# Enhance packet transmission using intelligence routing method in wireless mesh network

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**Abstract** : Nowadays, with the increasing growth of technology, many scientists and researchers are looking for ways to reduce costs and improve efficiency and performance in all scientific fields. Researchers in computer science and communication technology have not strayed from this category and as one of the pioneers in the field of technology have made many efforts in this direction. After much effort in the field of hardware that has led to the creation of new technologies in the field of communication and data transmission, many efforts have been made in the field of software and creating faster and more dynamic methods of communication and data transfer. Meta-heuristic optimization algorithms, many of which are nature-inspired, are one of these software methods. In recent years, the use of these algorithms has found a special place in improving efficiency in various sciences. In this study, which is performed on Wireless Sensor Networks (WSNs) as part of Wireless Mesh Networks (WMNs), a creative hybrid method has been proposed using meta-heuristic optimization algorithms, that has tried to improve the energy consumption in these networks. In this intelligence hybrid method, two optimization algorithms of ant colony and gray wolf have been used. The developed hybrid method has been implemented in MATLAB version R2018a. The results of this study show the improvement of energy consumption using the developed hybrid method compared to other methods.

**Keywords**: WSN, WMN, meta-heuristic algorithm, ant colony algorithm, gray wolf algorithm

## 1. Introduction

Nowadays, due to the increasing growth of technology and the need for fast and easy access to information and the establishment of strong and robust communications, Wireless Mesh Networks (WMNs) have found a vital role. Wireless mesh networks provide dynamic bandwidth access for all mobile clients anywhere. The WMN components are divided into three categories: mesh routers, mesh clients, and gateways [1].

Mesh routers is an essential component of these networks, in fact they are backbone of wireless mesh networks and in the transmission of packets from clients using multi-hop technology to cover a large area with low cost are used. Mesh clients can act as a router, or it can be from other networks such as WSN and Cellular. The nodes that provide the Internet connection are called gateways. In addition, wireless mesh networks can be adapted to wired or wireless networks through gateways [1].

Wireless mesh networks have several challenges in their different layers including: compatibility of animated links, variable transmission power, multiple receivers, directional antennas, link quality, transmitter function, scalability, reliability, security, channel allocation and routing protocol, packet transfer capacity, traffic, performance, flexibility and quality of service.

One of the major challenges of wireless mesh networks is packet transmission and traffic control, which can cause delays and disruption of packet transmission by destroying some network links [1]. Hence, several works [2,3,4,5,6,7,8,9,10] have been done to improve packet transfer and traffic control.

Franklin et al. [2] have addressed the issue of directional control and channel allocation for Mesh Router Mesh Clients (MRMCs). In [2], non-overlapping channels were replaced by channels with partial overlap to improve the performance of multi-channel networks. Avallone et al. [3] have proposed a channel allocation algorithm based on transmission power, flow traffic, and allocated data rates. Liu and Bai [4] have proposed a method that could improve network performance with the MRMC architecture.

Lin and Lin [5] have proposed a new approach depending on the size of the connection window, the moving distance receiver, and the weight factor of the guided path. Thenral and Sikamani [6] have based on node angles. If the node has an angle of less than 600, it is selected to transmit packets and more distant communications.

Bozorgchanani et al. [7] have presented a method based on gateway selection and clustering in a multimedia WMN. Deng et al. [8] have proposed a plan based on intermediaries that works in transceiver mode to allocate channels. The simulation of this design has been shown to improve network performance and load balance with existing routing protocols. Son pa and Mandala [9] have proposed NCAM based on Ant Colony Optimization (ACO) algorithm, in this method, avoiding congestion by improving load distribution, by avoiding congestion after finding the optimal route. Sathyasri et al. [10] have proposed the Enhanced Traffic aware Channel Assignment (ETCA) algorithm using ACO algorithm to maintain route and control traffic using a timeline.

Based on this motivation, this chapter presents and evaluates a creative hybrid method using meta-heuristic optimization algorithms on WSNs as part of WMNs. In this intelligence hybrid method, two optimization algorithms of ant colony and gray wolf have been used to improve the energy consumption in these networks. The developed hybrid method has been implemented in MATLAB version R2018a.

The remaining of this chapter is organized as follows. Section 2 presents a background of the WMNs, optimization algorithm, and related works. Section 3 briefly described the meta-heuristic algorithm. Section 4 presents a hybrid intelligence algorithm. Section 5 presents the simulation results and compares the developed algorithm. Finally, section 6 concludes this chapter.

## 2. Backgrounds

This section outlines the WMNs, WSNs, Optimization algorithms, and related works.

### *2.1. WMNs*

WMNs are considered in industry and research due to their breadth and the possibility of establishing strong and dynamic communications. These networks have relatively good stability and strength. Wireless mesh networks are divided into three different architectural categories based on network topology and node performance, WMN infrastructure, WMN client, and hybrid WMNs.

#### 2.1.1. WMN Infrastructure

In this group, different nodes of routers and clients are connected to the network, the more common ones act as the backbone of the network and communicate between clients.

#### 2.1.2. WMN Client

One of the key features of clients is the point-to-point communication between network clients. Numerous nodes are used to deliver packets from origin to destination. Only one type of radio is used to form wireless client mesh networks. In addition, mesh clients offer other functions such as self-configuration and routing that are more limited than the mesh network infrastructure.

### 2.1.3. Hybrid wireless mesh networks

Hybrid networks are better than the previous two categories and are formed by combining two networks. Not only can the network be accessed through more consultants and clients, but also a direct network can be established between clients. Network infrastructure also creates connections between different networks such as Wifi, Wimax, Cellular, WSNs, which ultimately improves communication and covers a wider space with wireless mesh networks.

## *2.2. Optimization algorithms*

Nowadays, innovative and meta-heuristic optimization algorithms in all scientific fields, especially information technology, have been considered by researchers and scholars. Meta-Heuristic optimization algorithms are often inspired by nature. Researchers in various sciences have achieved good results using these optimization algorithms. In this research, two Gray Wolf Optimization (GWO) and ACO algorithms are utilized. The ACO algorithm is inspired by ants' natural foraging behavior. The GWO algorithm is also based on wolf herd behavior in siege and hunting situations.

