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WIRELESS SENSOR NETWORKS: OPTIMAL ROUTING STRATEGY BY BLUETOOTH MESH LOW POWER NODES USING ACO ALGORITHM

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ABSTRACT

As smart homes, factories, and farms developed, it has used sensors that communicate with wireless signals such as Bluetooth mesh-low power node (M-LPN) with the wireless sensor network (WSN) system, which causes them to be interfered with by different signals coming from different sources, which causes them not to function properly. The Bluetooth M-LPN is critical that enables the wireless sensor network to function. t makes up the inter-node controller of a WSN and collects information about nodes and sends commands to them on behalf of the founder/client node. A mesh system uses each node as a sensor and repeater. This means that each node must always listen for, relay, and route network traffic. This most likely results in decreased battery life. This proposed takes advantage of Bluetooth M-LPNWSN systems and algorithm-based efficient approach by using label-based Ant Colony Optimization (ACO) in the clustering process for allocating routing. Theoretical analysis and simulation results show that the proposed algorithm has a better performance in terms of total routing length, number of hops, and communication load when compared with the other existing algorithms such as Artificial Neural Networks (ANNs) that were used with the Bluetooth low energy system.

Keywords: *Bluetooth M-LPN; WSN; Bluetooth M-LPNWSN; ACO; ANN*

1. INTRODUCTION

The number of WSN in the any-area is increasing rapidly and is predicted to more than a thousand sensor nodes [1]. The telecommunication of WSN that used in each sensor network is a radio transceiver with an internal antenna or connection to an external antenna, a microcontroller, an electronic circuit for interfacing with the sensors [2]. This includes a significant range of applications that will increase congestion on the license-free 2.4 GHz Industrial Scientific and Medical (ISM) band [3]. The communication protocols utilizing the ISM band need to coexist and preferably interoperate. However, this great increase in connected networks can also be considered problematic when considering power consumption. Moreover, the vast majority of Bluetooth LPN that use Bluetooth low energy for communication run on small batteries, which dies after a period of time, and thus the issue with have very strict power requirements [4], [5], [6]. Research has been conducted in Bluetooth mesh low energy networks to reduce energy consumption but the issue of high-energy consumption has still not been resolved. When the battery runs die in Bluetooth LPN networks, nodes are inoperable which makes the LPN networks useless. There are three modules in an LPN: sensing, processing, and communication. The largest consumer of power is the LPN communication module. The communication module transmits and receives data during the active state, and continuously scans the air interface for incoming messages during the idle state [3]. As well as, friend nodes and Time-to-Live (TTL) is a field in which all Bluetooth mesh low energy include and commonly used to improve the performance, increase lifetime for LPN and manage the caching of data, controls the maximum number of hops over which a message is relayed, and the maximum achievable device lifetime is 644 days with 235 mAh battery capacity, but in fact and the issue for both features are still not good for reducing power consumption in Bluetooth low energy [7]. In addition to that, there are three energy performance parameters that developed analytical models for reducing the power consumption and increase LPN lifetime in Bluetooth low energy such as the average current consumption, the theoretical lifetime of a battery-operated, and the energy consumed per each user data bit delivered by Bluetooth LPN, but it was not developed well to reduce energy consumption and make the LPN lifetime as long as required [3]. Therefore, problems and issues mentioned above, along with the impact that Bluetooth LPN networks can have on WSN development, will be addressed in this proposal during literature study and implementation and backed up to some extent with measurement results. This proposal focuses on investigating the possibility of making use of both the power consumption and the higher lifetime for the LPN by dynamically adjusting the configuration of the battery to allow building more energy-efficient sensor networks based on Bluetooth mesh low energy. By returning back to the literature and searching the available articles and papers dealing with this subject, it has been noticed that the available researches and publications did not mention the use of modern artificial intelligence techniques with wireless sensor networks that deal with the Bluetooth feature, such as the genetic algorithm (GA), ant colony optimization (ACO) algorithm, and artificial bee colony (ABC) algorithm, and other advanced smart technologies. As most of the research and theses that dealt with this topic dealt with the use of traditional artificial intelligence, such as neural networks (ANN) techniques, fuzzy networks technology, and other traditional techniques concerning the issue of reducing energy for WSN Bluetooth systems. Therefore, Sharareh Naghdi utilized Bluetooth Low Energy technology, vision systems, and ANN algorithm to improve the accuracy of pedestrian position solutions in indoor environments [8]. However, this technology faces challenges related to the speed of data transfer from/to the node, low battery, as well as signal interference due to the AAN algorithm used for routing. In addition to that, Wireless Sensor Networks was presented with a novel routing approach based on the ACO algorithm. It offered significant reductions in energy consumption but the topologies techniques of the nodes are not clarified [9]. Thus, it allows communication over the network by multiple devices and combining the energy efficiency of ultra-low-power radios with the interoperability of Bluetooth low energy with a long operational lifetime.

