# Creating Frame Structures for Position-based Hybrid Routing Algorithm

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***Abstract*— Ad hoc wireless networks are composed of mobile nodes that communicate with each other without any infrastructure like a base station or access device. Routing algorithms of ad hoc networks can be classified as table-driven, on-demand and hybrid algorithms. Position-based Hybrid Routing Algorithm (PBHRA) is a hybrid routing algorithm that based on nodes position information. In this study, protocol implementation of PBHRA has been done. Frame structures of protocol have been formed. The protocol was simulated using these created frames. The simulation results show that the proposed frame structures suitable for ad hoc networks.**

***Keywords-routing protocol; wireless network; routing; ad hoc network***

## I. INTRODUCTION

Infrastructureless wireless networks, also known as Mobile Ad Hoc Network (MANET), are composed of randomly moving mobile nodes without a central control like a base station or a predefined infrastructure. At the present time, these mobile nodes -that may take part in airports, ships, trucks, automobiles, very small devices and on people-are prevalently used in many industrial and commercial applications. This mentioned place necessitates the mobility of nodes. Therefore, mobile nodes in ad hoc networks must use routing algorithm in order to communicate each other.

Routing algorithms for MANET can be classified as table-driven, on-demand and hybrid algorithms. PBHRA that has been developed by us a hybrid routing algorithm depends on the node position information. PBHRA and its performance analysis have been presented in [1].

It is required to establish packet structures for the hardware and protocol realization of the routing algorithms used for ad hoc and sensor networks. This requirement involves determination overhead of packet structure to effect of performance. It is important for performance examination of algorithms. Accordingly, many researchers have studied on determination of frame structure and protocol realization for MANET routing algorithm [2-9].

In [2], software is developed and an application environment is set to apply Ad Hoc On Demand Distance Vector (AODV) algorithm as protocol. A protocol realization is done on Ns-2 simulator for Dynamic Source Routing (DSR) and AODV algorithms and the comparisons related to the functioning of these two algorithms as protocol are done [3].

Protocol design and realization of Fisheye Routing Algorithm that aims to decrease the consumption of band width studied in [4]. Holter et al. [5] made an implementation over Quagga Routing software protocol for the realization of wireless Open Shortest Path First (OSPF) algorithm that aims to minimize protocol overloads [5]. A protocol realization is done on ns-2 simulator for DSR and AODV algorithms and the comparisons related to the functioning of these two algorithms as protocol are done [6].

Working steps of Optimized Link State Routing (OLSR) protocol, the selection of detailed multi point relay sets, frames used in protocol realization, and their structures are given in [7]. The general packet and heading structures have been described that is needed to be used for the packet exchanges of MANET routing algorithms in routers [8]. Since MANET routers themselves are the wireless nodes, these structures are also used for protocol realization. In another study, Neighborhood Discovery Protocol (NHDP) is introduced and frame structures are given [9]. NHDP uses a local exchange of HELLO messages so that each router can determine the presence of, and connectivity to, its 1-hop and symmetric 2-hop neighbors.

In this study, the proposed frame structures for PBHRA will be presented as an original study because they are different from the algorithms of PBHRA that are implemented above.

Depending on all these, in this study, PBHRA algorithm is Summarized in section II. In Section III, the frame structures for implementing PBHRA are given. In Section IV, according to evaluation consideration given in RFC 2501 [10], the parameters/values of PBHRP, which is developed in Matlab 7.01, are given; according to performance issues,

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which are specified in same RFC, their analyses are also presented.

## II. Frame Structure of Position Based Hybrid Routing Protocol (PBHRP)

PBHRA algorithm that is suggested in [1] entails to provide GPS in every node to determine the positions of the other nodes in the network like other position-based algorithms. According to the algorithm, the node in the center of the network behaves as a master node. Master node realizes route determination process using position, node density, and battery life information of the other nodes in the network.

PBHRA has the following steps [1]:

*a.*The first activated node in the network is assigned as master node.

