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ALTINBAŞ UNIVERSITY

Institute of Graduate Studies

Electrical and Computer Engineering

**EFFICIENT ROUTING SCHEME FOR OPTIMAL  
ENERGY CONSUMPTION IN WIRELESS SENSOR  
NETWORK USING METAHEURISTIC ALGORITHM**

**Ali Haider Mohammed AL-AMMARI**

Master`s Thesis

Supervisor

Asst. Prof. Dr. Ayca Kurnaz TURKBEN

Istanbul, 2022

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The thesis titled EFFICIENT ROUTING SCHEME FOR OPTIMAL ENERGY CONSUMPTION IN WIRELESS SENSOR NETWORK USING METAHEURISTIC ALGORITHM prepared by ALI HAIDER MOHAMED AL-AMMARI and submitted on 20/05/2022 has been **accepted unanimously** for the degree of Master of Science in Electrical and Computer Engineering

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Submission date of the thesis to Institute of Graduate Studies: \_\_\_/\_\_\_/\_\_\_

I hereby declare that all information/data presented in this graduation project has been obtained in full accordance with academic rules and ethical conduct. I also declare all unoriginal materials and conclusions have been cited in the text and all references mentioned in the Reference List have been cited in the text, and vice versa as required by the abovementioned rules and conduct.

Ali Haider Mohammed AL-AMMARI

Signature

## **DEDICATION**

This work is completely dedicated to my respectful parents and family without whose constant support this thesis paper was not possible. They always encourage and inspire me. At the same time, my thanks also go to my caring siblings whose advice really worked for this thesis paper.



## **ACKNOWLEDGEMENTS**

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## **ABSTRACT**

# **EFFICIENT ROUTING SCHEME FOR OPTIMAL ENERGY CONSUMPTION IN WIRELESS SENSOR NETWORK USING METAHEURISTIC ALGORITHM**

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The development of wireless networking has helped to the growth of the Internet by making it easier for people to connect from anywhere in the world. Mobile computers and wireless communications are growing more popular, and mobility components are becoming much more widely available as a result. Wireless sensor networks, like many technology advances, have evolved for military purposes, such as battlefield monitoring, like many other technological advances. Civilian use followed, then military. In today's "smart surroundings," wireless sensor networks are a critical component. When it comes to protecting our homes, for example, they have become an essential part of our lives. When a high number of sensors must be deployed in risky conditions, these networks are critical. Numerous sensors may be dropped from a helicopter in the case of disaster management Small, low-cost devices with processing, storage, sensing, and communication capabilities may open the door to a wide range of new applications. The main motivation of our work is the efficiency in the use of these devices. This efficiency is of vital importance given that these sensors are generally battery operated and in many

applications these batteries cannot be replaced or recharged. Techniques designed for traditional ad hoc networks are not well suited to sensor networks

