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ENHANCING MULTIPLE CHANNELS IN WIRELESS MESH NETWORKS BY USING ARTIFICIAL BEE COLONY SCHEDULING ALGORITHM WITH RANKING STRATEGY

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ABSTRACT

The communication links of multi-hop wireless networks are less efficient than those of traditional wired networks. For example, collision-free data transmission is difficult to achieve in a wireless network. This work introduces a smart algorithm that enhances multiple communication channels in a wireless network. This study aims to implement the artificial bee colony (ABC) algorithm to prevent data collisions. A thorough review is conducted to identify the drawbacks of a wireless network. The investigation reveals that, within a given range, the nodes of a wireless network cannot transmit signals simultaneously because the transmission from multiple nodes interferes with one another. Unwanted communication is also difficult to detect because of the presence of hidden and exposed nodes. Free transmission by network stations may lead to message collision. For example, if two communicating nodes are out of range, then a third node within the range may interfere with the communication. Results of this study show that the ABC algorithm enhances the communication channel in a wireless mesh network by preventing data collision during transmission. The implementation of the swarm intelligent algorithm provides a simple solution to the aforementioned deployment problems. Therefore, combining the general ABC algorithm and a ranking strategy in a packet radio network improves the communication among multiple nodes in rapid time

Keywords: *Artificial Bee Colony Algorithm, Ranking Strategy, Multiple Channel, Wireless Mesh Network, Packet Radio Networks.*

1. INTRODUCTION

Artificial bee colony (ABC) algorithm is an optimization algorithm based on particular intelligent behavior of honeybee swarms. The performance of this algorithm in solving multi-dimensional numerical problems [1] is considered better than those of differential evolution [2], particle swarm optimization [3], and evolutionary algorithm [4].

In this study, we adopt the ABC algorithm as a concrete method to enhance the multiple channels in packet radio networks (PRNETs) and wireless mesh networks (WMNs) [5]. PRNET is a type of wireless network that transmits digital data via radio or wireless communication links [6]. The multiple channels in PRNET are enhanced because PRNET is a basic type of radio mesh network with an algorithm that can simply be extended to WMN. The broadcast-scheduling problem (BSP) is a design problem that occurs in PRNET [7]. The multiple channels in PRNET can be enhanced by maximizing the number of transmissions for the maximum use of these channels. Therefore, this research introduces a hybrid ABC (HABC) scheduling algorithm with a ranking strategy by combining a general ABC algorithm and a ranking strategy for PRNET and WMN.

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2. TRAINING OF PARAMETERS

Previous studies and their approaches have developed several hypotheses in terms of using bio-inspired algorithms in WMN. However, [8] proposed an improved ABC algorithm for optimum real-time dynamic network functioning to match the different characteristics of the wireless sensor network deployment process.

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One of the important surveyed papers has determined a weakness of previous studies in applying the channel-splitting strategy, in which handoff signaling packets were delivered through a split control channel in a wireless mesh backbone; an ABC algorithm was proposed in this previous work to improve the overall handoff performance and energy consumption [9].

A related study was presented by the RWTH-Aachen University with their designed WMNet, a novel multi-path routing algorithm for WMN, and combined the Filter–Kruskal algorithm (FKA) and HABC algorithm [10]. Other researchers have achieved route setup results by applying the FKA algorithm [11] and by examining and maintaining such results using the swarm intelligence-based HABC algorithm in WMN [12].

TABLE 1

SUMMARY OF THE RELATED WORKS

Author	Methodology	Description	Strengths And Weaknesses
(Sampaio et al. 2015)	One of the important surveyed papers determined a weakness of previous studies in applying the channel splitting strategy, in which handoff signaling packets were delivered through a split control channel in a wireless mesh backbone	an ABC algorithm was proposed in this previous work to improve overall handoff performance and energy consumption	***Strengths:*** More stable and scalable recommendation IEEE 802.11s mesh networks deployments ***Weaknesses:*** *Some open research challenges not presented and discussed, for example, the effectiveness of multiple channel for high organize signal*
Seeniselvi & Shanmugapriya 2014	ABC	In this work, the node detected a critical occurrence throw and a node alongside a prearranged path according to the delay energy efficient scheduling offset beginning from the ABC algorithm	*Strengths:* 1 they try to solve the important problem of minimization of the message delay over the energy when it moves from sleep state to active state periodic sleep cycles for nodes inWSN. *Weaknesses:* 1. Leak of nectar nodes delay results discover earlier than and generous information for the future bees in the highest level with less delay in the sleep scheduling nodes about the superiority of the food source sites(delay broadcasting data)