*b.*Master node announces master node announcement packet periodically to make the network know that it is a master node.

*c.*The other nodes in the network send update packets in which their position information exists to the master node.

*d.*Master node constitutes position matrix using update information.

*e.*Master node constitutes distance matrix after it calculates the distances in between every node by using position information.

*f.*The node that corresponds to the smallest valued row after the row elements of position matrix are summed is determined as central and candidate master node is fixed.

*g.*Current master node proposes to be the new master node by sending proposal packet to the master node.

*h.*New master node sends master node announcement packet to the network.

*i.*Other nodes send their update packets to new master node if necessary.

*j.*Master node calculates cost criterions of every node by fuzzy logic method using distance and position matrices, and then fuzzy matrix is constituted [11].

*k.*Optimization is done using fuzzy matrix to determine the paths between nodes with the lowest cost.

*l.*Nodes ask for the shortest path when they send data to another node by sending path demand packet to the master node. Master node tells the shortest path to the node which demands according to the optimization result.

*m.*Master node circuits its role to another appropriate node if it moves away from the center or its battery life decreases to the below of the threshold value.

*n.*Other nodes in the network keep only the identity number and the position of the master node in their memories.

The flow chart of PBHRA is given in Figure 1 [1].

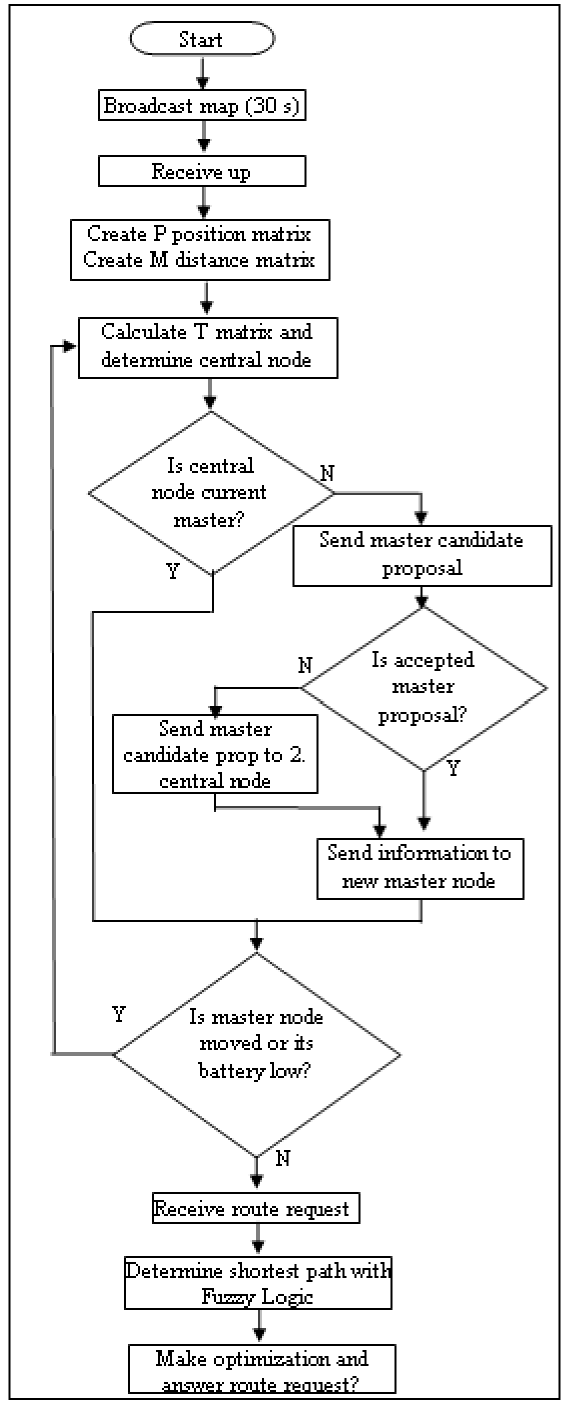


Figure 1. The flow chart of PBHRA [1]

## III. Frame Structure of Position Based Hybrid Routing Protocol (PBHRP)

The frame structure of PBHRA whose working steps are given above is determined for the protocol realization. Designed frames for PBHRP have been given below.