2. BLUETOOTH M-LPN MANAGED FLOODING IN WSN

The Bluetooth network profile demonstrates the strategies to improve the flooding activity for a useful network. Normally called oversaw flooding. Consequently, the significant methodologies used in administered flooding are:

- Message Cache: All nodes should execute an organization message reserve. The message reserve contains all the actually seen orchestrates messages. On the off chance that the gotten message is observed to be inside the reserve, by then it gets disposed of.
- TTL controls the quantity of ricochets a message is moved in a framework. Picking an ideal TTL regard conservatives' control over the framework. If the TTL regard at a node is more conspicuous than or make back the initial investment with to 2, it exhibits that the message might have been given off and can be transferred. TTL regard under 2, shows the message might have been moved yet won't be transferred.
- Heartbeats: Pulse messages are sent by the nodes discontinuously. It is used as a sign to the tolerant nodes, that the sending node is enthusiastic. At the tolerant node, the ideal TTL regard for conveying a message to the not set in stone from the heartbeat message.

3. FRIENDSHIP IN BLUETOOTH M-LPNWSN SYSTEM

WSN is known to be an incredible asset compelled exercise of organizations where energy utilization is one of the natural concerns. The majority of the sensors are battery-controlled devices. In WSNs, sensor nodes are passed on for an enormous scope and thus it is outlandish to override the batteries of sensor nodes. As such, every sensor node should use power viably to outlast for quite a while. The Bluetooth M-LPNWSN describes the companionship convenience for the energy-obliged addresses. The vehicle layer (upper and lower) inside the Bluetooth M-LPNWSN is principally aware of the

Friendship's convenience. It describes two kinds of nodes. A low force node consolidates a compelled control source and works at decreased beneficiary commitment cycles. This node changes to on state in a manner of speaking to get stacks of info. A companion node enables the companion to feature and stores the messages appointed for low-power nodes. This node communicates the messages as it was the point at which the low force nodes unequivocally demand. This proposed reinforces companionship between one companion and one low-power node. Friendship is developed among companions and low force nodes. The low force node begins the friendship in a little while on the grounds that it is provisioned into the Bluetooth M-LPNWSN system. This proposed to acknowledge that partnership is at this point set up among friends and low force nodes. After the kinship is set up, the companion node stores the messages for the benefit of a low-power node inside the companion line. A surveying instrument is used for improving energy utilization at the low force nodes. The Bluetooth works message exchange between the low force node. Get postpone boundary demonstrates the time between the low force node sending a solicitation and tuning in for a response from the companion node. The low force node is in a rest state for the complete length of the get delay. The authority window boundary shows the ideal opportunity for which a low force node tunes in for a response from the companion node. low force node is inside the genuinely taking a look at state for the all-out term of the get window. The survey break boundary demonstrates the most outrageous time between two progressive requests from a low force node. Inside the survey break, in the event that the companion node or the low force node misses the mark to get an ask or response from the other node, the fellowship is finished. Every so often, low-power nodes survey companion nodes for any data messages set aside inside the companion line. Subsequent to surveying the Friend node, low force nodes enter the rest state for the length of getting delay. The Friend node occupations the prepare delay getting the response for the low force node. After the get delay, the companion node responds to the low force node once in a while as of late the entire of getting postpone and get the window. Bluetooth M-LPNWSN is designed to empower devices to have exceptionally low power consumption. A few chipmakers counting Cambridge Silicon Radio, Discourse Semiconductor, Nordic Semiconductor, STMicroelectronics, Cypress Semiconductor, Silicon Labs, and Texas Rebellious had presented Bluetooth Low Energy optimized chipsets by 2014. Devices with fringe and central parts have distinctive power necessities. A think about by signal software company Walkway labs detailed that peripheral such as vicinity guides as a rule work for 1-2 a long time felled by a 1,000mAh coin cell battery. This can be conceivable since of the power effectiveness of Bluetooth Low Energy protocol, which as it were transmits little. packets as compared to Bluetooth Classic which is also suitable for audio and high bandwidth data.