**Keywords:** LEACH, WSN, PSO, Routing.



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## **ABBREVIATIONS**

AI : Artificial Intelligence

IoT : Internet of Things

WSN : Wireless Sensor Network

FSK : Frequency Shift Keying

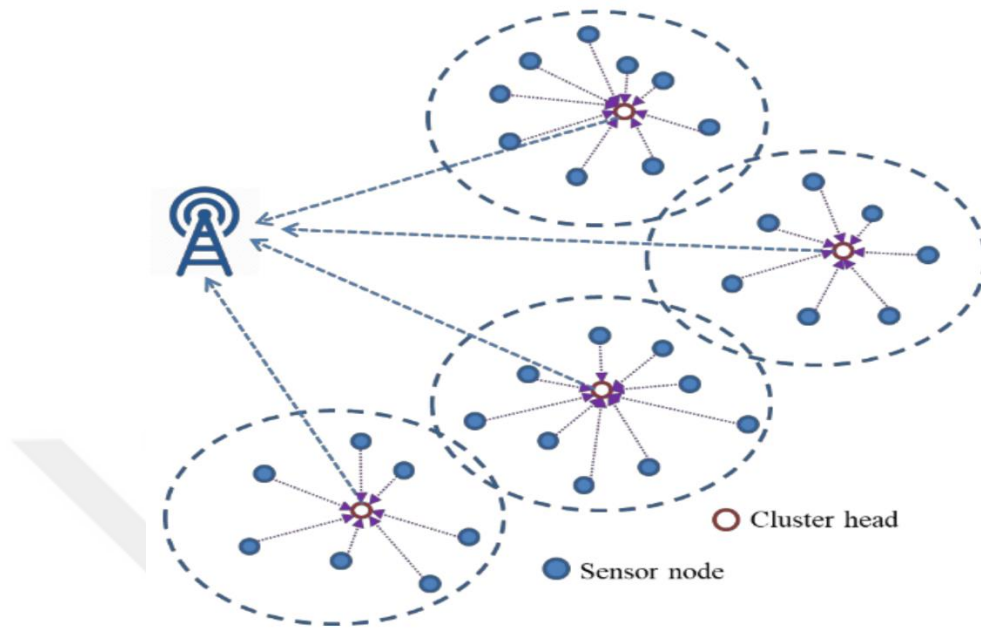
TDMA : Time Division Multiple Access

OFDM : Orthogonal Frequency Division Multiplexing

# 1. INTRODUCTION

## 1.1 BACKGROUND

The development of wireless networking has helped to the growth of the Internet by making it easier for people to connect from anywhere in the world. Mobile computers and wireless communications are growing more popular, and mobility components are becoming much more widely available as a result. Wireless sensor networks, like many technology advances, have evolved for military purposes, such as battlefield monitoring, like many other technological advances. Civilian use followed, then military. In today's "smart surroundings," wireless sensor networks are a critical component. When it comes to protecting our homes, for example, they have become an essential part of our lives. When a high number of sensors must be deployed in risky conditions, these networks are critical. Numerous sensors may be dropped from a helicopter in the case of disaster management. It is possible to use these sensors to locate survivors, indicate potential danger zones, or warn rescuers. Rescue operations will become more efficient and safer because to this increased need for sensor networks. There is no permanent infrastructure in sensor networks, therefore the topology is constantly changing owing to sensor mobility and battery depletion. Sensor networks are made up of a number of small sensors or nodes. It is common practice to gather data from all of the sensors at a given location in order to analyze or archive the information. The routing protocol, node power consumption, security, data aggregation, and unexpected node mobility are some of the most pressing concerns of Wireless Sensor Networks (WSNs).