Master node announcement frame (*maf*) that is to be sent to the other nodes in the network by master node according to *step b* of the algorithm is given in Figure 2.

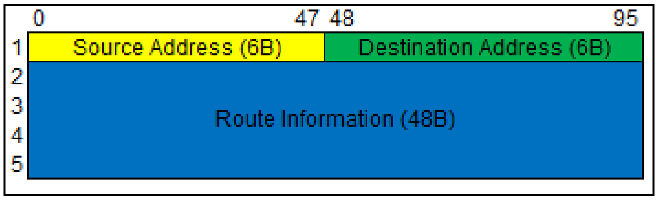


Figure 2. Master node announcement frame

According to the structure in Figure 2, the source address space of size 6 Bytes is the physical address of the master node and the destination address space of size 6 Bytes is the broadcast address to enable every node in the network for being a receiver. The route information space of size 48 Bytes is used to be filled by every node which transfers master node announcement frame to its neighbors along itself. With regard to this structure, the addresses of at most 8 addresses are stored except source and destination addresses. maf is transferred with broadcasting method in this algorithm.

Every node except master node sends update frame (*uf*) that includes position, battery, and density conditions according to *step c* of PBHRA. The structure of the update frame is given in Figure 3.

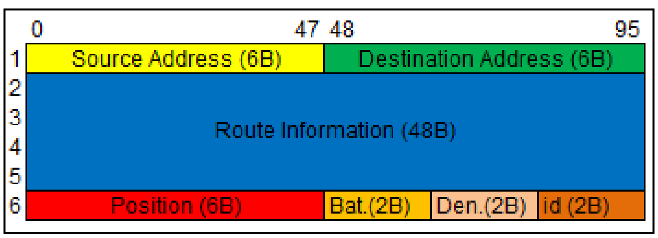


Figure 3. Structure of update frame

The source address space of the update frame given in Figure 3 is the physical address of the node which sends data, and its destination address space is the physical address of the master node. Route information space is the inverse of the route information of *maf*. So, *uf* is to be send along the way where *maf* is sent. There exist latitude, longitude, and height information gathered from the GPS inside the node in the position space. Battery life (as percentage) is given in the battery space, buffer fullness rate (as percentage) is in density space, and an integer value that is incremented by 1 in each sending exists in identity space. The value in identity space is used by master node to determine whether the update frame is old or the new one. *uf*'s are transferred to the network after their destinations and routes are determined. They are unicast and source-routing frames.

According to *step d* of PBHRA, master node stores update information, taken from other nodes, into position matrix. According to *step b* of the algorithm, master node calculates the distances between every node by using the position information matrix.

Master node offers a candidate after it determines the node at the center of the network by adding the elements of the row or the column of the distance matrix. Structure of master node candidate suggestion frame (*mcsf*) is given in Figure 4.

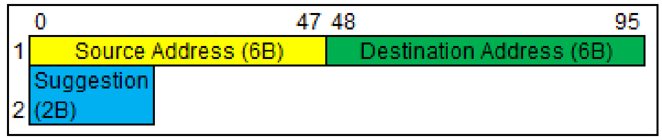


Figure 4. Master node candidate suggestion frame

The source address space is the physical address of master node, and the destination address involves the address of the candidate master node with regard to *mcsf* given in Figure 4. Suggestion Data space includes "01" value in base 10. The node which receives the suggestion declares if it accepts the suggestion response frame (*srf*) or not. Data in Suggestion Data space of *srf* given in Figure 5 is made "00" to deny the candidate suggestion, and it is made "11" to accept the suggestion.