4. BLUETOOTH M-LPN FOR ROUTING IN WSN SYSTEM USING ACO ALGORITHM

The proposed Bluetooth M-LPN for Steering in WSN System using ACO Algorithm Code to discover the most limited way between two hubs (source and target) so that by begins sending information till one node included in route (path) dies (battery OFF). As before long, one node dies, it looks another path and restarts sending till node included in routing dies due to finishing energy and so on, till the network has no more connections between source and the target node. The source and goal node pairs, power source, and their corresponding TTL values are indicated and the paths between source and destination nodes are recognized as shows in figure 1. Additionally, the ACO Algorithm underpins the LPN to remain lively for a long time. The proposed show that there's a chance of having a path between the chosen source and destination nodes, indeed in the event that a few of the middle transfer and end nodes fall flat within the network. Inside the ultimate two sections, it modeled and assessed the energy consumption execution parameters of a Bluetooth M-LPNWSN using the ACO Algorithm. Based on the profiles of the notice transmissions and the checking between times, another calculates the Bluetooth M-LPNWSN using ACO Algorithm typical current consumption.

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Figure 1: Ants' Colony

Each insect must build a solution to move through the chart. To choose another edge in its tour, an ant will consider the length of each edge accessible from the current position, as well as the comparing pheromone level. At each step of the algorithm, each ant moves from a state-to-state y, comparing to its total middle arrangement. Hence, each ant k computes a set A(z) of attainable extensions to its current state in each cycle and moves to one of these likelihood [10]. For ant k, the likelihood p_{xy}^{k} of moving from state x to state y depends on the combination of two values, the attractiveness η_{xy} of the move, as by a few heuristics demonstrating the a priori attractive quality of that move and the trail level τ_{xy} of the move, indicating how capable it has been within the past to form the specific move. The path level speaks to a posteriori sign of the allure of that move. In common, the kth ant moves from state x to state y with the likelihood [11].

$$p_{xy}^{k} = \frac{(p_{xy}^{\alpha})(p_{xy}^{\beta})}{\sum_{z\in allowed_x}(p_{xy}^{\alpha})(p_{xy}^{\beta})} \quad (1)$$

τ_{xy} is the amount of pheromone kept for the transition from state to y, ≤ α could be a parameter to control the impact of τ_{xy}, η_{xy} is the attractive quality of state transition xy (a priori information, ordinarily $1/d_{xy}$. where d is the distance) and 1≤ β may be a parameter to control the impact of η_{xy}. τ_{xy} and η_{xy} represent the trail level and engaging quality for the other conceivable state transitions [12]. Trails are ordinarily overhauled when all ants have completed their arrangement, expanding or diminishing the level of trails comparing to moves that were portion of "great" or "bad" arrangements, individually. An illustration of a global pheromone overhauling run the show is:

$$\tau_{xy} \leftarrow (1-P)\tau_{xy} + \sum_{k}^{m} \Delta\tau_{xy}^{k} \quad (2)$$

where τ_{xy} is the sum of pheromone kept for a state move ay, ρ is the pheromone dissipation coefficient, m is the number of ants and $\Delta\tau_{xy}^{k}$ is the sum of pheromone stored by k^{th} insect, ordinarily given for a TSP issue (with moves comparing to circular segments of the chart) by [13]:

$$p\Delta\tau_{xy}^{k} = \begin{cases} Q/L_k & if\ ant\ k\ uses\ curve\ xy\ in\ its\ tour \\ 0 & otherwise \end{cases} \quad (3)$$

where Lk is the taken a toll of the k^{th} ant's tour (regularly length) and Q may be consistent. Within the ant colony optimization algorithms, a manufactured ant may be a basic computational specialist that searches for great arrangements for a given optimization issue. To apply an ant colony algorithm, the optimization problem needs to be changed over into the issue of finding the most limited path on a weighted chart. Within to begin with the step of each Cycle, each ant stochastically develops an arrangement, I.e., the arrangement in which the edges within the graph ought to be taken after as shown in figure 2. Within the moment step, the paths found by the diverse ants are compared. The final step comprises upgrading the pheromone levels on each edge [14].