Another study has determined that previous methods could not reduce the broadcast delay in wireless sensor networks; therefore, an ABC algorithm in which the sleep-scheduling node sought the path in the graph for broadcasting communication was proposed [13]. In this work, the node detected a critical occurrence throw and a node alongside a prearranged path according to the delay energy-efficient scheduling offset beginning from the ABC algorithm [14].

Considering the developments in the usages of wireless sensor networks, a rapid access of broadband communication is required between one access point and another access point. WMN is one of the most suitable methods for solving the problem of path selection and providing rapid access of networks. Reference [21] developed an ant-colony-based multi-path-routing method for WMN. The recorded Internet gateway information was considered the ants and consequently called pheromone trails. The information of the ants was updated simultaneously.

Table 1 shows the latest related studies with their strengths and weaknesses.

3. PROPOSED APPROACH

We use the ranking strategy to improve the performance of the ABC algorithm [15]. One of the goals of a completely general and flexible WMN is to make as a few assumptions as possible [16]. By contrast, the current research makes several key assumptions. These assumptions are mainly developed to keep the amount of time for the research within a reasonable length and to maintain the system complexity to a manageable level.

The assumptions made for this study are common among similar works. However, our work is unique with respect to certain aspects because we reduced several assumptions. One of the main assumptions in this study is that several studies have used the ant colony system (e.g., the ant-based dynamic routing algorithm) to solve the routing problem. Nonetheless, significant development must still be achieved to solve the problem efficiently, and the routing algorithm is not the only algorithm employed.

Therefore, an effective heuristic algorithm must be developed to achieve the optimal solution or the approximate optimal solution in polynomial time to enhance the multiple channels in PRNET. In this study, we introduce an ABC algorithm with a ranking strategy that enhances the multiple channels in PRNET. We also extend this method to the same problem in WMN.

The initial valid solution (i.e., the valid time division multiple access [TDMA] schedule), which also means packet *scheduling* (dynamic *TDMA*), is selected using the randomized algorithm. This solution is further modified to improve utilization (ρ) and used as a starting solution in BSP. Modifications are implemented using the information provided in the compatibility matrix

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(matrix D) [17]. The valid solution mechanism is used to improve the solution (i.e., the TDMA schedule). We modified these procedures shown in figure 1, and the procedures to generate the initial feasible solutions are as follows:

1) The sequence to allot time slots for different nodes in the permutation sequence is decided.
2) Time slot 1 is assigned to the first node of the sequence.
3) Time slot 1 is checked if it can be assigned to the second node using matrix D.
4) Time slot 2 is assigned to the second node if time slot 1 cannot be assigned to the second node. In our study, we assume that time slot 2 is assigned to the second node.
5) Time slots 1 and 2 are checked if they can be assigned to the third node using matrix D.
6) Time slot 3 is assigned to the third node if time slots 1 and 2 cannot be assigned to the third node.
7) The previous steps are followed until all nodes are assigned to minimize time slot M if possible.
8) After all nodes are assigned, time slot utilization is maximized, if possible, using matrix D. BSP is considered to obtain the best/optimal TDMA schedule to minimize the number of time slots (M) and to maximize utilization (ρ).

Food source solution can be represented 2x2 matrix consisting of 4 time slots and 5 nodes as shown in table 2

Table 2
Solution Representation For Food Sources For A Five-Node Network Using Four Time Slots

Time Slot	Node 1	Node 2	Node 3	Node 4	Node 5
1	1	0	0	0	1
2	0	1	0	0	1
3	0	0	1	0	0
4	0	0	0	1	0

