 brought to the normalized scale 10, keeping view the ratio of communication parameters used, as the amplifying weights.

A1 = 4 A2 = 3, A3 = 3

The route function of each node in the first time zone, accordingly, comes out to be-

A=11.5
B=12.3
C=13.5

Performance in 2nd Time Zone

α = 1, β=2, γ=3
α = 5, β=1 γ=6
α = 2, β=4, γ=5
α = 4, β=6, γ=7

Table 5:Performance in 2nd Time Zone

Performance parameter (X1)	Performance parameter (X2)	Performance parameter (X3)
4.1	3	1
3	5.6	4
2.1	2.5	1.8

Optimized values of above performance parameters (X_S) using GA are follows-

Table 6:Optimized Performance in 2nd Time Zone

Performance parameter (X1)	Performance parameter (X2)	Performance parameter (X3)
3	2.87	0.67
2.56	3.8	2
1.4	2.1	1.2.

A1 = 5.2 A2 = 2.8, A3 = 2

A= 12.5
B= 20.4
C=21.6

Performance in 3rd Time Zone

After performing similar function of AHP and GA as in the previous time zones, the following route function values are obtained

A1 = 5, A2 = 2, A3 = 3

A= 4.5
B= 14.6
C= 19.2

Performance in 4th Time Zone

A1 = 4, A2 = 2 A3 = 4

A= 5.6
B = 11.3
C= 23.4

The most optimum node for routing the information is selected by calculating the cost functions for all the nodes in the region under consideration and selecting the node with the maximum/minimum/moderate cost function.

The cost function depends upon the application under consideration. For example: -

1. If battery power consumption is the main parameter of interest, as in the mobile application taking into account the battery life, then nodes having lowest cost function

should be selected. More power consumption may results in high power dissipations.

2. If high node mobility is the main consideration, then moderate cost function nodes need to be selected. The MANET is likely to have moderate number of nodes to cover the entire area of the network.

3. For heavy traffic condition, low cost function nodes need to be selected. The heavy traffic may results in traffic congestion and high power consumption in multi-hop wireless networks due to nearest node communication.

4. For bandwidth requirement to be active, high cost function need to be selected. For easy passage of information all nodes of the network must be active, for that there is only one solution to select high cost function irrespective of high power dissipation.

The overall route can be selected by passing information through the most cost effective nodes, as the overall cost function will be the summation of cost functions of all the intermediate nodes involved on the way.

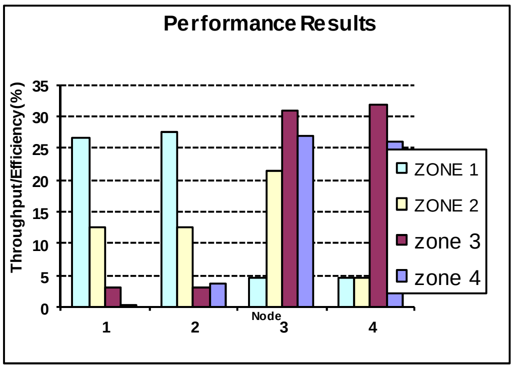

Fig 4: Route Function of Different Nodes in Complete Time Zone

Optimization on Battery Power Consumption: - if power consumption is main parameter then lowest cost function node is selected from each time zone as shown in the following figure

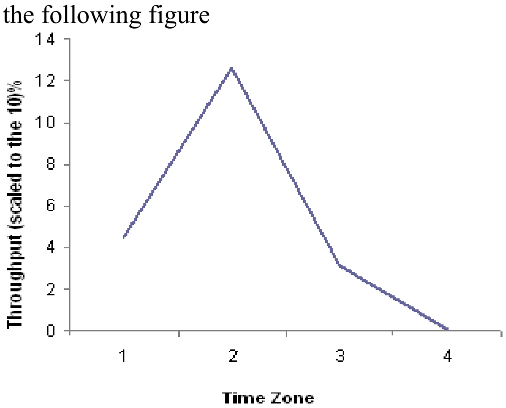

Fig 5 Lowest route Function of a node in each time zone

Optimization on Node Mobility: - If node mobility is kept high then moderate cost function node is to be selected:-

