Position Based Hybrid Routing Algorithm in Wireless Ad Hoc Networks

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ABSTRACT

Ad hoc wireless networks consist of nodes which communicate with each other without infrastructure. In these type networks, the network topology frequently changes due to the movements of the nodes. Broadcast packets are regularly sent to network so that nodes in network can stay in communication with each other. Reactive and proactive routing algorithms are used in ad hoc networks, where routing overhead increases in the case of large number of nodes and raised mobility. Bandwidth and battery lives of nodes are two main sources in ad hoc networks. The reduction of routing overhead and efficiently use of sources are very important issues in these networks. In this study, it was proposed a new routing algorithm that based on the positions of nodes and consists of specification of reactive and proactive algorithms in order to achieve the issues. The nodes were considered as directed graph structure and cost value between nodes was determined by using fuzzy logic. Furthermore, proposed algorithm was compared with reactive and proactive algorithms.

I.INTRODUCTION

Wireless networks emerged in the 1970's, since then they have became increasingly popular. The reason of their popularity is that they provide access to information regardless of the geographical location of the user. They can be classified into two categories: infrastructured and infrastructureless networks. Infrastructured wireless networks, also known as cellular networks, have permanent base stations which are connected to other base stations through links. Mobile nodes communicate with another one through these base stations. Infrastructureless wireless networks, also known as ad hoc wireless networks, are a collection of wireless nodes that does not have any predefined infrastructure or centralized control such as base stations or access points [1].

Ad hoc wireless networks are different from other networks because of following characteristics: absence of centralized control, each node has wireless interface, nodes can move freely which results in frequent changes in network topology, and nodes have restricted amount of resources and lack of symmetrical links.

In wired networks, shortest path is usually obtained with distance vector or link state routing protocols. These protocols do not perform well in ad hoc wireless networks because wireless networks have limited bandwidth and there is not central control. Therefore, modifications to these routing protocols or entirely new routing protocols are required for the ad hoc wireless networks [1],[2],[3]. Table-driven, on-demand and hybrid routing protocols are three main categories of routing protocols for ad hoc wireless networks.

Table-driven protocols, also called proactive protocols, find routes between all source-destination pairs in the network and maintain the latest routes information by sending periodic route update messages. The updates are sent even if no change in topology has occurred. In this category, protocols have been developed by modifying the distance vector and link state algorithms. Protocols store routing information into routing tables. These protocols converge very slowly and generate a lot of routing overhead because of periodic updates. That is why they are not suitable for ad hoc wireless Networks. Destination Sequenced Distance Vector (DSDV), Clustered Gateway Switch Routing (CGSR) and Wireless Routing Protocol (WRP) are variety of table-driven protocols [1].

Destination Sequenced Distance Vector (DSDV) protocol is used commonly for analyzing the protocols in table-driven protocols category. DSDV protocol adds a sequence number to the Routing Information Protocol's routing table. This sequence number field is used to differentiate between stale and fresh routes. Each node maintains a routing table which contains next hop information for all reachable destinations. Each entry of the routing table consists of destination address, the number of hops required to reach the destination and the sequence number received from that destination. Whenever a node receives new information about a particular route it compares sequence numbers and the one with the greatest sequence number is kept while the other one is discarded. If it receives two updates with the same sequence number then the one with lower number of hops is used. The routing table is updated by periodic advertisements or whenever new information is available. The performance of the protocol depends on the periodic update interval value. If this value is very small, there will be a very large routing overhead and if this value is very large, there will be delays in getting the latest route information. This protocol is highly unfavorable for networks which have high mobility and a large number of nodes [4].

On-demand protocols do not maintain the valid routes all the time. Routes are discovered only when they are required. A few existing on-demand routing protocols are: Dynamic Source Routing (DSR), On-Demand Distance Vector Routing (AODV) and Temporally Ordered Routing Algorithm (TORA).

Ad Hoc On-Demand Distance Vector (AODV) protocol is used commonly for analyzing the protocols in on-demand protocols category. In AODV protocol each node maintains a routing table but it does not necessarily contain route to all other nodes. AODV uses a broadcast route discovery method. Whenever a packet is generated for a particular node for which there is no entry in the routing table a route request message is broadcasted. Each neighboring node receives that packet and checks its own routing table. If there is no entry in the routing table this node also broadcast the packet and also records in its table the address of the node from which it received the route request packet. The request message is forwarded until it reaches some node which has a fresh entry for the destination in its routing table or it reaches the destination. The routing overhead for AODV is not as much as that for DSDV but increases with an increase in the number of nodes [5].