## *2.3. Related works*

Due to the importance of proper packet transmission and proper traffic control in wireless mesh network, many researchers [2,3,4,5,6,7,8,9,10,16,17] have tried to improve packet transmission and traffic control in these networks.

Franklin et al. [2] have proposed the issue of directional current control and channel allocation for MRMCs in WMNs. In the proposed method, overlapping channels are replaced with channels that have partial overlap to improve the performance of multi-channel networks. In the simulation of the proposed transmission power method, the lost path information, noise rate, and traffic load at each node are integrated, and the widespread use of spread spectrum with the use of advanced channel and flow allocation methods without the use of produces spectrum.

Avallone et al. [3] have proposed a channel allocation algorithm. This algorithm depends on the Flow-based Channel Power and Rate Assignment (FCPRA) algorithm. In this algorithm, which analyzes channel allocation competence, the effect of transmission power control, and data rate on a channel by controlling transmission power rate and data transfer in wireless links, the authors try to increase the effect of channel allocation.

Liu and Bai [4] have proposed a method that could improve network performance with the MRMC architecture. According to this method, network functions that are integrated are routing, Topology Control (TC), Power Control (PC), and channel allocation. As a result, according to the MRMC/WMN protocol layer, topology control can be a management function block.

Lin and Lin [5] have proposed a new approach depending on the size of the connection window, the moving receiver, the distance and the weight factor of the guide path. In this method, channel allocation and packet transfer are performed using the distance between channel separation and nodes. So, it can improve the use of all channels. In general, the network performance in this method is obtained by organizing a custom channel for all nodes depending on the sequential reduction of the weights of the conductor path.

Thenral and Sikamani [6] have proposed an approach based on node angles. If the node has an angle of less than 60˚, it is selected to transmit packets and more distant communications. This approach results in the best network performance when associated with CAMP Angle based Multicast Routing Algorithm (AMRA).

Bozorgchenani et al. [7] have proposed a method based on gateway selection and clustering in a multimedia WMN. They had two main phases in the developed method. In the first phase, the Internet gateway candidates are selected from network mesh nodes based on network traffic. In the second phase, the best candidates for the Internet gateway have been selected using the route tracking method. In addition, reliability and a traffic-aware gateway have been proposed to reduce network energy consumption, the Genetic-based clustering has also been used to prioritize nodes.

Deng et al. [8] have proposed a plan based on intermediaries that works in transceiver mode for channel allocation. The simulation of this design has been shown to improve network performance and load balance with existing routing protocols. In this design, they consider a mesh network with static routers. In addition, they try to optimize the load status of each router, which is changed slowly. The switching delay, which is the switching delay of the interface from one channel to another, is a factor that affects multiple interfaces. The switching delay is a few milliseconds and cannot be omitted. First, in the proposed Load Balance Link Protocol (LBLP) framework, there are three multimedia mesh nodes C, B, and A, which can operate on both the sender and receiver modules. To ensure connection, the first interface is always in receiver mode, known as the static interface, and the second interface is always in transmitter mode, known as the dynamic interface. An adaptive interface can change the balance and load modes between channels and interfaces. After selecting the work channel, the channel information will be broadcast on all channels available to neighbors. Neighbors keep this recorded information for sending packages to neighbors. To ensure a connection between neighbors, the static channel does not change. Packets sent over the same channel are routed to the same queue, and sender interfaces route them to a different queue.

Son Pa and Mandala [9] have proposed a New Congestion Avoid Method (NCAM), which is based on the ACO algorithm. This is to avoid congestion by improving the load distribution by avoiding congestion after finding the optimal path, after which the data packets are separated for an optimal path. Four types of ants are used in this method, (a) Forward Ants (FAs) that move from source to destination to discover paths, (b) Rear Ants (BAs) that move from destination to source to update the route chart, (c) Local Forward-facing Ants (LFAs) and (d) Local Rear-facing Ants (LRAs), both for optimal sub-paths (on optimal node pairs) when each optimal node pair exceeds the closed limit. After finding the optimal path, this algorithm works with three mechanisms updating the path, closed navigation, and finding the optimal path.

Sathyasri et al. [10] have investigations that led to the introduction of the Enhanced Traffic aware Channel Assignment (ETCA) algorithm. In this algorithm, the ACO algorithm is used to maintain the route and control the traffic using the time window. In the ETCA algorithm, path maintenance is designed based on multi-route routing concepts using ant colonies, with ants Moving Backward (MB) or Forward (MF) multicast. This structure helps to create routes in the network. This method uses a time window that is used for the received traffic information to assess the traffic situation at a specific time.

Panda et al. [16] have used meta-heuristic optimization algorithms and combined them to guide submarine robots. Elrefaei et al. [17] have offered an approach to improve latency in WSNs using particle swarm optimization algorithms and firefly.

## 3. Meta-Heuristic algorithms

There are usually two ways to find the answers of a problem. First method is Brute Force, which is the same old search methods with searching and viewing all data, binary search and dynamic programming are some of these methods. The second method is the use of heuristic methods that are based on exploration and initiative. In the first method, by observing and searching all the data, an accurate and definite answer can be given. These algorithms have a low speed and are not very efficient for large area. In contrast to the second method, using the existing initiative and information, a part of the data can be searched and the search speed can be increased, but even these algorithms do not guarantee that the obtained answer is the best possible answer [20].

Innovative algorithms need to know the problem and to solve a specific problem. They are considered with special conditions. So, they certainly do not give the best answer and are used in some problems. To solve these problems, other algorithms, called Meta Heuristic, were developed. They do not need to know the problem and are usually not limited to a specific problem and the terms are problem independent. By providing a general solution, these algorithms solve the problem with reasonable accuracy and speed. In recent years, many meta-heuristic algorithms inspired by nature and studying the behavior of living organisms such as the ACO algorithm, gray wolves, fireflies and frogs, have been proposed [20]. Two well-known of these algorithms including ACO algorithm and GWO algorithm are described in the next section.

