AN EFFICIENT MULTI-PATH ROUTING ALGORITHM BASED ON HYBRID ARTIFICIAL BEE COLONY ALGORITHM FOR WIRELESS MESH NETWORKS

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1. SWARM INTELLIGENCE IN WIRELESS MESH NETWORKS

In order to solve distributed problems, Swarm Intelligence (SI) encompassing a modern computational and behavioural metaphor becomes vaible as the inspiration has originatedfrom the biological instancesgiven by social insects (ants, termites, bees, wasps) and their behavioural modes such as swarming, flocking, herding and so on Kennedy & Eberhart (2001).SI is based on the collective behaviour of social insects and other animal societies in view of designing algorithms or distributed problem-solving devices Bonabeau et al (1999);Dorigo&Sttuzle (2004).

The entire distribution of control occurs among a number of individuals;

- The localized way of communications among the individuals ;
- System-level behaviors tends to surpass the behavioral modes of the single individual; and
- The overall response of the system is used to be vigorously better and adaptive with respect to the environmental changes.

Swarm intelligence (SI) is referred as an effort of designing algorithms or distributed problem-solving devices based on the inspirations of the collective behavior of social insect colonies and other animal societies"Bonabeau et al (1999). In general, the term "swarm" is used to refer to any such loosely structured collection of interacting insect or animal communities. The typical example of inspiration of SI is a swarm of bees, however the comparison can also be extended to other systems possessing similar style. An ant colony being a swarm and the individual ants of the colony are its agents, Similarly the trend goes on in which swarm refers to a flock of birds, traffic, crowd, an immune system, an economy for which its agents are birds, cars, people, cells and molecules, economic agents respectively. Rather than considering only the collective motion in space, the idea of swarm becomes varies sometimes especially in case of flock of birds along with spatial motion all other types of collective behavior of birds are been taken into account.

Keywords : HABC , SI, FKA, ABC, DAWNet

1.1 ARTIFICIAL BEE COLONY (ABC) ALGORITHM

The artificial bee colony algorithm proposed by Karaboga (2005) and Karaboga&Basturk (2008)is a novel population-based metaheuristic approach, which attained further developments by research studies byKaraboga&Basturk (2007) and Karaboga and Akay (2007). ABC algorithm is very facile and powerful which can be applied to various complex problems as it simulates the intelligent foraging behavior of honey bee swarms. In the ABC algorithm, the artificial bee colonies are classified into three categories namely employed bees, onlookers and scouts. Employed bees usually associate with a particular food source it has employed with or which are been presently exploiting. The information about the specific food source will be carried by them for share themto onlookers. Onlooker bees used to wait in the dance area of the hive for assimilating the information on food sources shared by the employed bees so that to arrive at a decision about choosing a food source. The scout bees usually carry out the random search. In the ABC algorithm, the initial steps of the colony consist of the employed artificial bees whereas the later steps include the onlookers. For every food source, there is only one employed bee. It can be also stated that the number of employed bees is equal to the number of food sources around the hive. The employed bee becomes the scout bee once its food source gets exhausted. The position and the nectar amount of a food source represents a possible solution to the optimization problem and the quality (fitness) of the associated solution respectively. With the help of probability-based selection process, onlookers are placed on the food sources. The probability value associated with the preferred food source by onlookers increases based on the increase in the nectar amount of a food source. Karaboga&Basturk (2008). The main steps of the algorithm are as follows summarized .

Drawbacks in ABC

In ABC algorithm, the exploration and exploitation processes are in contrary with each other and hence those two capabilities should be well balanced in order to achieve good optimization performance. In case of global optimization, the ABC algorithm has been already proven as very effective. ABC even being high performance optimizer is very easy to understand and apply. However, ABC tends to converge slowlyor at times gets trapped in a local optimal solution.

1.2 HYBRID ARTIFICIAL BEE COLONY ALGORITHM

a. Orthogonal Initialization

Initialization of population is the primary important step in evolutionary algorithms as it can affect both the quality of solution as well as the convergence speed. Before solving an optimization problem, information on the solution location will not be available Kong et al (2012). It is better to uniformly scatter the initial population over the feasible solution space, so as to enable the even algorithm search across the whole solution space. It has been inferred thatthe orthogonal array that specifies a small number of combinations are scattered uniformly over the space of all possible combinations. Hence, orthogonal design is considered as s good population initialization method. In this work, initial population is generated with the help of the orthogonal initialization method which works based on orthogonal array and quantization technique as described by Leung & Wang (2001).