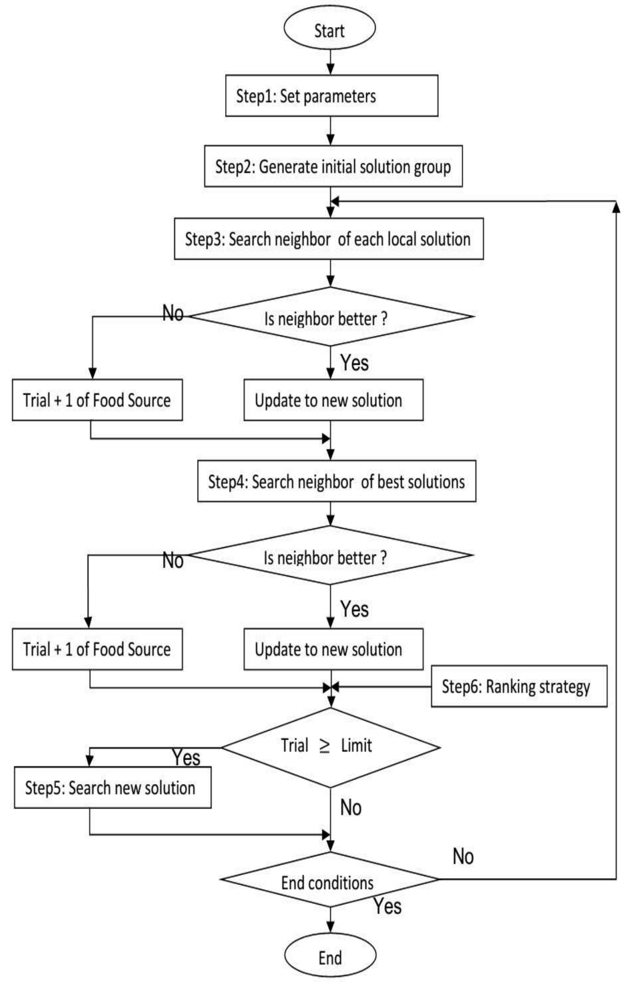

Figure 1: Algorithm Setting

The aforementioned problem can be expressed as matrices C and D as follows:

However, in generating the initial solution, a one-time slot must be randomly assigned to each node in the mesh network. The same time slots cannot be directly assigned to the node linked to a node or to the node that are two edges from a node. Nonetheless, additional time slots can be added to the rest of the nodes. We construct matrix D with element 1 or 0 to generate a possible neighbor feasible solution for each node in the given graph.

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$$C = \begin{pmatrix} 0 & 1 & 1 & 0 & 0 \\ 1 & 0 & 1 & 0 & 0 \\ 1 & 1 & 0 & 1 & 0 \\ 0 & 0 & 1 & 0 & 1 \\ 0 & 0 & 0 & 1 & 0 \end{pmatrix},$$

$$D = \begin{pmatrix} 0 & 1 & 1 & 1 & 0 \\ 1 & 0 & 1 & 1 & 0 \\ 1 & 1 & 0 & 1 & 1 \\ 1 & 1 & 1 & 0 & 1 \\ 0 & 0 & 1 & 1 & 0 \end{pmatrix}.$$

Generating an unsuitable solution and applying a penalty to the method are easy; however, the efficiency of the method is reduced.

After searching for all possible feasible nodes and time slots, the algorithm generates possible neighbor solutions from the current solution with appropriate probability. With the ABC algorithm, scout bees can generally determine various solutions via random searching. However, this random strategy may be disturbed because of its convergence with the optimal solution in time. Thus, the algorithm applies a ranking strategy in step 5 prior to step 6 to fix this issue. In step 6, a predefined number of improved solutions with the same time slots and excellent usage is selected, and a new food source from the probability of the sigmoid function for each factor is generated. Convergence is also accelerated in this procedure; thus, wrong solutions are removed from the set of feasible solutions [18]. Each element generates a new solution selected from the solutions with better evaluation values and higher probability. Figures 2(a) and 2(b) illustrate the application of the ranking strategy in the proposed algorithm to generate a new food source.