## *3.1. ACO Algorithm*

This algorithm was first proposed by Marco Dorigo (1991) to solve the problem of a traveling salesman with 75 cities [11]. It is based on the behavior of ants in search of food. This algorithm is in the category of NP-complete algorithms. This meta-heuristic algorithm is based on the behavior of real ant colonies [20].

### 3.1.1 Behavior of natural ants

3.1.1.1. Being social

Deneubourg et al. (1983) [12] have shown that ants are social insects, who live socially in a colony and their behavior is towards the survival of the colony rather than the survival of a component of colony. They have a division of labor and the ability to solve the complex problems of their lives. Their colony is called a superorganism.

3.1.1.2. Mass intelligence

Ants find the shortest commute from home to food despite their blindness. This is one of the most important and interesting behaviors of ant. This behavior of ants has a kind of mass intelligence, which has random behavioral elements and there is no direct connection between them. They only communicate indirectly with each other using signs. Of course, this type of intelligence has been observed in many other creatures such as bees and swallows and has become the basis of other algorithms [13].

3.1.1.3. Pheromones

Ants leave a trail of a chemical called pheromone when they walk, which evaporates quickly, but stays on the surface for a short time as an ant trail [13].

3.1.1.4. Decision making

In choosing between two paths, ants prefer the path with more pheromones, or the path with more ants who have crossed it. Grass´e (1995) [14] called this intelligence in routing environmentalization or stigmergy. Two functions are involved in this decision, one is the amount of pheromone secretions and the other is the length of the path, the first is called the pheromone function and the second is called the innovative function.

### 3.1.2. Process of ACO Algorithm

The ACO algorithm is one of the meta-heuristic algorithms used in this research. This algorithm has a special process that is derived from the behavior of ants in nature and is described below. In this algorithm, the initial pheromone value for the pheromone function and the initiative function must first be determined. Each ant has a forbidden list in which the names of the cities it has passed are placed, so in the second step, the city of origin must be included in this list. After these two steps, the probability function must be calculated to select the next city for each ant. After each round, the number of cities must be adjusted and the names of the cities passed must be added to the banned list. . After these steps, the best path for the ant must be determined. Finally, if the tour is not over for all the ants, an update must be made and the ants go to the third stage by the end of the tour. All these steps are implemented and calculated in the ACO algorithm as different functions.

Algorithm process include [13]:

I. Determine the initial value for the pheromone function and the innovative function

II. Put the city of origin on the forbidden list for any ant for which there is no right for the ant to cross that city again.
III. Calculate the probability function to select the next city for each ant in each city
IV. Adjust the population of cities for the choices of each round
V. Add the selected city of each ant to the banned list of that ant
VI. Determine the best route
VII. Update and go to the third stage (if not all ants end the tour)

## *3.2. GWO algorithm*

The GWO algorithm is another meta-heuristic algorithm developed in recent years inspired by nature. This algorithm follows the leadership hierarchy and the mechanism of hunting gray wolves in nature [15]. There are 4 kinds of gray wolves that are used to simulate leadership hierarchies, alpha, beta, delta and omega. Moreover, there are 3 main stages of hunting, namely hunting search, hunting siege and hunting attack, are implemented in this algorithm [15].

### 3.2.1. Social hierarchy of gray wolves

The Gray wolves prefer to live in groups. The average group size is 5-12. Interestingly, they have a very strict social dominant hierarchy as illustrated in figure 1[15].

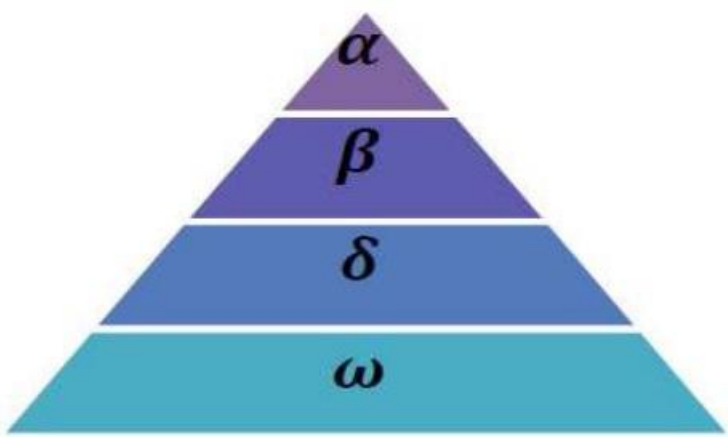


**Fig 1.** Gray wolf hierarchy [15]

3.2.1.1. Alpha Wolf

Leaders include a female wolf and a male known as alpha. The alpha wolf is responsible for group decisions such as hunting location, waking time, sleeping location. The alpha decisions are given to the group, although some of the democratic behaviors that alpha follows are also seen in the group. The alpha wolf is also called the dominant wolf because the group must obey his orders. Only alpha wolves in the herd are allowed to mate. Interestingly, the alpha is not always the strongest member of the herd, but rather the greatest at managing the herd, demonstrating that the herd's structure and order are more significant than its size [15].

3.2.1.2. Beta Wolf

Beta wolves, which are inferior wolves, make up the second level of the gray wolf social structure. They support the alpha wolves' judgment or other herd actions. The greatest replacement for alpha wolves in the event of death or aging are beta wolves, which can be either female or male. Although they respect alpha wolves, beta wolves are in charge of other weaker wolves. Greg the beta wolf serves as the alpha wolf's advisor and the herd's moderator. The beta wolf carries out the alpha wolf's orders across the herd and provides the alpha wolf with feedback [15].