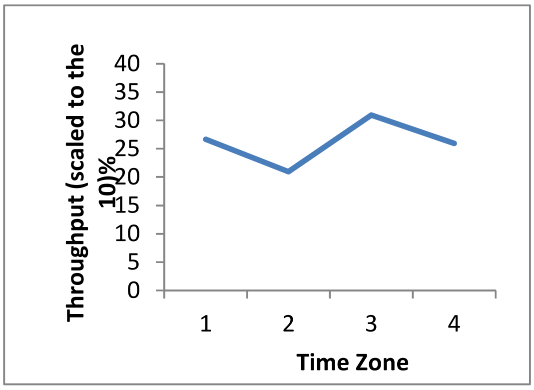

Fig 6 : Moderate route function of a node in particular zone

Optimization on Bandwidth Requirement:-

For Bandwidth requirement, higher value of route function is selected from each zone.

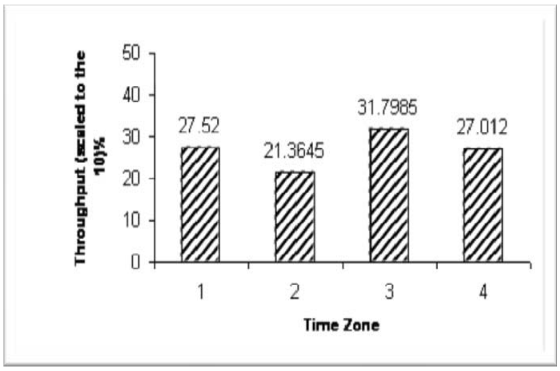

Fig. 7**:** Highest cost Function of a node in each time zone

For optimized route selection, keeping in mind that in our problem the power consumption is the major characteristic of the MANET, out of the four values of the route function in each zone, the lowest one is being represented by lowest power consumed node as being the optimized node/route for passing of information in that particular time zone of the day. The lowest value of the cost function determines the most optimized route or communication being traversed by the nodes.

4. Results and Discussions

The Simulation results using GA and AHP show an average throughput gain of 45% to 55%, depending on network density, over traditional minimum hop route selection in 802.11b networks. If the traffic patterns are not local 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. It is important to note that link rates by definition change faster than link connectivity.

5. Conclusion

Optimized node selection is an essential component in deciding the route that is to be followed in a Mobile Ad-hoc network. However, owing to the variety of communication parameters that need to be optimized at the same time the problem tends to become highly complex. In this work, an efficient node selection technique based upon the evolutionary approach, in the form of Genetic algorithm and AHP, a powerful tool for comparing alternative design concepts in a comprehensive, logical and structured framework, is made use of for the optimum selection of the node. AHP and GA have been combined together for route/node optimization in Ad-hoc networks.

From the results obtained it is concluded that the use of adaptive techniques in combination with the mathematical tools such as AHP, brings a pronounced throughput improvement in ad-hoc networks. By using GA and AHP for routing, the MANET throughput has shown an improvement of 45-55% in comparison to the existing routing algorithms. The proposed model is relatively simple (using GA and AHP), but can be parameterized in a way that allows different scenarios to be modeled both at the level of social organization and topographical translation.

As obtained from the results routing in MANETs, based on traditional routing techniques (proactive and reactive), tend to give throughput gain (efficiency) in the range of 30%-40%, whereas, it has been observed that the route optimization by using GA and AHP techniques together, results in greater saving of power (taking power consumption as the backbone). It may be noted that by using GA, the probability of passing the information through a particular node thrice is less than 33% (due to the effects of crossover and mutation) as the two values after mutation tend to change drastically. If we consider that the probability of passing information is 40% for a certain instance using GA then we are saving about 60% of the power consumed by that particular node, which results in higher efficiency/ throughput. In general, if the probability of passing information through a node is less than 33.33% then the power saved by the node is in the range of 45 – 55%.

Although, in this work a small size network has been taken into consideration for the sake of simplicity, but it exposes the hidden potential in GA and AHP techniques that can be tapped for the efficient route determinations in the emerging future commercial application of Mobile Ad hoc Networks.

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