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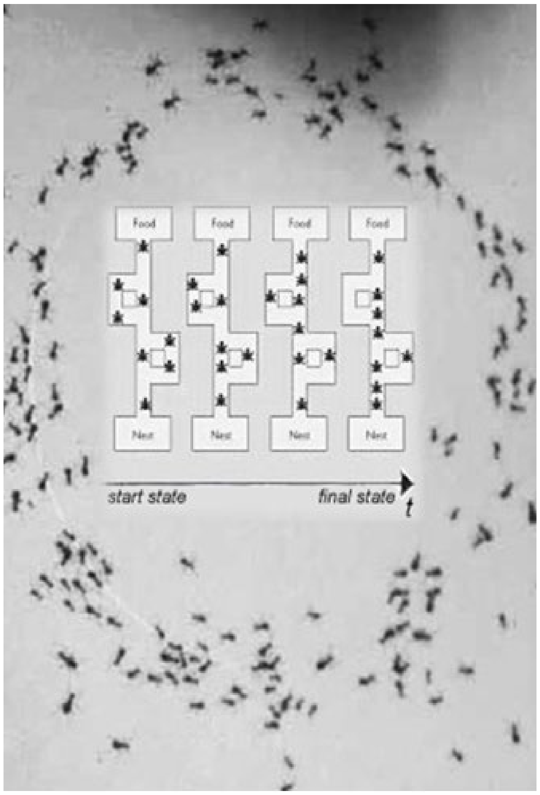

Figure 2: Ants' Food Searching Action

Travelling Sailor Problem (TSP) can be utilized in arranging to get the guideline of operation of the Ant Colony Optimization ACO technique. An illustration of a sailor traveling among four cities found at distinctive positions. The distance between every two cities has been calculated as outlined in Figure 3 a underneath. The development of the traveling sailor will be to begin within an arbitrary way similar to the activity of ants as well the number of cities will speak to the number of food destinations for ants or basically the number of network nodes. So, the sailor will take all the conceivable path openings among the four cities to reach his destination as shown in Figure 3. b [15]. Usually precisely what ants will do in their activity from nests to food sources. The scientific connection that matches this path choice method in each step will be the factorial of all the cities (nodes) number but one which is known as the stage as illustrated in Figure 3.c underneath. After computing all the conceivable paths among the cities (nodes), the comes about are arranged to discover the most limited path length among all conceivable combinations of cites (nodes) traveled by a sailor (ants) as displayed in Figure 3. d. Figure 3. e illustrates diverse schemes of TSP for different numbers of cities (nodes) with their isolating separations. At long last, Figure 4 shows the stream chart of the ACO activity amid the TSP operation [16, 17].

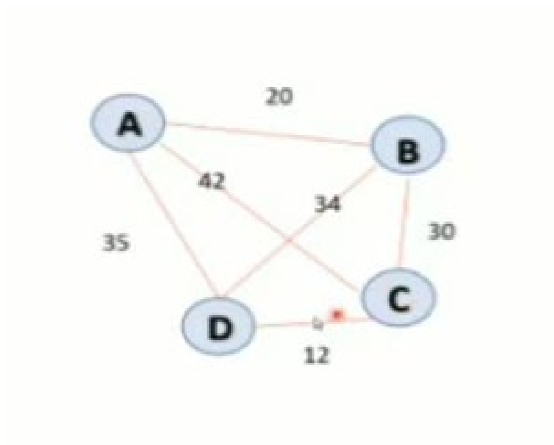

Figure 3(A): TSP Example Possible Paths.

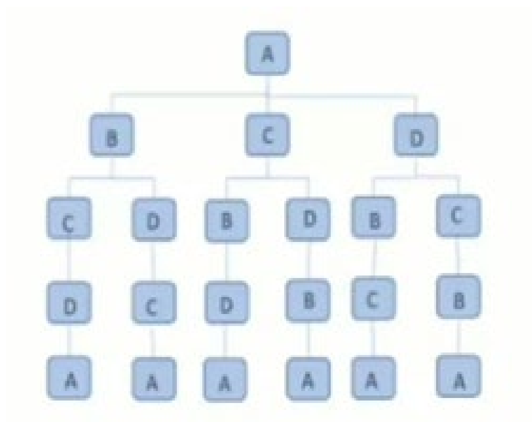

Figure 3 (B): TSP Example Possible Paths.