3.2.1.3. Omega Wolf

The hierarchy of gray wolves has an omega wolf as its lowest rank. The victim is represented by the omega wolf. All high-level and dominating wolves must be obeyed by the omega wolves. They are the final wolves that can eat. The presence of the omega wolf in the herd does not appear to be significant, but it has been observed that if the omega wolf is lost, the entire herd becomes involved in civil war and problems. This is because the omega wolf is the herd's own outlet for violence and despair, which helps to satiate the entire herd and maintain the dominance structure. The omega wolf occasionally serves as the herd's nanny [15].

3.2.1.4. Delta Wolf

A wolf is referred to as a delta wolf if it is neither an alpha nor an omega wolf. Omega wolves are subjugated by delta wolves, who must be alpha and beta wolf. This group consists of leaders, guards, senior wolves, hunters, and guardians. The task of keeping an eye on the boundaries of the territory and warning the herd of any threat falls to the leading wolves. The guards are the herd's protectors and guarantee of protection. Old wolves are seasoned individuals who were once alpha or beta wolf. In addition to helping the alpha and beta wolves with the hunt, hunters also give the herd food. The final duty of carers is to tend to the needs of sick, injured, and frail wolves [15].

### 3.2.2. Social behavior of gray wolves

Group hunting is another intriguing social characteristic of gray wolves, in addition to their social hierarchy. The following are the key phases of hunting gray wolves, according to Muro et al. [18].

I. Tracking, chasing and approaching prey
II. Pursue, besiege and bore the hunt until it stops
III. Attack the hunt

In GWO design for mathematical modeling, the most appropriate solution is considered as alpha (a). The second and third proper paths are also called beta (b) and delta (d), respectively. The rest of the candidate pathways are called omega. In this algorithm, hunting (optimization) is done with the help of a-b-c. Other wolves follow these three wolves. During the hunt, gray wolves circle around the prey and surround it. The following equations have been developed for mathematical modeling of the siege behavior:

$$\vec{D} = | \vec{C} . \vec{Y_p} (t) - \vec{Y} | \quad (1)$$

$$\vec{Y} ( t+1) = \vec{Y_p} (t) - \vec{A} . \vec{D} \quad (2)$$

where t, Yp, and Y denote the current iteration, the hunting position vector, and the gray wolf position vector, respectively. In addition, A and C are used to show the coefficient vectors.

$$\vec{A} = 2\vec{a} . \vec{r} - \vec{a} \quad (3)$$

$$\vec{C} = 2. \vec{r} \quad (4)$$

Components a decrease linearly from 0 to 2 during iterations, and r is random vector at {1 , 0}. The gray wolf is able to improve its position within the space around the hunt in any random position using Equations (1) and (2).

It is expected that alpha (best candidate solution), beta, and delta have a better understanding of the probable hunting situation in order to mathematically replicate gray wolf hunting behavior. In order to force other search agents, such as Omega, to update their positions depending on the positions of the best search agents, it maintains the first three solutions (best solutions) obtained thus far. In this regard, the following equations are suggested.

$$\overrightarrow{D_\alpha} = | \overrightarrow{C_1} . \overrightarrow{Y_\alpha} - \vec{Y} | , \overrightarrow{D_\beta} = | \overrightarrow{C_2} . \overrightarrow{Y_\beta} - \vec{Y} | , \overrightarrow{D_\delta} = | \overrightarrow{C_3} . \overrightarrow{Y_\delta} - \vec{Y} | \quad (5)$$

$$\overrightarrow{Y_1} = \overrightarrow{Y_\alpha} - \overrightarrow{A_1} . ( \overrightarrow{D_\alpha} ) , \overrightarrow{Y_2} = \overrightarrow{Y_\beta} - \overrightarrow{A_2} . ( \overrightarrow{D_\beta} ) , \overrightarrow{Y_3} = \overrightarrow{Y_\delta} - \overrightarrow{YA_3} . ( \overrightarrow{D_\delta} ) \quad (6)$$

$$\vec{Y} ( t+1 ) = \frac{\overrightarrow{Y_1}+\overrightarrow{Y_2}+\overrightarrow{Y_3}}{3} \quad (7)$$

## 4. Proposed hybrid algorithm

Recall that one of the important issues in wireless networks is the energy consumption in the transmission of transmitted packets. In this study, a new approach using meta-heuristic algorithms has been proposed to decrease the energy consumption in the transmission of data packets sent in WSN as part of WMN. The WSNs have several wireless sensors operating in the network, which depending on the type of network activity must receive information and send it to the database. They are usually clustered due to the large number of sensors and better network order.

The developed method is implemented in a way that hybrid two optimization algorithms, ACO and GWO algorithms. To implement this part, the obtained results of the ACO algorithm is required. The pseudo-code of the proposed hybrid algorithm is given as follows.

**Procedure** *Proposed Hybrid Algorithm*

```
Set initial values.
*/ Start by call ACO algorithm
 Set initialize pheromone trails
While (termination condition not met) do
          Construct Solutions
          Apply Local Search            */ optional
          Update Trials
End
End ACO algorithm

*/ call GWO Algorithm
t=0.
For i=1: n
          Generate Yi(t)    */  Yi(t) is initial population and it is randomly generated in this step
          Evaluate f (Yi)        */  f(Yi) is the fitness function of each search agent (solution)
End
Assign Yalpha, Ybeta, Ydelta
For i=1: n
          Update Y using Eq.(7).
          Reduce "a" from 2 to 0.
          Update A and C using Eq.(3) and Eq. (4)
          Evaluate f(Yi)
End
Update Yalpha, Ybeta and Ydelta.
t=t + 1.
While (t >= Maxiter) Produce best solution Yalpha.
End
```

To create a program space according to the values of Table 1, first there must be a number of nodes on the page, which are placed randomly with the code snippet below 200 nodes per page.

numberOfNodes=200;

Each node is a vertex graph and there are paths between them. The edges of the graph are the paths on which the ants should move, so a number of ants are placed on the edges.

numberOfAnts=100;

According to the ACO algorithm, ants randomly select a path at the beginning, then mark the path by pouring a pheromone over the selected path. In the iterations of the algorithm, the ants choose different paths, and the higher the pheromone value of the path, the closer the chosen path is to the desired path.