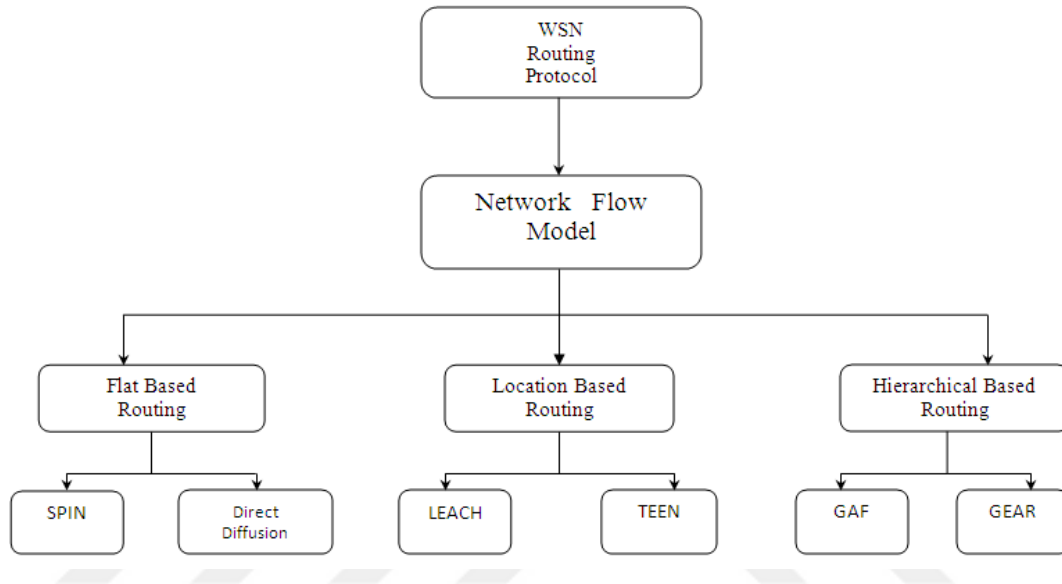
**Figure 1.1:** Wireless Sensor Network

It is not uncommon for these sensors to be stationed in dangerous environments. As a result, an effective approach that takes into account the network's energy consumption is required in order to extend the network's lifetime while also responding to environmental changes. Many protocols have been developed expressly in sensor networks where the display of energy is a significant consideration. In addition to wireless LANs, 802.11 Wi-Fi is also utilized for sensor networks, which are connected to the Internet. But because of their high-power consumption and high throughput, these protocols are not suited for sensor networks, and researchers have developed energy-efficient access protocols. In most routing protocols, the primary objective is to create energy-efficient methods and strategies in order to extend the network's lifespan.

## 1.2 PROBLEM STATEMENT

Small, low-cost devices with processing, storage, sensing, and communication capabilities may open the door to a wide range of new applications. The main motivation of our work is the efficiency in the use of these devices. This efficiency is of vital importance given that these sensors are generally battery operated and in many applications these batteries cannot be

replaced or recharged. Techniques designed for traditional ad hoc networks are not well suited to sensor networks.



**Figure 1.2:** Wireless Sensor Network routing protocol

Wireless sensor networks face a slew of challenges. During the course of this thesis, we will examine the limits imposed by routing & energy usage in this sort of network in order to prolong the life of the networks. For this, our goal is to design routing algorithms that prioritize energy saving by engaging nodes that have full batteries relative to its neighbors while avoiding places that lack power or sensors. Our routing system operates on the idea of detecting clear parts of the network and sending packets from of the origin to the destination traveling via these areas, and here is how it does it.

### 1.3 OBJECTIVES

#### Main goal

In this paper, a routing algorithm based on the bee colony algorithm is presented to reduce the network's energy consumption and, as a result, improve the nodes' lifespans via the efficient

development of clusters in the network. Based on the LEACH-C protocol, this method is designed for continuous data dissemination networks.

### **Specific Objectives**

- i. Increase the lifetime of the network, if possible.
- ii. Increase the amount of data sent from the nodes to the base station.
- iii. Increase the total network coverage time (accounted for until the death of the first node).
- iv. Optimize grid energy consumption.

## **1.4 CONTRIBUTION**

The main contribution of this work is the proposal of a routing method between the Cluster Heads (intercluster routing) based on the Djikstra algorithm with the residual energy metric and the joining of two state-of-the-art proposals for data link layer access in a WSN a homogeneous and hierarchical topology.

The elaboration of this work brings the following contributions:

- i. Use of an algorithm inspired by the behavior of bees to cluster a WSN.
- ii. Adaptation of the algorithm to the WSN clustering problem.
- iii. Use of new objective functions that seek to find better clusters for the network.

In this thesis, our contribution focuses on the realization of routing algorithms whose objective is to deal with the resource management problem in order to maximize network life. For this, we have proposed algorithms based on the fusion of two aspects:

- routing in wireless sensor networks.

The principle of these algorithms is to consider the nodes in a network of sensors like a pixel map for an image. Then, using convolution filters, we let's define a new metric to choose the path based on the available energy and we use AODV to route packets using this new metric. Of this way, the routing of packets is carried out while passing by the nodes having an important energetic value. The filters used in our contributions determine the distribution of the energy around a central node in order to choose the neighboring nodes which will participate in the packet routing.

## **1.5 THESIS STRUCTURE**

The thesis is structured as follows: Section 2 is where we review some of the previous work and implementation on smart grids. Section 3 is where we give a background about all the components. Section 4 is where we explain our model in details and implementation of that model in details, Section 5 is where we simulate our model and record the results obtained. Section 6 is where we conclude our work and put a future scope into perspective.