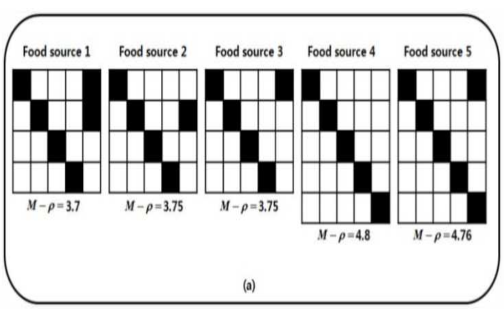

Figure 2a: Ranking Strategy With Five Feasible Solutions

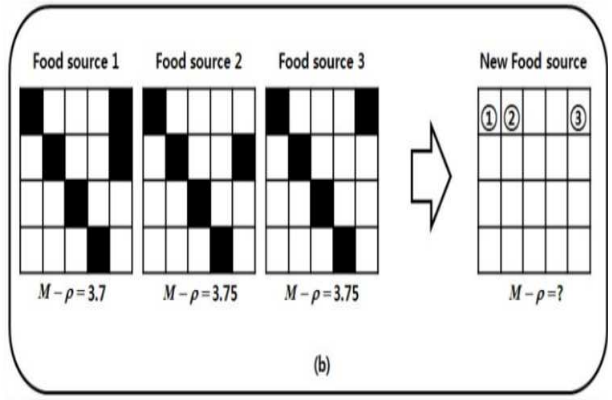

Figure 2b: Generating A New Solution Using Three Solutions For A Five-Node Network

Thus, the algorithm removes food source 4 from the feasible solution group and places a new food source generated from the process shown in Figure 3(b). The values of food sources 1, 2, and 3 are evaluated using the following equations:

$$① : \frac{\frac{1}{3.7}+\frac{1}{3.75}+\frac{1}{3.75}}{\frac{1}{3.7}+\frac{1}{3.75}+\frac{1}{3.75}} = 1,$$

$$② : \frac{0}{\frac{1}{3.7}+\frac{1}{3.75}+\frac{1}{3.75}} = 0,$$

$$③ : \frac{\frac{1}{3.7}+\frac{1}{3.75}}{\frac{1}{3.7}+\frac{1}{3.75}+\frac{1}{3.75}} = 0.6682.$$

These values are transformed into the interval [−4, 4], as follows:

$v_i(t+1) \in [-4, 4]$ is then obtained.

$v_1(t+1) = 1 \times 8 - 4 = 4,$

$v_2(t+1) = 0 \times 8 - 4 = -4,$

$v_3(t+1) = 0.6682 \times 8 - 4 = 1.3456.$

The time slots in nodes 1, 2, and 3 for a new food source can be obtained by substituting $v_i(t+1)$ into the sigmoid function, as expressed in Eq. (1):

$$S\,(v_i(t+1)) = \frac{1}{1+e^{-v_i(t+1)}}, \qquad (1)$$

$p_1 = S\,(v_1(t+1)) = \frac{1}{1+e^{-4}} = 0.9820,$

$p_2 = S\,(v_2(t+1)) = \frac{1}{1+e^{4}} = 0.0180,$

$p_3 = S\,(v_3(t+1)) = \frac{1}{1+e^{-1.3456}} = 0.7934.$

Thus, new food sources 1, 2, and 3 generate food sources that can assign time slots into nodes 1, 2, and 5 with probabilities of 98.2%, 1.80%, and 79.34%, respectively.

A flowchart for determining the optimal solution or an approximate optimal solution using the proposed ABC algorithm to solve a given BSP .

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4. EXPERIMENT AND RESULT

Before the enhancement of the multiple channels in WMN using the ABC as a scheduling algorithm, MATLAB tool or C++ code can be used to apply the ABC algorithm to mesh networks. The newly proposed algorithm and even the previous ones cannot be coded using Network Simulator version 2 (ns-2) or OPNET. However, the code of these methods can be promptly written in MATLAB. The code can be executed, and the results of the proposed algorithm are considered to obtain improved results. ns-2 and OPNET can also be used for this task; however, they cannot easily implement our model.

Average packet delay is reduced if the use of channels is maximized. Previous studies have reported that BSP is a nondeterministic polynomial time complete combinatorial optimization problem [19]. Thus, numerous scholars have adopted genetic algorithms, mean field annealing, neural networks, factor graph and sum product algorithm, sequential vertex coloring algorithm, and simulated annealing to solve this scheduling problem [20].