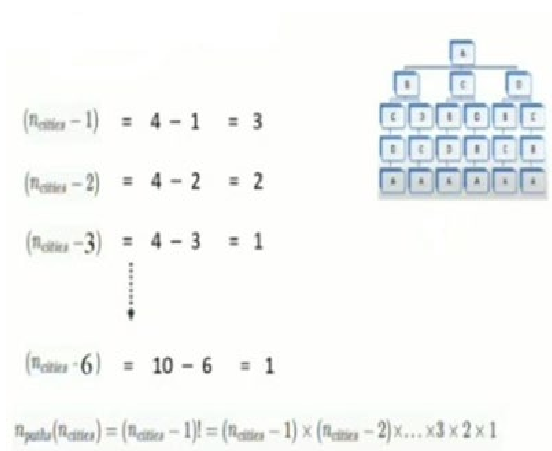

Figure 3 (c): TSP example with path selection.

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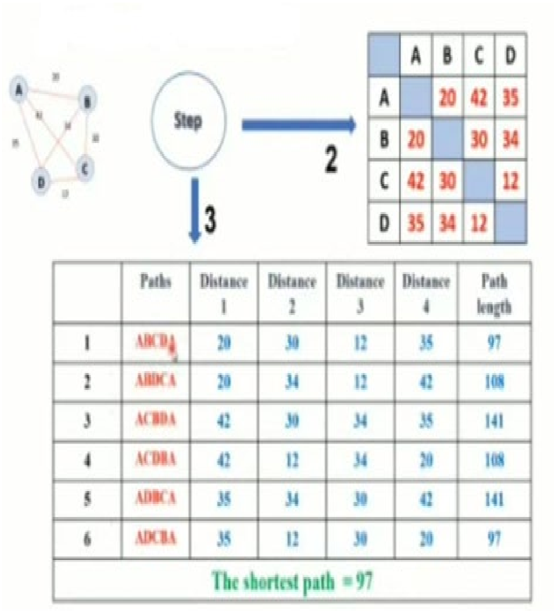

Figure 3 (D): TSP Example Of Four Cities Optimum Path.

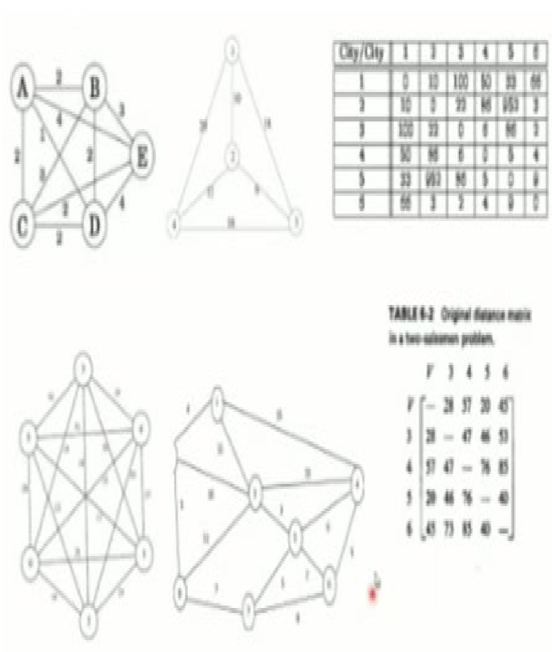

Figure 3 (E): TSP Example Of Different Number Of Cities.

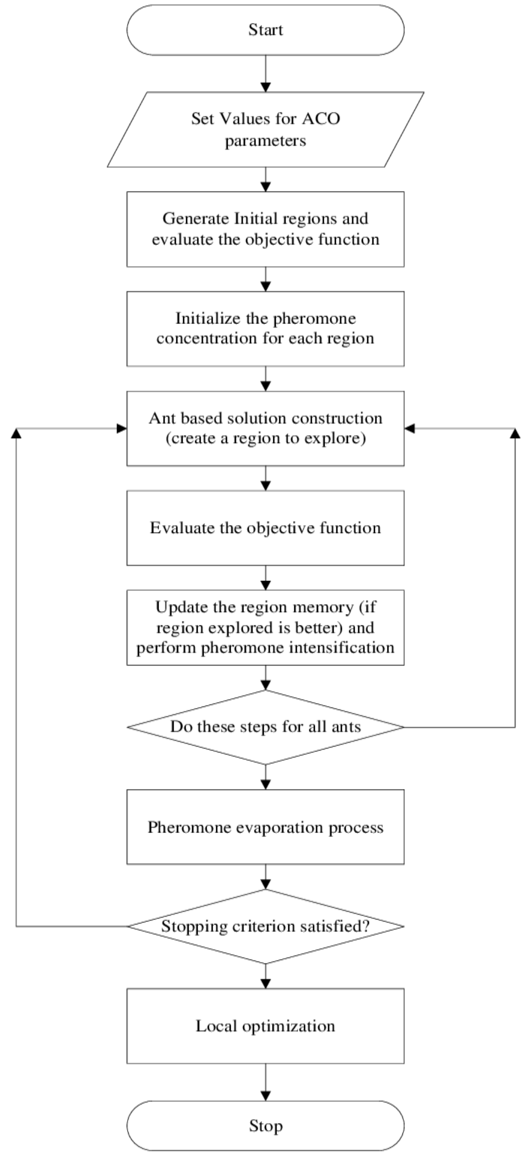

Figure 4: Flowchart Of ACO Technique Utilizing TSP Approach.