b. New Search Mechanism

The optimization will be functioned using Differential Evolution (DE) which is as population based algorithm. The main strategy of DE is generating a new position for an individual by calculating vector differences between other randomly selected members in the population. Efficiency of many optimization problems has been proved in real-world applications. "DE/current-to-rand/1" is a variant DE mutation strategy that helps for effective maintainenance of population diversity. The inspiration of DE and property of ABC algorithm triggers the proposal of a new solution search equation:

$$v_{ij} = x_{ij} + \phi_{ij}(x_{ij} - x_{r_1,j}) + \psi_{ij}(x_{r_2,j} - x_{r_3,j}) \quad (3.1)$$

where the indices $r_1, r_2\ and\ r_3$ are mutually exclusive integers randomly chosen from $\{1, 2, \ldots, SN\}$,and all of them are different from the base index $i;\ j \in \{1, 2, \ldots, D\}$ is a randomly chosen index;ϕ_{ij} , $\psi_{ij} \in [-1, 1]$ are random number.

As given in (3.2), only one element is different from the old one in the candidate solution. This becomes the reason for poor search efficiency. However, the problem can be overcome by modifying search equation (3.2) t as follows:

$$v_{i,m} = x_{i,m} + \phi_{i,m}(x_{i,m} - x_{r_1,m}) + \psi_{i,m}(x_{r_2,m} - x_{r_3,m}) \quad (3.2)$$

where $1 \leq m \leq D$ is a positive randomly selected integer, which controls how many elements evolve.
The solution procedure of HABC is as follows.

2. MULTI-PATH ROUTING ALGORITHM BASED ON HABC

In WMN, nodes in the network used to possess lesser battery power, lesser memory consumption, based on which WMN has been expanded by the routing algorithm into a larger area having no transmission communication support Koh et al (2003). For meeting out extremely important requirements to achieve reliable communication in routing algorithm, the hybrid multi-path routing algorithm for WMN called FKAWMNet combining the Filter Kruskal Algorithm (FKA) and HABC algorithm has been presented in this work. Filter Kruskal Algorithm (FKA) helps to achieve route setups whereas examination and maintenance of the route setups are enabled by using HABC algorithm. First the intitalization step of WMN has to be done before applying route setup algorithm to find the shortest path the WMN. Then Filter Kruskal Algorithm (FKA) is employed in network manager stage to find shortest paths to each end node. In the route examination stage, using HABC the shortest path routes are examined during transmission of data between mesh clients. The storage of multipath routing information from one node to other nodes takes place in the routing tables after which data transmission is carried out based on this routing table information for each node in the WMN. All the WMN nodes maintain a group of routing table for managing the data transmission communications between nodes. Some of the other tables needed for gathering information of nodes are neighbor table and graph table. The examined information about food sources will be updated by path exploration table for all nodes in WMN.

(1) Neighbor Table. This table enables **straight** communication among nodes by maintaining possible information of all nodes. The neighbor table for each node is then formed once after the initialization of the WMN.

(2) Graph Table. In order to find route messages from source to destination nodes in the WMNs, network graphs are used. Although each and every node in the graph doesn't contain information of entire route, information of earlier and next node will be known for reaching destination for distributing the packet. The performance of the data communication among one to another nodes is based on the graph ID for each nodes as mentioned in the graph table. For selecting the best route in WMN, the updated results given by regular bee path exploration for routes in graph table are used as the important key factor.

(3) Path Exploration Table: The information on food sources from source node i to reach destination node all the way through intermediate node j used to be stored in path exploration table. Moreover, information about the middle nodes in the route (path) selected results from FKA were also present and calculated regular fitness value (fit_i^d) to each node in the route setup results or a Probability value$Prob_i^d$. The fitness value results for each node helps for approximating the accurate path route setup values of each node in WMN so that to arrive at the optimal route setup results for data transmission process. The fitness value of each node in the route is then continuously bootstrapped with respect to the information on the nearest neighbour nodes at the time of examining route in HBAC. The bootstrapped value of the each node is temporarily stored in path exploration table and each iteration in HABC is updated. The goodness value of each route is calculated based on the cost value which is also considered as fitness value for route

path results from FKA. In this work, the cost of the each route is calculated based on the calculation distance value between nodes in the WMN (graph structure). The cost of a route setup (Fitness value) for nodes in the WMN is expressed using the following equation:

$$fit_i^d = c_i^j = d_i^j \qquad (3.10)$$

where c_i^j denotes the cost of route value results from source node i to middle node j in the WMN, d_i^j is the distance between nodes i and j.

i. Route Maintenance for Topological changes

Based on the number of fault nodes presents in the WMN, topological changes can be implemented. Route maintenance in the topological network plays a vital role in the WMN as any changes made in the network affects the route examination results. Generally changes made in the network topologies are adding a new node in the network, removing fault node in the network, moving path from one to another node etc. To adjust to this abovementioned process in route maintenance stage, each one of the steps is performed separately based on their different topological changes.