The following variable indicates the pheromone evaporation rate, which should always be between 0 and 1 in the algorithm. In this algorithm, the following value is selected. This amount is very important in terms of helping the ants to choose the right path.

roh=0.5; %Evaporation rate

The following parameters, which have been obtained by many tests and are standard values, are used for pheromone distribution, and these parameters also play a role in updating the pheromone in subsequent performances.

alpha=1; %Phromone exponential parameters

beta=1; %Desirability exponetial parameter

To determine the next point of movement of the ant, it is necessary to identify the nodes that are in the neighborhood of the desired node. For this purpose, a threshold should be considered for each node, which becomes a circle with a certain radius.

radius=5; %radius for finding nearby nodes

If it takes this value too low, it may not be the starting point of the node in the neighborhood. In this case, it issues the following message, to prevent this message, it takes a radius of 5.

Suppose there is a situation where there are several other nodes in the defined radius of one node, as you know ants do not always act intelligently and there is a possibility of choosing the wrong node, if the ant has to go to the nearest node, to avoid making the wrong choice, a parameter must be considered that assigns to each possible choice. The ant then chooses a path with a probability and another path with another probability, which is determined by the following value.

$q_0$ =0.5; %Treshold probability

In each section, using the information in the table, and the equation (8) after finding the optimal path by the algorithm used, the amount of energy consumed to send 50 data packets is calculated. Equation (8) [19] is the same as $f(Y_i)$ in the pseudocode of the proposed hybrid algorithm.

$$E_{AB} = E_{transmit} * K * d^a + E_{receive} * K * N * E_{ReceiveClusterHead} * K \quad (8)$$

When the program is executed, the ACO algorithm finds the optimal path according to its specific characteristics. This part of the ACO algorithm is used as part of the input of the developed hybrid algorithm. According to the basic structure of our GWO algorithm, there are 4 kinds of gray wolves, which are named alpha, beta, delta and gamma, respectively, which include the best answer and the next answers, respectively, in terms of better. Therefore, with these explanations, it should be known that the minimum number of answers required from the paths found in the ACO algorithm is 4.

In other words, the ACO algorithm must answer at least 4 possible paths as the answer. Therefore, it requires all possible paths obtained from the ACO algorithm for initialization to the hybrid algorithm. After the developed algorithm receives the paths obtained from the ACO algorithm, the GWO algorithm is implemented on the paths and only one path is obtained as the optimal path of the hybrid algorithm. In the next step of the hybrid algorithm, the energy function is implemented on the optimal path and the final solution is obtained.

## 5. Simulation results and comparison

To fair comparison, obtain simulation results for ACO algorithm, GWO algorithm, and hybrid of the ACO and GWO algorithms. Then, compare the obtained results with each other. One of the factors that is effective in optimizing energy consumption in data packet transmission is finding the optimal path.

This research consists of three parts, the first part, which applies the ACO algorithm to the data, in the second part, the GWO algorithm is used for implementation, and this algorithm is applied to the data, the third and proposed section is a hybrid method, which is described below and the results of each section.

**Table 1.** Values and parameters [10]

| Parameter | Value |
|---|---|
| $B_x$ | 50 |
| Area | 100 |
| $T_r$ | 100 |
| $B_y$ | 175 |
| Length of data packet | 2000 |
| Dead node | 0 |
| Length of control packet | 100 |
| Energy at node$E_n$ | 0.25 |
| Number of nodes | 200 |
| Transmit amplifier energy (Efs) | 0.0000001 |
| Data aggregation energy | 0.000000005 |
| Energy at receiver | 0.00000005 |
| Energy at transmitter | 0.00000005 |
| Transmit amplifier energy (Emp) | $13*10^{-4}$ |
| Y field dimension maximum in meter ($Y_m$) | 100 |
| X field dimension maximum in meter ($X_m$) | 100 |
| Intermediate node | 1 |
| Optimal election probability (P) | 0.2 |
| Alpha (a) | 1 |
| Initial energy ($E_0$) | 0.1 |
| Cluster head counts | 0 |
| Cluster | 1 |
| Maximum number of rounds (rmax) | 50 |
| Percentage of nodes than are advanced (m) | 0.0 |
| Sum | 0 |
| Previously sensed value | 0 |
| Final temperature (tempf) | 200 |
| Soft threshold | 2 |
| Hard threshold | 100 |
| Initial temperature (tempi) | 50 |
| Cluster head count per round | 0 |
| Alive node | 1 |

## *5.1. The ACO algorithm*

In this section, the optimal path is found using the ACO algorithm. Each time the program is executed, according to the table 1, 200 nodes are randomly distributed on the page, and in different sections, using the algorithm of each section, the optimal path is found for them. Figure 2 shows an example of a random distribution of nodes on the page.