## 2. LITRITAURE REVIEW

It will be discussed in this section how the UWSN currently uses cluster-based routing. As a result of Nguyen et al LEACH.'s approach, this node's power consumption is balanced while also increasing the network's overall lifespan. To classify networks into layers, the depth of the network areas is taken into consideration. Data is routed across a multi-hop routing network when it is obtained by nodes. When selecting CHs, the depth of the node is utilized. Data packets from each cluster member are combined by the CH before being sent to the SN's upper layer for the further processing. Collaborative energy harvesting based UWSN system has been developed by Khan and his colleagues. The relay node uses the AF technique to transfer data, whereas the destination node uses the FCR method to choose exact signals. The amount of energy that each relay node collects is taken into consideration when selecting relay nodes using the method outlined below. Energy harvesting strategies are absent from most UWSN routing systems is based on cooperative routing protocols. By combining an energy-based clusters optimization approach with piezoelectric energy at the relay node, EH-ARCUN may increase the output capacity of UWSN sensor network by up to three times. Ideas for just an energy efficient underwater network were put out by Bhattacharjya and his team of researchers. To take use of the advantages of CH & multi-hop transmission, a loose collection underwater wireless sensor network (CUWSN) architectural style has been created. As previously mentioned, the multi-hop transmissions of the CUWSN help to lengthen the life of the network. The EERBLC technique, put out by Zhu and Wei, is a routing mechanism that does not necessitate prior familiarity with the local language. There are a number of EERBLC protocols that include transmission routing, layering, with uneven clustering. Monitoring zones beneath the sea were used to gather nodes from comparable strata as just a learning tool. A novel clustering approach is being tested to remove "hot spots" in the UWSN so that energy usage is evenly distributed across the network. Fuzzy-based CH selection, as proposed by Sahana & Singh, has the potential to lengthen the life of a network. Next, they devised a fuzzy-based routing system that could dramatically increase packet transmission speeds while minimizing latency. For underwater use, their power consumption is small, allowing the network to run for extended periods of time and so overcome the obstacles associated with underwater operation. To prevent internal assaults,

Fang et al. propose the following LTMS technique based just on binomial distribution: One way to address these issues in a hierarchical WSN is to use an MSCR systems with dynamic dimension weighting, which examines and shows data from several domains at once. For UWSN dynamic CH choices, Gomathi et al. suggest using the EE-MDCHSRP technique, developed by the authors. This is a brand-new method of routing. The residual energy, the least mobility, and the node density all go towards defining the dynamic CH. Three energy-efficient routing algorithms may be used to monitor a field with square and circular geometries: All three of these clustering protocols are designed to be energy-efficient while minimizing the amount of data that has to be sent between nodes. Finding sparse network fields may be done using density search methods or sparsity search algorithms, both of which considerably reduce the power consumption of sparse regions. The VHANCRP method for talking about local maximum nodes as well as the ANCRP technology for dealing the consistent transmitting data metrics were given by Karim et al. Clusters of smaller cubes are being used to divide network regions. All of the CH's cubes are distributed using the anchor nodes. It is assumed that the CHs are connected to the cube's centroid via strings just after source node is free allocated. Data transmission to assigned CHs in such an ANCRP network is shared across nodes. The following are some of the study's most important findings: The issue of wireless sensor networks' energy efficiency has lately come to light as a major roadblock. We must not forget that sensor networks is powered by batteries, and batteries have a finite life expectancy. Thus, extending sensor device life while concurrently enhancing data dissipation in such an energy-efficient manner becomes increasingly difficult. Clustering and forest data aggregation may significantly increase the life of sensing devices. For UWSN implementations, clustering & multi-hop routing are considered the most energy-efficient options. Cluster-based routing approaches for traditional wireless networks are infeasible in underwater wireless networks because of the presence of underwater current, bandwidth consumption, high pressure, propagation delay, and error probability. It is possible to create a very effective clustering & tree-based routing system using PSO and ACO together. In order to address these issues, our research focuses on the development of metaheuristic-based clustering as well as the MCR-UWSN routing protocol. It is possible to choose cluster heads (CHs) using an MCR-UWSN technique, and then use those CHs to figure out the best route to the desired destination. It is the CEPOC (culture emperor

penguin optimization-based clustering) methodologies that form the basis of the MCR-UWSN clustering methodology. To design multi-hop routing, grasshopper optimization (MHR-GOA) may be used, which takes into account a large number of input factors.