Joining of new nodes

If the nodes require joining ofthe existing WMN, the network has to be joined based on their information obtained from "Advertise" messages.The advertise messages are then sent by other nodes which is not included in part of route path. After adding the new nodes to WMN, the connection is established from one node to another node provided the distance value of the nodes does not exceed within communication range. The examination of the route information of the newly added node is done by using route examination stage in HABC. From the obtained results, several numbers of routes were selected by the network manager to transmit their data from source node to a destination node in WMN.

Nodes moving

While nodes are moving from one place to another place, keep alive messages are sent to all the nodes for updating the position of the nearest nodes in moving stage. Also, performance of route examination by the network manager based on the specified network conditions specified by the user is been done. If any specific node moves with smallest distance value, route examination stage can be eliminated however if it moves to long distance, route examination is required and performed by applying HBAC. In case of path breaking, the network manager is triggered to route maintenance stage.

(1) Some other route which is already available in the Path exploration table is selected and, then the alternatively selected routes are automatically added to the graph table.

(2) If no other routes are presented for path exploration table, then route examination is performed again. If any of link failure occurs in the route examination stage, it also affects bee values for route examination process , thus, the possibility of route maintenance depend on the precise conditions.

Node failure

In case if the particular node doesn't obtain message from adjacent node and exceeds time interval, automatic sending of alarm graph route failed message command to network manager takes place. Later, the failure node information will be updated by the network manager to all nodes in the WMN. In this stage, if any path gets broken, then network manager is been transferred to route maintenance stage, the procedure of which is similar as in node moving stage.

b. EXPERIMENTATION RESULTS

The estimation of the performance of the proposed FKAWMNet is done by executing the model experimentation using Ns2 simulator. For performing simulation experimentation, random selection of nodes within the range 100, 200, 300, and 400 nodes in a square area with area distance end to end of 10 units. Data transmission communication is performed among two nodes based on their distance values, which may be less than or equal to $\sqrt{2}$ units. The following parameters are mostly used to analysis the results of the algorithm in WMN.

(1) End-to-End delay measure the delay time taken for sending packets from source to destination during data transmission communication path.

(2) Packet delivery ratio is defined as number of packets which is effectively received at the destination without loss of any packets or failure, if the packet delivered ratio of the system is high, it becomes more secure and highly efficient

(3) Overhead in number of packets is defined as the association among the number of packets controlled throughout data transmission communication and the totally delivered packets at the receiver side.

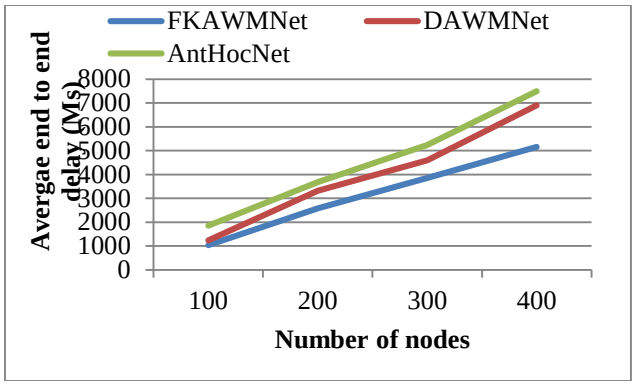

Figure 3.1. Average End to End Delay

The above mentioned three metrics are used to analyze the end to end delay for comparison. The performances comparison results of the end to end delay between the methods such as FKAWMNet, DAWMnet and AntHocNet is illustrated in Figure 3.1 it shows that the proposed FKAWMNet, has less end-to-end delay than the other approaches DAWMNet and AntHocNet

Time taken for sending packets from source to destination during data transmission communication path of the proposed FKAWMNet schema is less for number of nodes. Since the proposed work quickly sends packets from source to destination path, multipath routing is performed based on the artificial bee colony algorithm. The average end to end delay comparison results of the proposed FKAWMNet schema is minimum delay, when compared to existing methods is shown in Figure 3.1 and tabulated in Table 3.1.