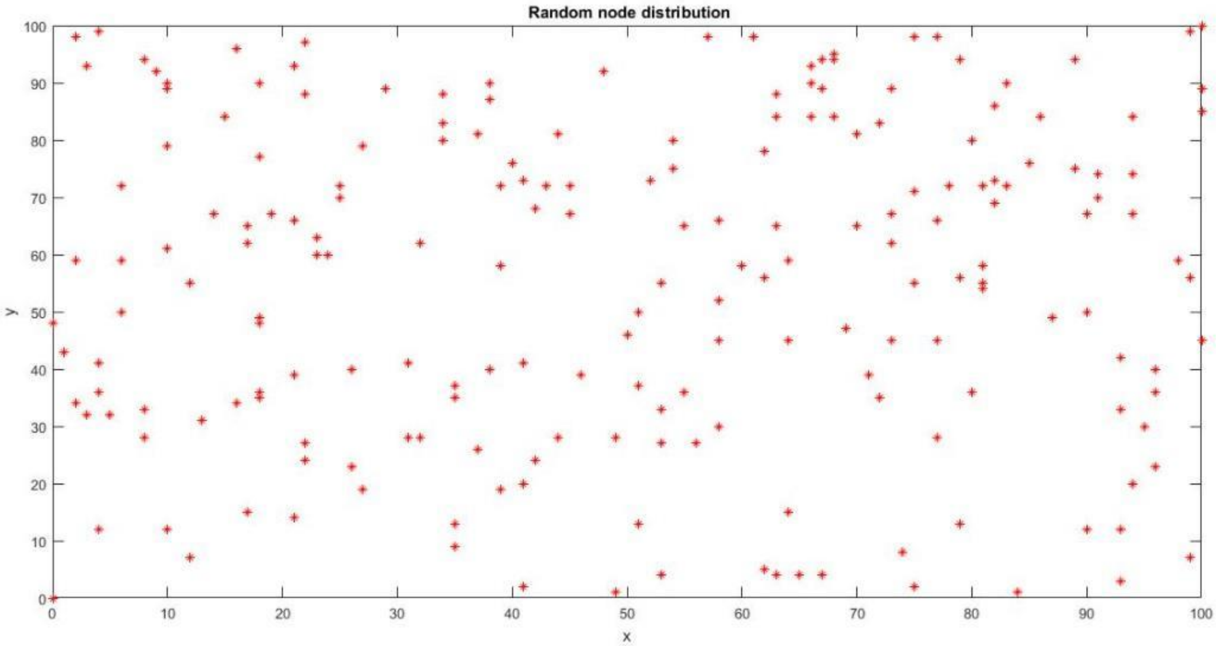


**Fig 2.** Random distribution of nodes on the page

In this section, the ACO algorithm is first applied to data. Using this algorithm, the optimal path between the nodes is found and the amount of energy consumed to send data packets in this path is calculated. Figure 3 shows the diagram for calculating energy consumption using the ACO algorithm in one run of this program.

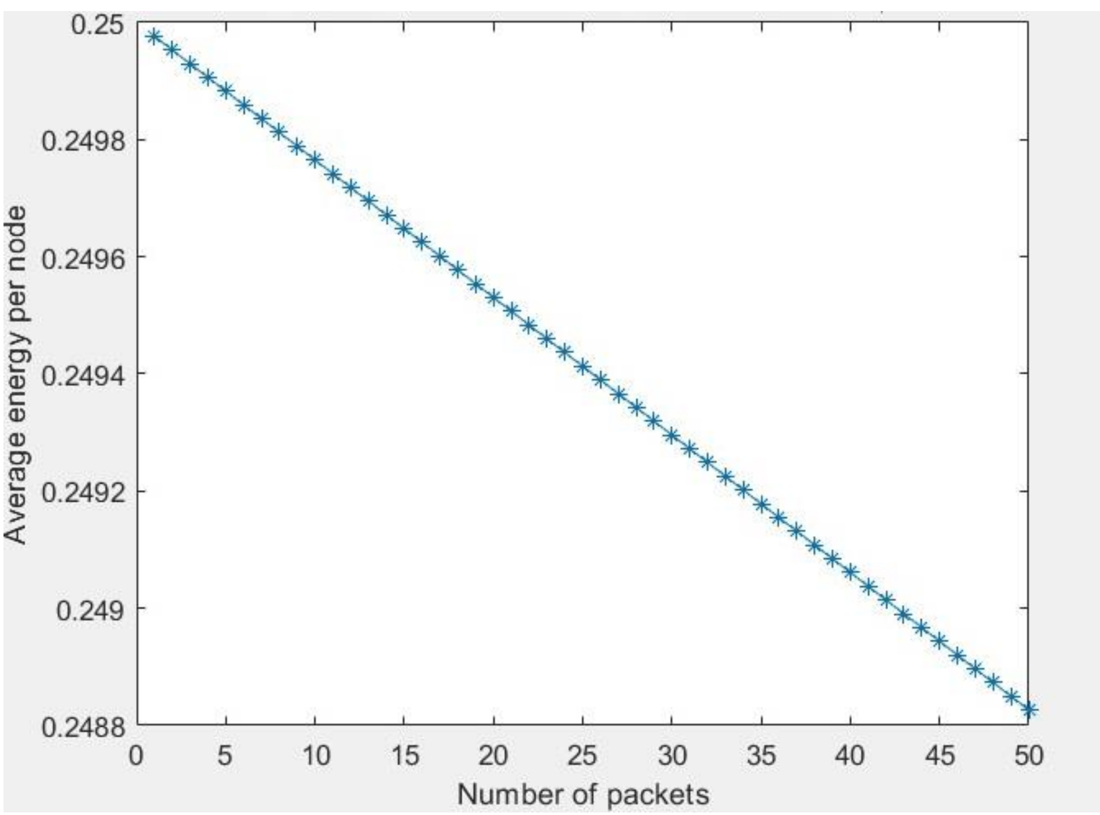


**Fig 3**. The energy consumption in routing using ACO algorithm

### *5.2. The GWO algorithm*

In the second part, the GWO algorithm is applied to data. The optimal path between the nodes is found using this algorithm and the amount of energy consumed to send data packets in this path is calculated. Figure 4 shows the diagram of the application of this algorithm in one run of this program.