### 3. MATERIALS AND METHODS

#### 3.1 WSN

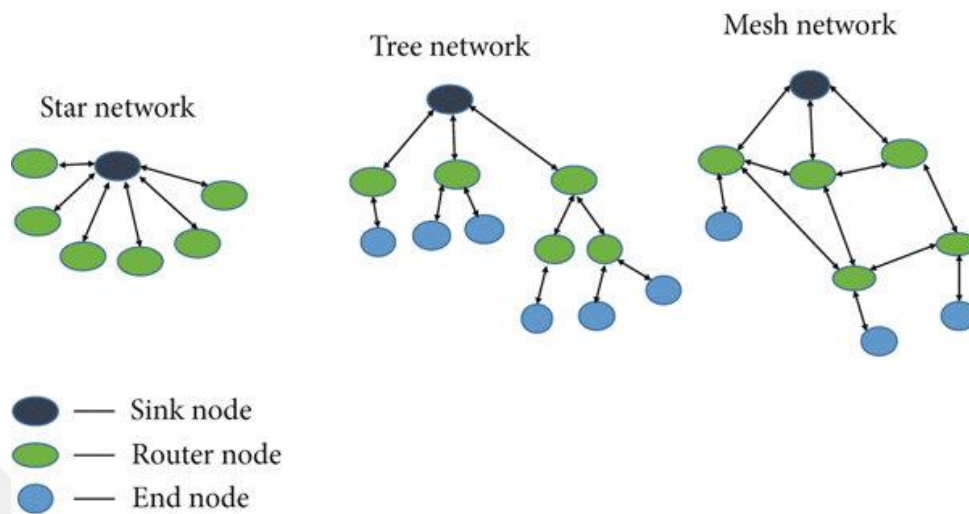
Wireless sensor networks are made possible from the expansion of low-power processing technology, wireless transmission devices, embedded systems and sensing equipment. Its area of application involves many sectors of society: security and military applications, health, industrial and residential areas, as well as underwater applications and for the acquisition of audio and video signals, better known as Multimedia Systems. In essence, a WSN is an ad-hoc network formed by sensor nodes that have operating limitations, one of which is its energy source, which is often non-rechargeable or cannot be replaced by another source. Allied to the low energy capacity, the sensor node still has limitations in its transmission power, but in compensation they are low-cost devices, low energy consumption and with multiple functionalities. The sensor node has the function of collecting and processing data, as well as transmitting this data wirelessly through an RF channel, being able to communicate with other sensor nodes or with the sink. In the WSN project, when sensor nodes cannot get a direct connection to the sink, it is necessary to use router nodes and the respective routing protocol, which traces the path along which the message travels from the sensor node to the sink. A typical WSN scheme is illustrated in Figure 1 in which sensor nodes are arranged over an area, connected to each other and to the sink via wireless means. The sink, in turn, is connected to a processing and control station or directly to the cloud<sup>2</sup>, responsible for the proper use of the data collected by the WSN. The connection between the sink and the station is made by any means, whether fixed or wireless, in the most secure and convenient way for the application, while there can be a direct connection to the cloud through wireless internet access. The transmission power and coverage radius limitation of the sensor nodes entails, in certain situations, the need for a data packet to be transmitted to other sensor nodes that are closer to the sink, so that they can then forward the message to their final destination. Networks with this feature are called multi-hop wireless networks, which is defined as networks that have one or more intermediate nodes responsible for receiving and forwarding packets over wireless connections. also lists some of the advantages of the multi-hop network, namely:

Connections between nodes increase the coverage radius of the network, which can extend as much as possible to expand the number of nodes in the network. The more connections are formed, the greater and easier the WSN's ability to communicate.