Table 3.1 Average end to end delay comparison vs. methods

No of nodes	Average end to end delay (ms)		
	FKAWMNet	DAWMNet	AntHocNet
100	1036	1238	1847
200	2582	3315	3684
300	3859	4587	5238
400	5148	6897	7489

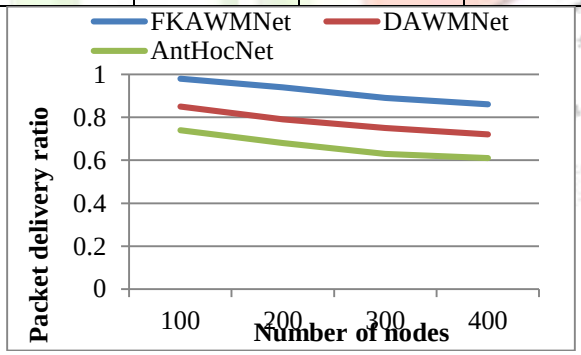

Figure 3.2 Packet Delivery Ratio Comparison

The results of packet delivery ratio of the proposed FKAWMNet and existing DAWMnet and AntHocNet rare illustrated in Figure 3.2. It shows that the proposed FKAWMNet has high packet delivery ratio when compared to existing approaches like DAWMNet and AntHocNet.Number of packets which is effectively received at the destination without loss of any packets or failure for proposed FKAWMNet is high, which shows higher packet delivery ratio results these results are tabulated in Table 3.2.In the proposed FKAWMNet methods, the packet delivery ratio achieves higher values, since in the proposed work multipath routing is performed based on the ABC. It quickly performs routing when compared to other methods.

Table 3.2 Packet Delivery Ratio Comparison vs. Methods

Number of nodes	Packet delivery ratio		
	FKAWMNet	DAWMNet	AntHocNet
100	0.98	0.85	0.74

200	0.94	0.79	0.68
300	0.89	0.75	0.63
400	0.86	0.72	0.61

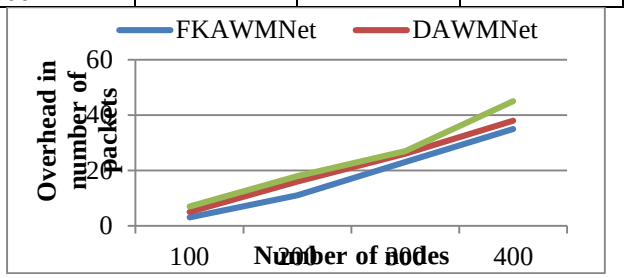

Figure 3.3 Overhead in Number of Packets Comparison

The Overhead in number of packets of the proposed FKAWMNet and existing DAWMnet and AntHocNet results as illustrated in Figure 3.3 shows that the proposed FKAWMNet has less Overhead in number of packets when compared to the existing like approaches DAWMNet and AntHocNet. Number of packets being effectively received at the destination by avoiding the wait in the queue or route path for proposed FKAWMNet is lesser; This represents the lesser packet overhead achievement which is tabulated as in Table 3.3.In the proposed FKAWMNet methods, lesser values were achieved by packet overhead when compared to other methods. The proposed work involves the performance of the multipath routing based on the ABC followed by quick performance of routing when compared to other methods.

Table 3.3 Packet overhead comparison vs. methods

Number of nodes	**Packet overhead**		
	FKAWM Net	**DAWM Net**	**AntHoc Net**
100	3	5	7
200	11	16	18
300	23	26	27
400	35	38	45

CONCLUSION:

This chapter summarizes the methodology of hybrid multipath routing algorithm for WMN. With the help of mesh connections between nodes, WMN can be made more consistent. Moreover, lesser cost estimation is been achieved for on-demand path discovery results over multiple links in WMN. Two major steps are being carried out in the proposed work in which one is for multipath route routing based on Filter Kruskal Algorithm(FKA) and the other is for route exploration based on the Hybrid Artificial Bee Colony(HABC) for developing the best route maintenance. The improved FKAWMNet and HABC enables achieving higher route setup results so that to enhance the route examination results by eliminating redundant routes. From the simulation results of the proposed FKAWMNet, it was observed that higher packet delivery ratio, lesser end to end delay, and lesser routing overhead than the existing routing protocols such as DAWMNet and AntHocNet has been achieved. Thus the proposed FKAWMNet helps to achieve highly reliable communication, assure load balancing, and can be easily applicable to topological changes without node failure.

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