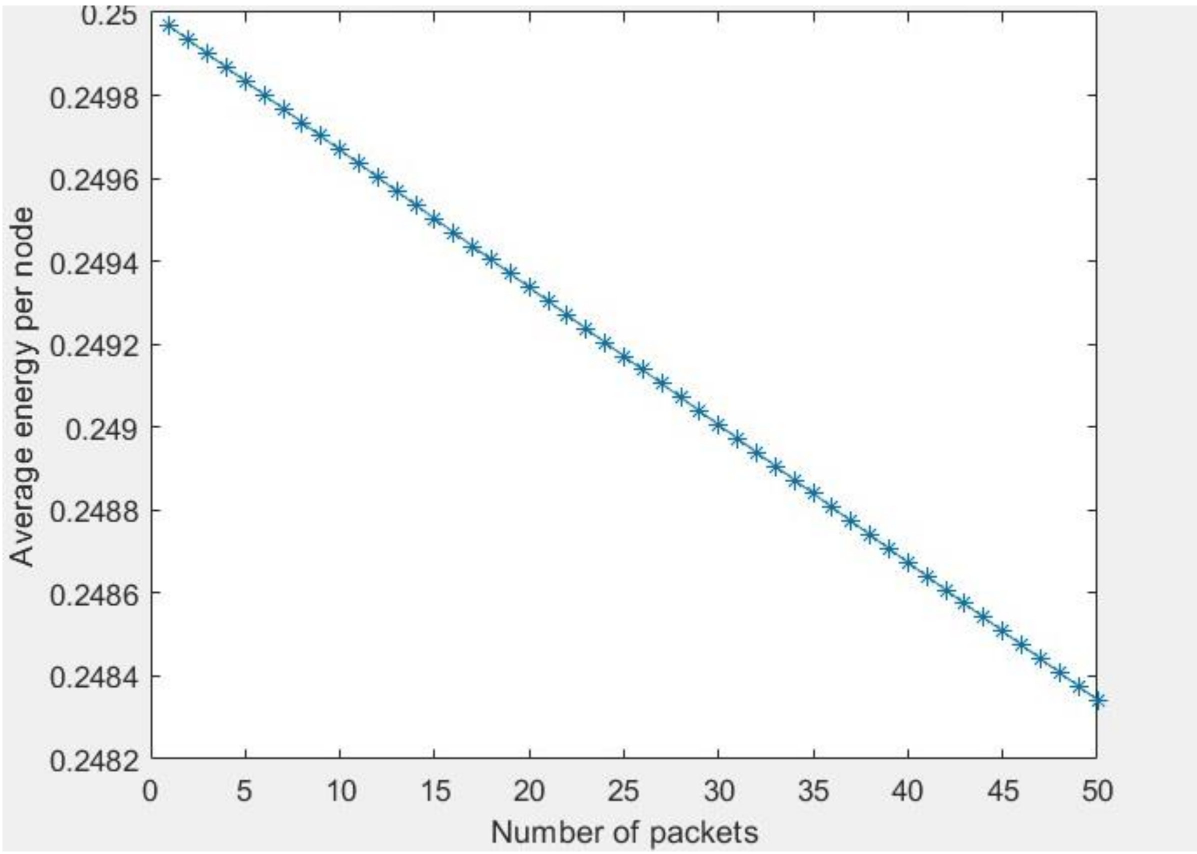


**Fig 4.** The energy consumption in routing using GWO algorithm

### *5.3. The proposed hybrid algorithm*

The third part of the program, the proposed method is implemented. Figure 5 shows the diagram obtained from the calculation of energy consumption of the proposed hybrid algorithm.

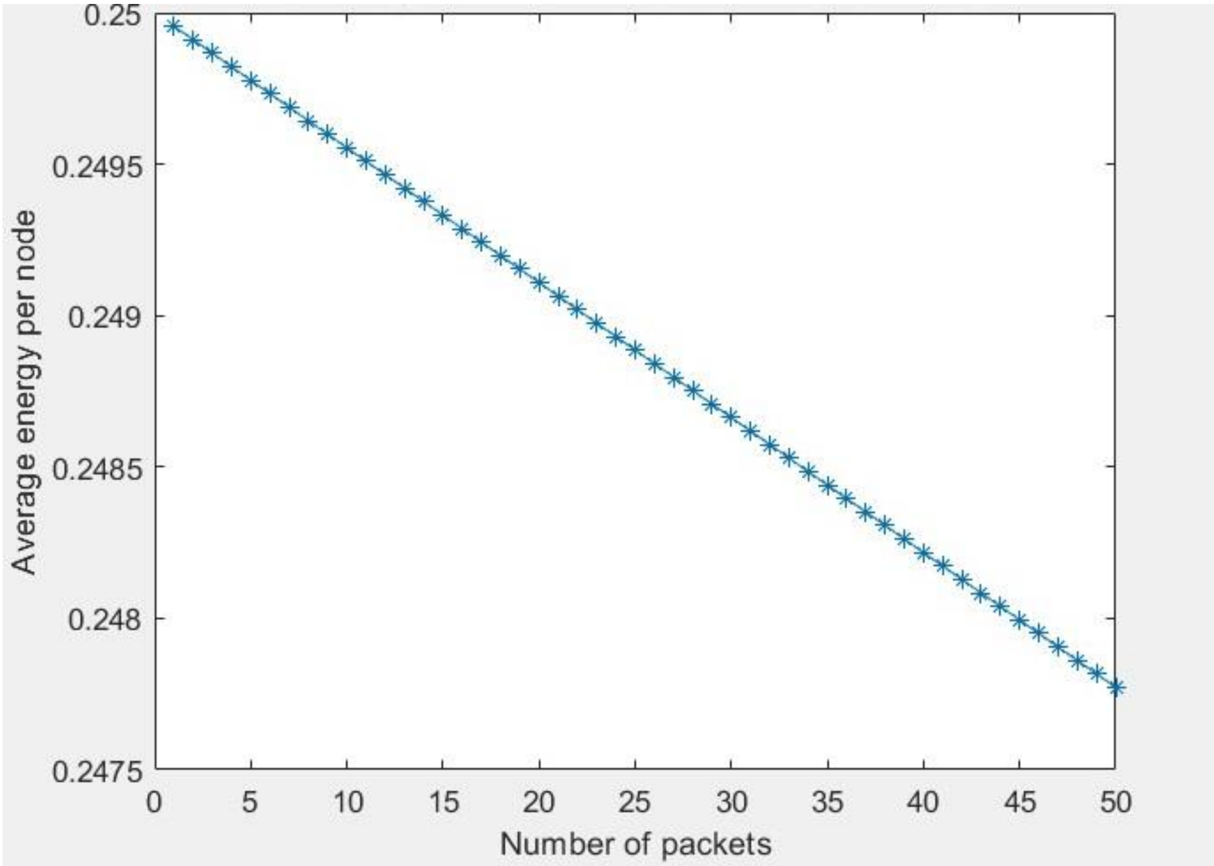


**Fig 5.** The energy consumption the developed hybrid algorithm

### *5.4. Comparison and discussion*

Figure 6 shows a comparison of the results from the proposed hybrid algorithm and the two GWO and ACO algorithms. As shown in this figure, the result of the hybrid algorithm is much better than the previous two algorithms. However, in the proposed method, the number of clusters is considered, but this method can be considered for other networks with more than ninety.