Hybrid routing algorithms include the features of table-driven and on-demand protocols and usually use the localized nodes. Localization means the determination of geographical position of nodes by means of Global Positioning System (GPS) or other mechanisms. GPSs have been preferred systems as they provide latitude, longitude and altitude with low cost and high accuracy. In this type of protocols, geographical position of the current node and other nodes are effective while making decision of routing [6]. Recent availability of small inexpensive low power GPS receivers and techniques provided justification for applying position based routing methods. Some of GPS based routing algorithms are Directional Routing Algorithm (DIR), Most Forward within Radius (MFR), Geographic Distance Routing (GEDIR) [7].

Geographic Distance Routing (GEDIR) algorithm use geographical information of neighbor and target nodes in order to determine message packet receivers. The meaning of the neighbor node is the closest node to target node. Algorithm determines the target within a few CPU cycle. Two adding, two multiplying and a following adding and compression as many as the number of nodes are performed in CPU [8]. GEDIR algorithm use only latitude and longitude parts of geographical information of whole nodes. Every node knows geographical positions of only its own neighbors. Sender knows the location of target node at the same time. When node A wants to send message *m* to node D, it uses location information of D and location information of the closest one to D among which are 1-hop neighbors.

Some of hybrid routing algorithms are based on Multi Point Relaying (MPR) technique. MPR aims to reduce routing overhead created by flooding. In flooding method, a control packet broadcasted by source is sent to all nodes. Accordingly, the node received the packet retransmits to other nodes. However, the retransmitted packet is not send to whole nodes but only predefined node. Consequently, it is tried to prevent a packet to be transmitted many times in networks in which there are many nodes [9]. In this study, a position based hybrid routing algorithm has been proposed.

II.POSITION BASED HYBRID ROUTING (PBHR)

The proposed method not only aims to efficiently use the bandwidth by reducing the routing overhead but also battery life is efficiently used by reducing the amount of data to be held and the number of operations to be done for routing by any node in network. In order to achieve above goals, the principles of both on demand and table driven algorithms have been utilized. Nevertheless, the proposed method is entirely different from them. The working principle of infrastructured wireless networks is also benefited in the proposal. As known, there is a central node or station in infrastructured wireless networks, and it is stationary. The nodes in coverage of this station take the information for routing from that and also realized the operation of sending and receiving process through this station.

However, procedures in infrastructured wireless networks have not been used in ad hoc networks up to now since there is not a central node in ad hoc networks or in other words, all nodes are mobile.

In the proposed algorithm, a central node, in other word a master node is assigned as it is in infrastructured wireless networks and directs the routing information. When nodes require sending data to a target node, they take the location of target node and the route to achieve it from master node. Accordingly, they send their data through that route. At this stage, the proposed algorithm differs from infrastructured wireless networks since data is sent via central station in infrastructured wireless networks. However in proposed algorithm, master node, behaving as if it is central node, help only while finding the route to achieve the target

2.1. STEPS OF ALGORITHM

The proposed algorithm consists of following steps:

a. The first node standing up is called as a master node.
b. The master node advertises itself as a master node in network by periodically sending broadcast packet

c. Other nodes in network send to master node update message containing their position information.
d. Master node establishes position matrix P by using update messages.
e. Master node firstly calculates distances between every node and others by using position information. Subsequently it forms distance matrix M.
f. Every row of distance matrix M is added. The node which has minimum value of row totals is considered that it is the closest node to whole nodes. Thus, it is assigned to be candidate master node.
g. The current master node suggests the candidate node to be master by sending a proposal packet.
h. The new master node sends a advertising packet to network
i. Other nodes send their update messages to new master node if necessary.
j. Master node determines cost value of each node to other by using fuzzy logic on M and P matrix.
k. An optimization is performed in order to resolve the minimum cost between sources and targets.
l. Nodes ask the master node for the shortest path by sending a route request packet when they want to send data to other node. The master node responds the node asking for the shortest path according to its optimization results.
m. If master node goes far from central position or battery life falls down a threshold, it transfers the mastership to other node, which has minimum row total value in M.
n. Other nodes in network hold in memory only identity and position of master node.

2.2. EXPLANATION OF ALGORITHM

If two nodes stand at the same time in the network, the one which has a smaller MAC address is assigned as the master node. Besides, if the master node closes with any other reason, in order not to lose the routing information, a secondary master should be assigned. The node which is the closest to the master node is chosen as a secondary master. Nodes in networks send update messages to master node so that established position matrix P, which was given in section 2.1 and item d. Information related to any nodes is hold a row of P matrix, where x_i, y_i, z_i are position data, b_i is battery life, d_i is density and id_i is order number of packet update. The row number of matrix P is equal to number of nodes in network. For a network with *k* nodes, the matrix is as follows:

$$P = \begin{bmatrix} x_1 & y_1 & z_1 & b_1 & d_1 & id_1 \\ x_2 & y_2 & z_2 & b_2 & d_2 & id_2 \\ . & . & . & . & . & . \\ . & . & . & . & . & . \\ x_k & y_k & z_k & b_k & d_k & id_k \end{bmatrix} \quad (1)$$