5. SIMULATION AND THE RESULT

Using m. files MatLab17 simulation program, the routing Bluetooth WSN system has been simulated with the influence of ACO technique. The simulation has been divided into two main subprograms, the first program was concerning simulation of the routing Bluetooth mesh WSN system, while the second program has been devoted for representing the ACO simulation. The two subprograms have been combined to integrate the whole idea and simulating the overall system. The routing Bluetooth WSN subprogram has been

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simulated using random nodes with N numbers. Figures 5 and 6 illustrate the running of this subprogram with N=10 and N=20.

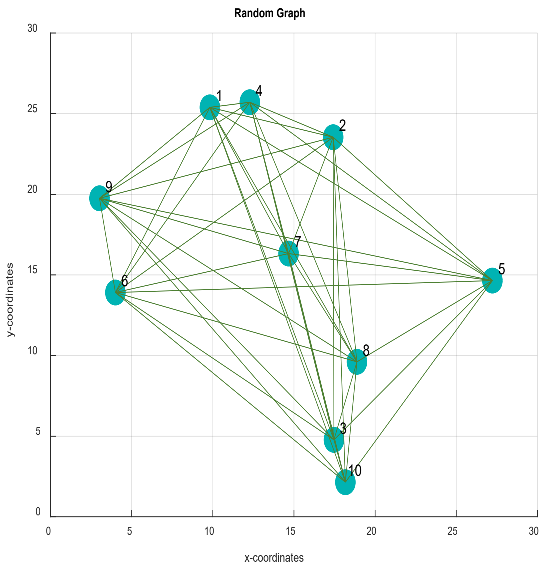

Figure 5: Scheme Of The Routing Bluetooth WSN Mesh With N=10.

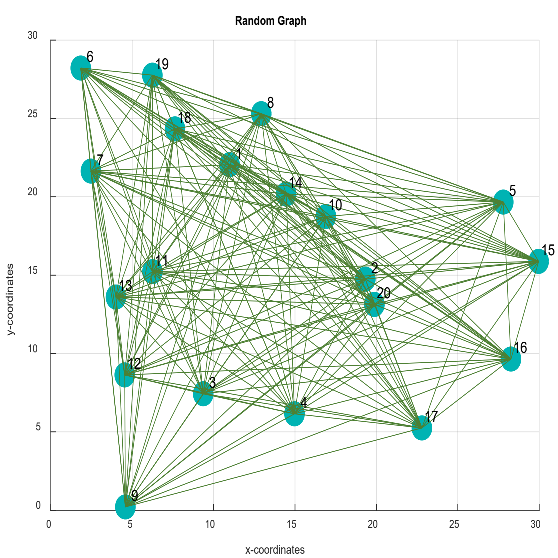

Figure 6: Scheme Of The Routing Bluetooth WSN Mesh With N=20.

The problem of power minimizing in the routing Bluetooth WSN mesh can be solved by applying the Travelling Salesman Problem TSP. By implementing the second subprogram the results of the ACO algorithm will be shown in Figures 7 for different iteration values.

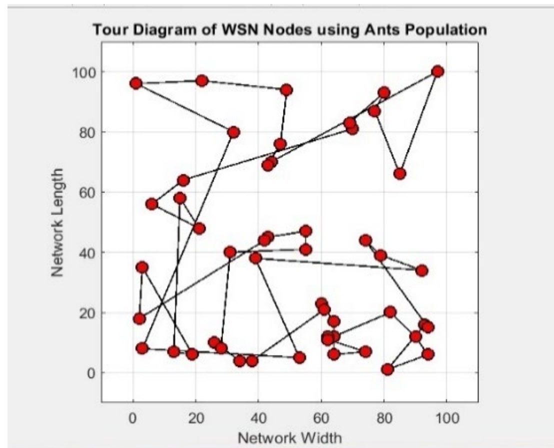

Figure 7 (A): Scheme Of The Routing Bluetooth WSN Mesh Using ACO With N=100, Maxit=500, It=100.