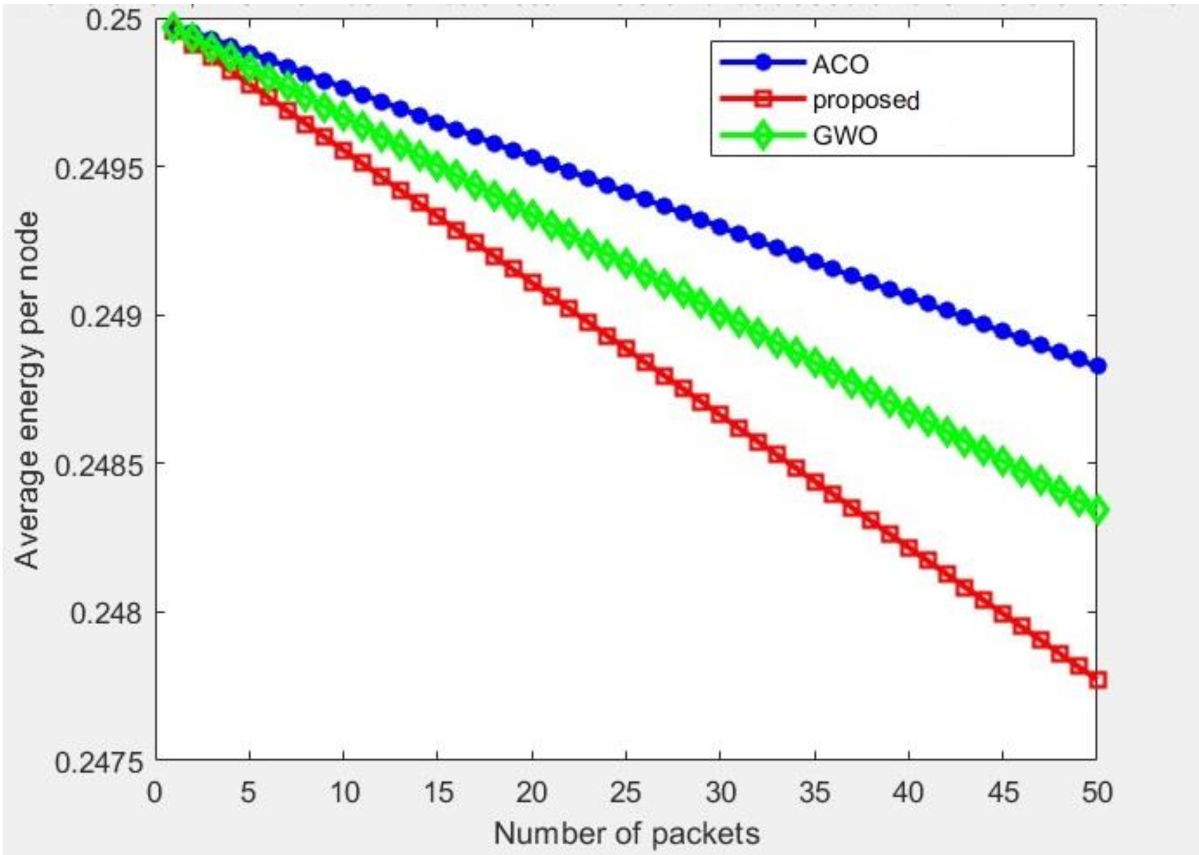


**Fig 6.** The energy consumption of ACO, GWO and proposed hybrid algorithm

For fair comparison, the program is run several times and see the results of each run separately in table 2.

**Table 2.** Compare energy consumption in each section

| Algorithm | ACO | GWO | Proposed |
|---|---|---|---|
| 1 | 0.2479 | 0.2478 | 0.2476 |
| 2 | 0.2480 | 0.2478 | 0.2474 |
| 3 | 0.2489 | 0.2481 | 0.2476 |
| 4 | 0.2487 | 0.2482 | 0.2481 |
| 5 | 0.2485 | 0.2479 | 0.2476 |
| 6 | 0.2481 | 0.2481 | 0.2476 |
| 7 | 0.2489 | 0.2476 | 0.2475 |
| 8 | 0.2485 | 0.2479 | 0.2477 |
| 9 | 0.2485 | 0.2482 | 0.2481 |
| 10 | 0.2483 | 0.2477 | 0.2461 |

Based on our implementation results that are shown in Table 2, the consumed energy for sending 50 data packets in 10 different program implementations, using the GWO algorithm, is better than the ACO algorithm, and using the proposed hybrid algorithm is far better than the previous two algorithms.

Based on our results, the proposed hybrid algorithm has advantages in comparison with the ACO, and GWO in terms of energy consumption.

## 6. Conclusion

Nowadays, due to the increasing growth of technology and the need for fast and easy access to information and the establishment of strong and robust communications, Wireless Mesh Networks (WMNs) have found a vital role. Wireless mesh networks provide dynamic bandwidth access for all mobile clients anywhere. One of the main concerns of these networks has always been the transfer of data packets and choosing the best route at the lowest cost. Improving energy consumption in data packet transmission improves cost and network performance. In this research, reduction of energy consumption has been done using meta-heuristic optimization algorithms. Using GWO algorithm and ACO algorithm, a developed hybrid optimization algorithm is proposed for optimizing energy consumption. For fair comparison, the implementation of the program consists of three parts: ACO algorithm, GWO algorithm and the proposed hybrid algorithm are presented. Based on our implementation results that are shown in figure 6 and table 2, the developed optimization algorithm has advantages compared to other methods.

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