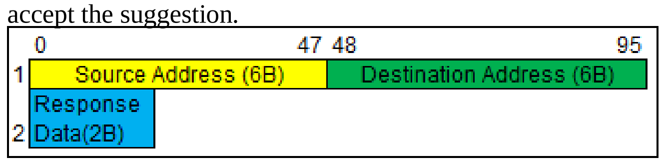


Figure 5. Structure of master suggestion response frame

According to *step j* of the algorithm, master node of the network stores the cost values, calculated by fuzzy logic, of each node to the others in fuzzy matrix.

According to *step l* of PBHRA, a node with a demand to send data asks the route through the destination node to master node via route demand frame (*rdf*). Based on the structure of *rdf* given in Figure 6, source address space is the physical address of the node which demands, and the destination address space is the physical address of the master node. Also, demand destination address space is the physical address of the node to which the data is intended to send.

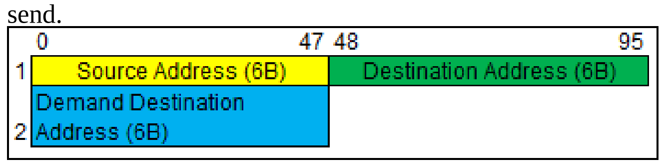


Figure 6. Structure of route request frame

Master node responds with a route response frame (*rrf*) after it receives route request frame. In Route Data space of *rrf* given in Figure 7, there exist physical addresses of nodes that include the path from source to destination. There are also physical addresses of eight intermediate nodes except source and destination. Master node uses the cost data of fuzzy matrix for this operation. If need more than eight inter node in order to routing data packet, PBHRA proposes node clustering [1].

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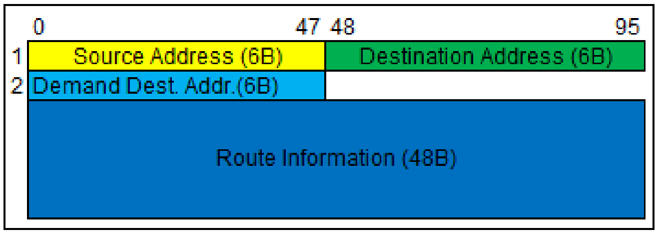


Figure 7. Structure of route demand frame

According to PBHRA, a node which will send data sends its data using data frame (*df*) given in Figure 8 after it learns about the path of its destination from master node.

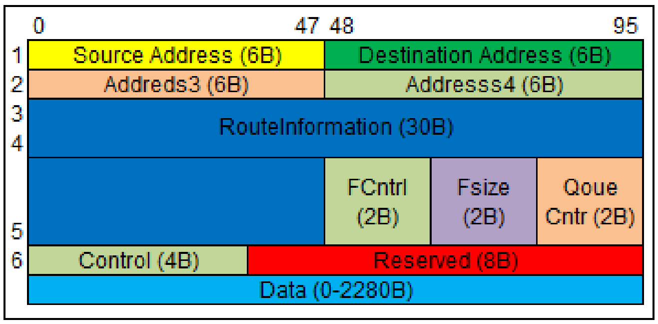


Figure 8. Structure of data frame

Control and data frames needed to send data in the network are formed. In the following sections, some simulations on sending data in network are performed by using these frames.

## IV. Performance Evolution Of PBHRP

A software is developed via MATLAB 7.01 evaluate the performance of the developed protocol. In the software, some functions are written to achieve the purposes and the processes, and a modular software environment is set. Evaluation environment and the parameters provided in RFC 2501 [10] is used for the performance evaluation.

The parameters below are used for the simulation.

*Number of Nodes:* 10, 20, 50, and 100-noded networks are used for the simulation.

*Environment Size:* A random distribution is used in the environment having 5000 $m^2$ per node in both horizontal and vertical axes, and 10 m height.

*Packet Size:* Fixed-sized data packets of size 512 and 1024 Bytes are used.

*Number of Sources:* 5, 10, 20, and 30-sourced networks are considered. Source number denotes the nodes that are able to send data packets simultaneously.