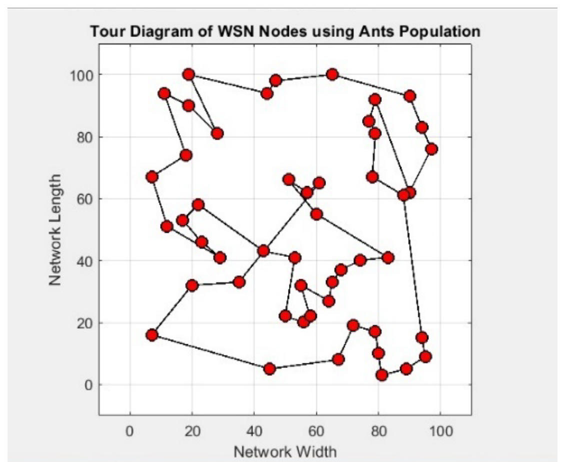

Figure 7 (B): Scheme Of The Routing Bluetooth WSN Mesh Using ACO With N=100, Maxit=500, It=300.

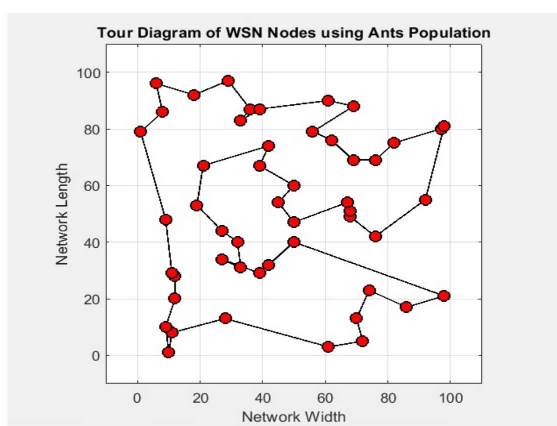

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Figure 7 (c): Scheme of the routing Bluetooth WSN mesh using ACO with N=100, MaxIt=500, It=500.

Figure 7: Scheme of the routing Bluetooth WSN mesh using ACO with N=100, MaxIt=500, (a) It=100, (b) It=300, and (c) It=500.

Where, the total number of nodes N=100 node, maximum iterations utilized in the program test MaxIt=500. The convergence curve of the ACO algorithm utilized in the simulation has been illustrated in Figure 8.

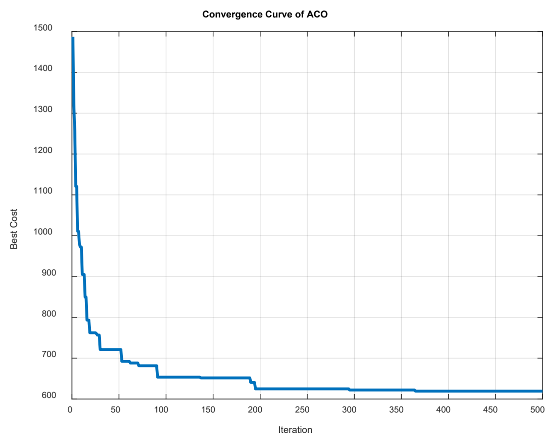

Figure 8: Convergence Curve Of The ACO Algorithm Versus Iterations Progress.

Actually, since some of the Bluetooth WSN nodes will not be active because of the out of power or because of the un functioning, the ACO algorithm will search of the most survived nodes those can be considered active within the total Bluetooth WSN nodes. Figure 9 show the configuration of the Bluetooth WSN nodes that having N=50 nodes under no action, and with few nodes action.

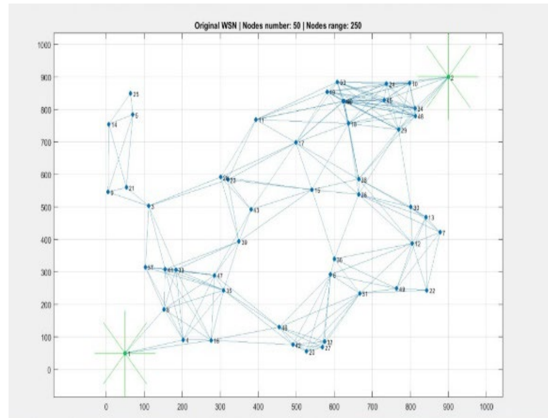

Figure 9 (a): Configuration of Bluetooth WSN using ACO algorithm, with passive nodes.