However, the initial node or the starting node allocation shows the node allocation for developing the path of multiple channels using the TDMA technique until the final node allocation that shows the final allocation after best fit ABC and ranking is achieved. Matrices C and D are applied and are considered optional in the script. Nevertheless, the most important of the two other channel utilization factors are not the graphs that grow up or down. These factors show how every node utilizes its channel under the ABC approach. A node can be assigned to multiple time slices.

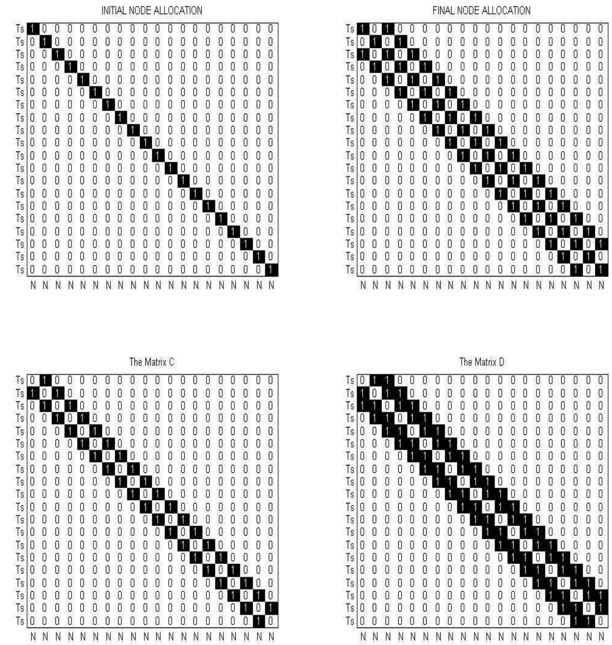

Figure 3: Node Allocation And Matrix

This proposed method enables us to program the channels easily for packet forwarding. The utilization of multiple channels can be potentially optimized, thereby maximizing the network capacity of WMN [21]. However, [21] focused on the framework; thus, the effective use of multiple channels was not completely addressed. The feasibility of the proposed channel utilization method, which balances the amount of traffic among multiple channels to maximize the network capacity, is assessed using several important metric components. These metrics are compared with routing metrics in terms of throughput, number of hops, and node count per channel or link capacity.

Figure 4 shows the node per channel capacity metric through the ABC mechanism. The capacity reaches the top level, and the optimization of the ABC starts to mitigate the load on the node to the stable level, thus producing high scalability of the channel.

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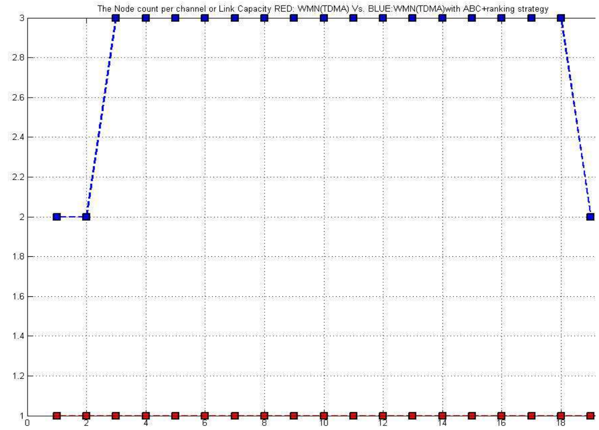

Figure 4: Node Per Channel Capacity

Figure 5 shows the channel utilization per node. As shown in Figure 6, the ranking strategy improves the signal enhancement and the utilization of each node after the application of the ABC algorithm.

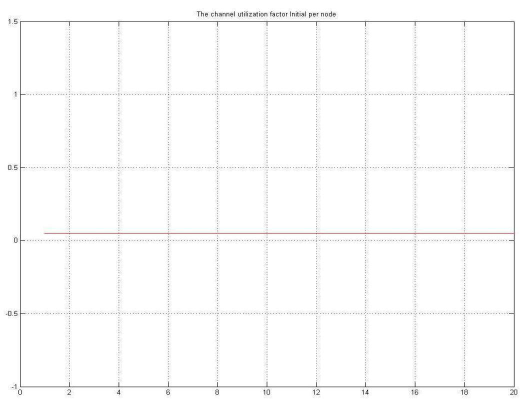

Figure 5: Channel Utilization Per Node

A comparison of channel utilization with TDMA in MATLAB and TDMA with the ABC ranking strategy is shown in Figure 8, which presents a significant result. The ABC can generate the best optimal solution for the TDMA. As a result, the ABC efficiently guides the multiple channel in WMN with the ranking strategy.