*Action Speed:* Random-waypoint model is used for the nodes acting with random speeds between 0-20 m/s.

*Stagnation Time:* 0, 10, 20, 50, and 100 seconds are considered as stagnation times. Stagnation time is the time in which nodes stay stagnant. 0 second tells that the node is always in action, and 100 seconds express that the node waits 100 seconds stagnantly after an action.

*Propagation distance:* Coverage area of the nodes is a circle with radius 100 m.

*Simulation Time:* Simulation models are run for 100 seconds.

*Number of Iterations:* Each different network handled with simulation software is run 10 times and average results are gathered.

Packet Delivery Rate -one of the criterions used for performance evaluation of ad hoc routing protocols- is a performance evaluation criterion which determines the access rate to packets when they are sent by data sender nodes in the network. It is expressed as the rate (as percentage) of the packets that reach to their destination. If the packets sent by the sender nodes in the network don't reach to their destination, then the packet delivery rate is low. If the number of packets that access to their destination increase, then the packet delivery rate increases, too.

Expression in (1) is used to determine packet delivery rate.

$$PDO = \frac{n_h}{n_T} \cdot 100 \qquad (1)$$

$n_h$ denotes the number of packets that reach to their destination, $n_t$ is the total number of data packets sent in this expression.

Simulation software is run on 10, 20, 50, and 100-noded networks with different stagnation times and different source numbers to determine packet delivery rate and the results given in Table I are obtained.

TABLE I. PACKET DELIVERY RATE VALUES FOR 10, 20, 50, AND 100-NODED NETWORKS WITH DIFFERENT STAGNATION TIMES AND DIFFERENT SOURCE NUMBERS

| **Stagnation Time (s)** | **0** | **10** | **20** | **50** | **100** |
|---|---|---|---|---|---|
| **10 Nodes-5 Sources** | 99,52 | 100 | 100 | 100 | 100 |
| **10 Nodes-10 Sources** | 100 | 100 | 100 | 100 | 100 |
| **20 Nodes-10 Sources** | 97,30029 | 96,35286 | 96,72257 | 97,81829 | 100 |
| **20 Nodes-20 Sources** | 99,5 | 99,75 | 98,20567 | 99,43567 | 99,062 |
| **50 Nodes-10 Sources** | 100 | 100 | 100 | 100 | 100 |
| **50 Nodes-20 Sources** | 100 | 100 | 100 | 99,759 | 99,345 |
| **50 Nodes-30 Sources** | 100 | 100 | 100 | 100 | 100 |
| **100 Nodes-10 Sources** | 100 | 100 | 100 | 93,473 | 99,623 |
| **100 Nodes-20 Sources** | 86,872 | 100 | 96,397 | 100 | 100 |
| **100 Nodes-30 Sources** | 98,663 | 100 | 100 | 100 | 100 |

According to the values in Table I, the networks with high mobility have less packet delivery rate than the networks with less mobility. The change in the number of nodes in network has not much effect on the performance.

Proposed PBHRP is compared with DSDV, DSR, and AODV protocols, which are the leading in performance evaluation in ad hoc networks in terms of packet delivery rate. 50-noded and 20-sourced networks with different stagnation times are compared and the results are given in Table II.

According to the values in Table II, the proposed PBHRP has better packet delivery rate values than AODV, DSDV, and DSR protocols.

Another performance evaluation criterion for routing protocols of wireless ad hoc networks is normalized routing load. Normalized routing load is determined dividing by routing packets to total packets.