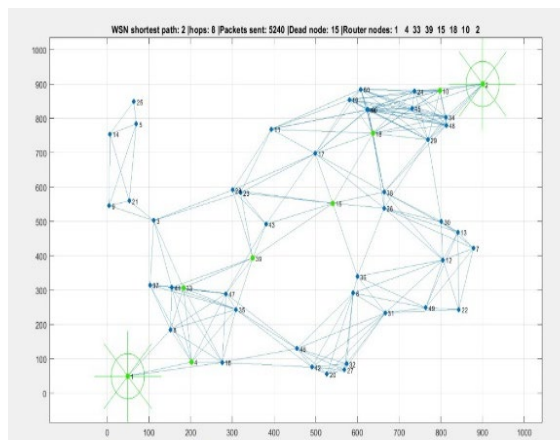

Figure 9 (B): Configuration Of Bluetooth WSN Using ACO Algorithm, With Several Active Nodes.

Also, the power consumption gained throughout utilization of the ACO algorithm in the Bluetooth WSN scheme has been computed as well presented in Figure 10.

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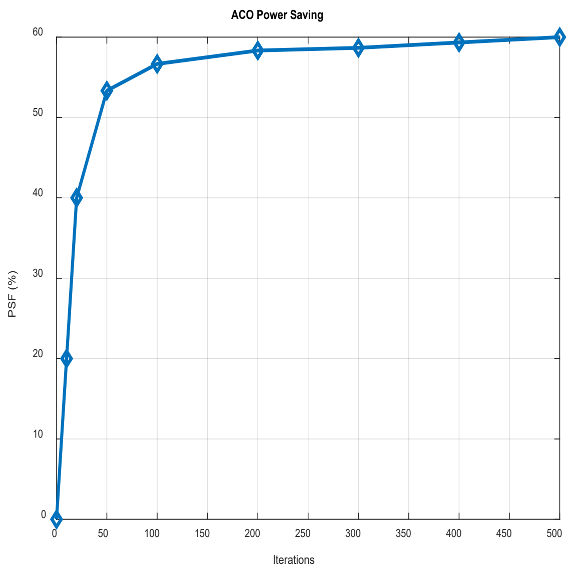

Figure 10: Illustration of the effect of ACO algorithm on power saving for Bluetooth WSN.

Furthermore, Table 1 demonstrates the effect of the ACO algorithm on the cost function and on the power saving for Bluetooth WSN scheme.

Table 1: Illustration Of The ACO Cost And Power Saving Factor With Iterations Progress.

Iterations	ACO Cost	Power Saving Factor1
0	1500	0%
10	1200	20%
20	900	40%
50	700	53,333%
100	650	56.666%
200	625	58.333%
300	620	58.666%
400	610	59.333%
500	600	60%

1Power saving factor is a percentage of the remaining nodes power compared to the total WSN power.

6. DISCUSSION

By reviewing the obtained results, we can note that the use of the ant colony technology greatly improved the process of regulating the transmission and receipt of Bluetooth WSN networks. This technology shortens the effort and time by reducing the calculations and investing the energy available to the nodes by choosing the shortest and easiest possible paths between nodes in the communication network. From Table 1 it is clear that by using ACO technique in the Bluetooth WSN networks will save the overall network power by 60%.

7. CONCLUSION

The scope of this proposed shall be the consideration of designing Bluetooth M-LPNWSN using ACO algorithm. This is proposed processes the power consumption and low power nodes lifetime issues. The conservation of both power consumption and low power nodes lifetime are the main points of the research. It is proposed that the Bluetooth M-LPNWSN using ACO algorithm combines a hybrid design between Bluetooth M-LPN and WSN mechanism to save energy with the one-hop communication technique to increase the lifetime of low power nodes. The proposed Bluetooth M-LPNWSN using ACO algorithm focuses on low power nodes that deploy randomly in the sensing field and all homogeneous nodes have the same capabilities, uniform sensing, and communication range. It is simulating with multiple Friend nodes and Low Power nodes pairs to calculate the time spent by each node on different states. The derive plot of the average time spent by each node in different states shows that the Low Power nodes always consume less energy by spending more time in the sleep state. The proposed Bluetooth M-LPNWSN using ACO algorithm is then test with a simulation known as MATLAB version R2020a.

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