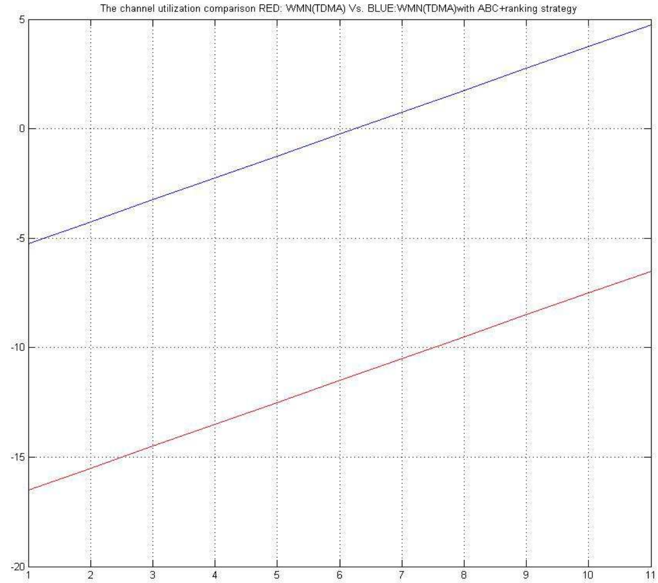

Figure 6: Channel Utilization Comparison Before And After The Solution

Channel utilization in WMN is important in the proposed algorithm. Figure 7 shows how the channel starts from the initial level and ends with the same initial level axis, such as in linear multiple channels.

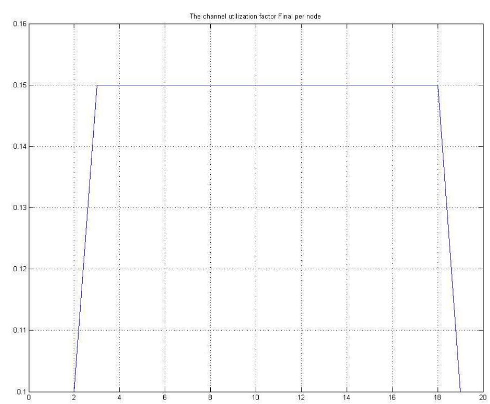

Figure 7: Channel Utilization For The Final Node

The final part of performance evaluation is shown in Figure 8, which exhibits high throughput establishment through multiple channels. In fact, the first node to the end node in WMN shows

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almost the same high level because of the best optimal solution motivated by the ABC.

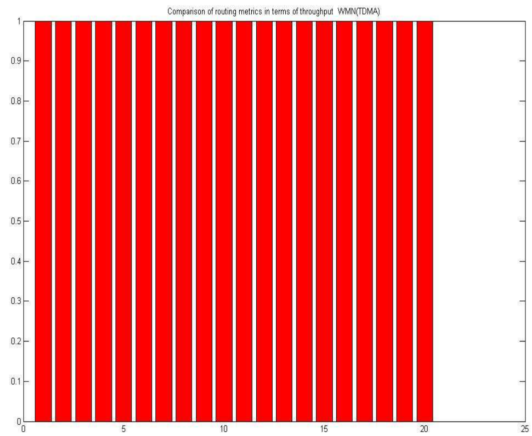

Figure 8: Positive Result For The Throughput Using The Proposed Algorithm

5. CONCLUSION

Our study focused on network utilization via the best node allocation using the ABC algorithm and a ranking strategy. We proposed a channel-splitting strategy to improve the link and network layer handoffs in WMNs. Two scenarios were considered when a mobile mesh client had one or two transceivers, and different handoff procedures using the channel-splitting strategy were proposed. Nevertheless, the network utilization factor was sufficient to determine the effectiveness of the algorithms, which were already calculated and included in our code. In future research, the fuzzy logic will be hybridized with the ABC algorithm for more multi-path and routing efficacy.

6. ACKNOWLEDGEMENT

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