TABLE II. PACKET DELIVERY RATE VALUES OF 50-NODED AND 20-SOURCED NETWORKS IN PBHRP, AODV, DSDV, AND DSR PROTOCOLS

| Stagnation Time (s) | 0 | 10 | 20 | 50 | 100 |
|---|---|---|---|---|---|
| PBHRP (PDR %) | 98,62 | 98,86 | 98,88 | 99,34 | 99,54 |
| AODV (PDR %) | 96,97 | 98,83 | 98,83 | 99,07 | 99,53 |
| DSDV (PDR %) | 71,39 | 73,72 | 67,44 | 79,06 | 99,53 |
| DSR (PDR %) | 83,72 | 93,25 | 92,09 | 92,09 | 99,53 |

Simulation software is run on 10, 20, 50, and 100-noded networks with different stagnation times and different source numbers to determine normalized routing load and the results given in Table III are obtained.

TABLE III. NORMALIZED ROUTING LOAD VALUES FOR 10, 20, 50, AND 100-NODED NETWORKS WITH DIFFERENT STAGNATION TIMES AND DIFFERENT SOURCE NUMBERS

| Stagnation Time (s) | 0 | 10 | 20 | 50 | 100 |
|---|---|---|---|---|---|
| 10 Nodes-5 Sources | 0,32062 | 0,29104 | 0,27102 | 0,25795 | 0,2357 |
| 10 Nodes-10 Sources | 0,35207 | 0,33053 | 0,30061 | 0,2933 | 0,28889 |
| 20 Nodes-10 Sources | 0,33659 | 0,29459 | 0,26316 | 0,24513 | 0,25496 |
| 20 Nodes-20 Sources | 0,35704 | 0,33475 | 0,30337 | 0,30967 | 0,29706 |
| 50 Nodes-10 Sources | 0,34729 | 0,24106 | 0,18958 | 0,15848 | 0,14292 |
| 50 Nodes-20 Sources | 0,24075 | 0,18157 | 0,16203 | 0,1385 | 0,12903 |
| 50 Nodes-30 Sources | 0,21231 | 0,17666 | 0,15236 | 0,14248 | 0,13818 |
| 100 Nodes-10 Sources | 0,5685 | 0,46341 | 0,35674 | 0,30115 | 0,25547 |
| 100 Nodes-20 Sources | 0,44066 | 0,33952 | 0,29364 | 0,26131 | 0,24 |
| 100 Nodes-30 Sources | 0,3923 | 0,30951 | 0,27837 | 0,25099 | 0,23836 |

According to the values in Table III, in the networks with same number of nodes, the networks with large number sources have higher normalized routing load.

TABLE IV. NORMALIZED ROUTING LOAD VALUES OF 50-NODED AND 20-SOURCED NETWORKS IN PBHRP, AODV, DSDV, AND DSR PROTOCOLS

| Stagnation Time (s) | 0 | 10 | 20 | 50 | 100 |
|---|---|---|---|---|---|
| PBHRP | 0,2408 | 0,1816 | 0,162 | 0,1385 | 0,129 |
| AODV | 0,42 | 0,35 | 0,38 | 0,41 | 0,15 |
| DSDV | 0,37 | 0,48 | 0,54 | 0,37 | 0,12 |
| DSR | 1,3333 | 1,3333 | 1,2427 | 1,2941 | 1,0161 |

According to the values in Table IV, the proposed PBHRP has better normalized routing load values than AODV, DSDV, and DSR protocols.

## V. CONCLUSIONS

Protocol realization of one of the position-based routing algorithms, PBHRA, which is developed to be used in mobile ad hoc networks, was presented in this study.

First of all, the frame structures to be used by the protocol are formed. The control frames that the protocol will use to control the network and the data frames intended to be used to send data are created.

To test the usability and the performance of the proposed protocol, a simulation is performed with MATLAB 7.01. With this simulation software, PBHRA is run for different node number, source numbers, and different mobility scenarios. According to the gathered results, the increase in the number of nodes in network does not make any change in packet delivery rate. In case of high mobility, the packet loss increases 1.6 % in the average.

It is shown that PBHRP performs better with 16% in case of high mobility when it is compared with other protocols in terms of packet delivery rate.

The obtained performance results show that the proposed protocol and frame structures are a new alternative for mobile ad hoc networks.

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