The master nodes calculates distance of each node to other by using the data given in first, second and third columns of matrix P in order to establish the distance matrix M given in item *"e"* of algorithm steps. The distances are calculated by following equation:

$$l_{i,j} = \sqrt{(x_j - x_i)^2 + (y_j - y_i)^2 + (z_j - z_i)^2} \quad (2)$$

Every item of matrix M is calculated by equation (2) and dimensions of M: row and column numbers are equal to number of nodes in network. For a network with *k* nodes, the distance matrix will be as follows:

$$M = \begin{bmatrix} l_{1,1} & l_{1,2} & . & . & l_{1,k} \\ l_{2,1} & l_{2,2} & . & . & l_{2,k} \\ . & . & . & . & . \\ . & . & . & . & . \\ l_{k,1} & l_{k,2} & . & . & l_{k,k} \end{bmatrix} \quad (3)$$

The diagonal of M will be zero as the distance of every node to itself is zero. Also with a condition $i \neq j$, the distance between *i* and *j* and the distance between *j* and *i* are the same, thus the matrix M will be symmetrical matrix. Therefore the upper triangular part of matrix M will only be calculated. The lower triangular part of M will be filled by upper triangle. As a result of this, the computational time, which is an important factor for battery life of a node, is reduced.

A row matrix T is created by using the total of rows or columns of matrix M given in equation (3) so that the node, which is in the center of network, could be found. The column number of matrix T, which has minimum value, gives the number of node which is in the center of network [10]. For a network with k nodes, the T matrix will be as follows:

$$T = \begin{bmatrix} t_1 & t_2 & t_3 & . & . & t_k \end{bmatrix} \quad (4)$$

According to item *"i"* of algorithm steps given section 2.1, the nodes in network send their event based update packet to master nodes when there is position change, and when the battery life downs lower than a threshold and processing load increases. The master node clears old knowledge related to node and rewrites the new knowledge by means of id value transmitted in update packet. Because nodes transmit a value of id in every update packet, which is higher than the value sent in previous packet.

Nodes in a network and distances between nodes are shown in directed and weighted graph as vertex and edges, respectively. Figure 1 shows a network with six nodes which has a structure explained above.

In the proposed strategy, master node does not only use distance between nodes but also use battery life of nodes and processing loads to respond the routing request of a node. If processing load of any of two very close nodes is high level or its battery life is about to finish, the data of sender reaches to receiver later than expected. Therefore we propose to estimate the cost value between nodes by means of fuzzy logic on distance, battery life and processing density variables. To be able to apply fuzzy logic, it is supposed that nodes provides following criteria: (i) each node can directly send packets to nodes l_T unit far from itself, and can only send its packet to nodes far away from l_T through other nodes. (ii) Link between nodes is bidirectional which means that two neighboring nodes can send packets each other.

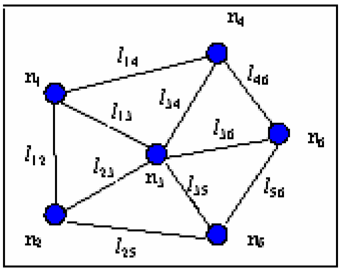

Figure 1. Topological review of nodes and distance of a network with six nodes.

There are three input variables: distance, battery life and processing density in fuzzy reasoning system. The output variable is only cost value. The input and output variables are shown in figure 2.

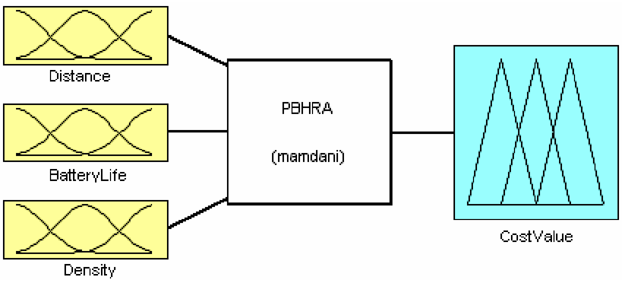

Figure 2. Fuzzy reasoning system for cost value estimation in a network.

Distance changes from 0 to l_T. Five triangle membership functions are equally replaced between 0 and l_T. l_T is scaled between 0 and 100. The assigned linguistic variables are *"very close"*, *"close"*, *"medium"*, *"far"*, *"very far"*. The parameters of membership functions are given in Table 1.

Density and battery life vary from 0 to 100 percent. Three membership functions for these input variables: "low", *"medium"*, *"high"* have been assigned. The parameters of triangle membership functions of density and battery life are shown in Table 1.

Output variable, cost value, varies from 0 to 100 units. Five membership functions for these input variables: "very low", "low", *"medium"*, *"high"*, *"very high" have* been assigned. The parameters of triangle membership functions of cost value are shown in Table 1.

The inference mechanism consists of 45 rules. Center of gravity method has been used for defuzzyfication of output variable. Consequently, the cost value of each node to other nodes (if they are within coverage) has been obtained. Table 2 shows some examples of typical values of input variables and accordingly estimated cost values.

Table 1. Parameters of membership functions of input and output variables.

Distance	**Parameters**	**Cost**	**Parameters**
Very Close	0 0 25	Very Low	0 0 25
Close	0 25 50	Low	0 25 50
Medium	25 50 75	Medium	25 50 75
Far	50 75 100	High	50 75 100
Very Far	75 100 100	Very High	75 100 100
Density	**Parameters**	**Battery Life**	**Parameters**
Low	0 0 40	Low	0 0 40
Medium	10 50 90	Medium	10 50 90
High	60 100 100	High	60 100 100

The shortest path has been obtained by means of Dijkstra's optimizations algorithm in order to achieve the optimization process given in item *"k"* of algorithm step in section 2.1. True optimal paths have been obtained on an example with thirty node network.

Table2. Cost values estimated with fuzzy logic.

Distance	Battery Life	Density	**Cost Value**
50	50	50	**50**
10	90	60	**25**
30	25	80	**66**
70	25	100	**80**
80	20	50	**76**

2.3. CLUSTERING OF NODES

The computation load at master node will be increased when the number of node in network and spread of them increases. Also there will be delays to reply to route requests. The nodes could be clustered to solve this problem in such a way that a new master node is assigned in each cluster created. So the new master node holds the routing information, and responds to routing requests in its own class.

The norm of distance matrix gives knowledge the spread of network. The larger norm it is, the more spread the network is. In proposed algorithm, the distances among nodes in network are hold in a matrix M given in equation (3). The classification is done when the norm of M gets larger than a predefined threshold, or when the number of nodes in network becomes larger than a threshold. The decision of how many cluster must be created was determined by number of nodes and value of norm. In our case, the well known fuzzy c-means (FCM) algorithm was employed to cluster the nodes.
Fuzzy c-means is a data clustering technique wherein each data point belongs to a cluster to some degree that is specified by a membership grade. This technique was originally introduced by Jim Bezdek in 1981 as an

improvement on earlier clustering methods [11]. It provides a method that shows how to group data points that populate some multidimensional space into a specific number of different clusters [12].

FCM is started with an initial guess for the cluster centers, which are intended to mark the mean location of each cluster. The initial guess for these cluster centers is most likely incorrect. Additionally, assigns every data point a membership grade for each cluster. By iteratively updating the cluster centers and the membership grades for each data point, so the cluster centers moves to the right location within a data set iteratively. This iteration is based on minimizing an objective function that represents the distance from any given data point to a cluster center weighted by that data point's membership grade [12].

The clustering performed when the number of nodes and spread increase. The use of the clustering process makes route determination process faster. This structure could be resembled scatternets in Bluetooth. However the key distinction is that there is no obligation for sending data via center of clusters.

2.4. PERFORMANCE OF ALGORITHM

According to the proposed algorithm, any broadcasting packet is not transmitted in network except the master node transmits an announcement packet which tells that it is a master node. On the other hand, in all reactive and proactive algorithms discussed in section 1, broadcasting packets are used for the processes of routing determination and creating routing table.

The route request packets and update packets for node position information are not any broadcast packet in the proposed algorithm. Nodes send packets only to master node for route request and position information update. Consequently, bandwidth of network is efficiently used.

An additional advantage of the proposed algorithm is that any node except master node does not hold routing table and the process of routing determination since only master nodes responds to routing requests. As a result of this, life times of batteries of nodes will be longer. The simulation study for evaluating the proposed algorithm is still on progress.

III.CONCLUSION

Bandwidth and battery life are limited sources in ad hoc networks. On the other hand, with the algorithm developed in this investigation, these restricted sources are affected with overhead generated by process of routing determination at minimum level.

The raise of nodes in network does not bring any disadvantage apart from the size of routing matrix held by master node. Nevertheless this drawback has been removed by clustering procedure of network. The route determination speed has been increased in this solution, where the nodes, which are geographically closed to each other, are in the same set. The assignment of a master node for each set and their responsibility of answer to route requests has been an effective solutions for networks which have large numbers of nodes and high mobility.

Also, in the proposed strategy, the process of finding the shortest path could be performed by genetic algorithm instead of conventional Dijkstra or Bellman-Ford algorithms. As known, genetic optimization algorithm could evaluate many criteria simultaneously. So employment of genetic algorithm for routing optimization is still on progress.

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