The reduced transmission radius reduces the power required for transmitting and receiving packets, thus enabling an efficient use of the energy sources that feed the nodes. – Possibility of high transmission rates with systems that are not very robust. This is due to the limited radius of coverage, which means a fast flow of messages over the network. – Depending on the network routing protocol, there is the possibility of multiple paths for a single message, meaning greater network robustness.

In a WSN there is no fixed network topology strategy and in certain cases

(Inhospitable places, difficult to access by any means) there are no physical means to apply a topology. The use of a topology directly affects the lifetime of the network, so the arrangement of sensor nodes in an orderly manner can drastically reduce energy use and thus prolong the network's operation. Although for the cases mentioned above and for large networks (networks that can contain thousands of nodes) it is not possible to coordinate the arrangement of nodes, show some topologies that can be useful for different situations. Figure 3.1 is used to illustrate an example of mesh and grid topology, widely used in WSN, whose objective is to maximize the coverage area and the robustness (associated with reliability) of the network. Nodes forward messages through multi-hop paths defined by message routing protocols, so that they can reach the sink.

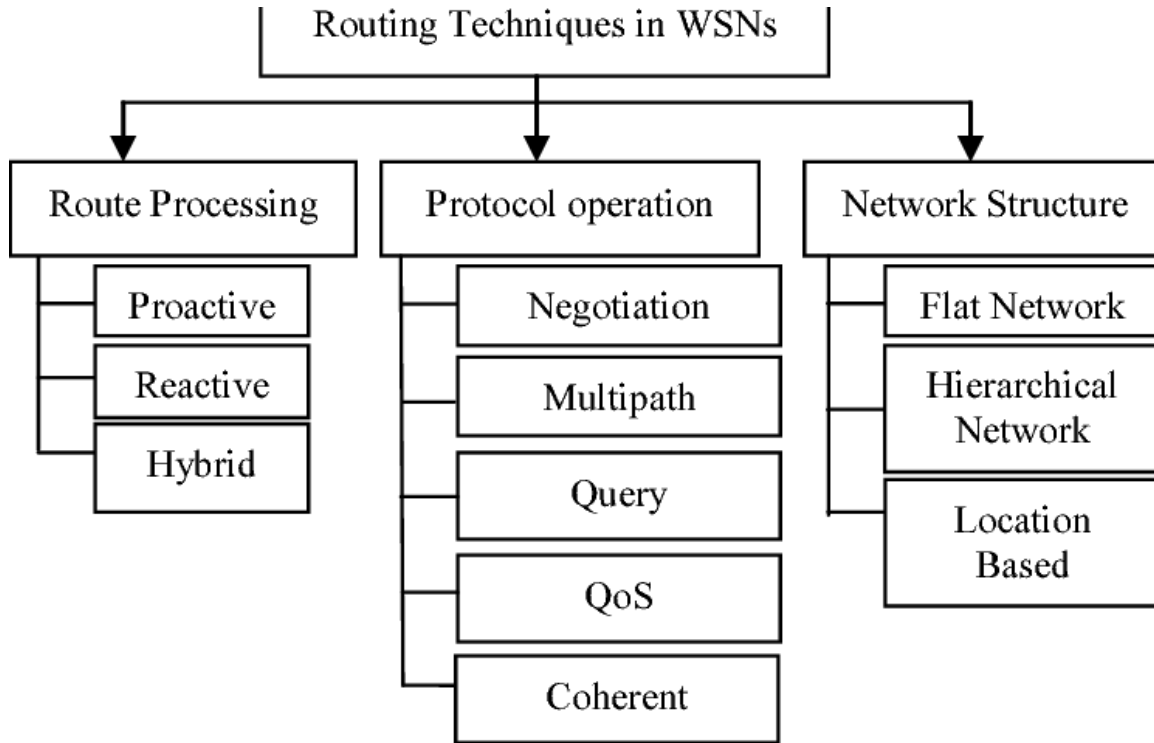


**Figure 3.1:** mesh and grid topology, widely used in WSN

### 3.1.1 WSN Routing Protocols

Directly, the role of the routing protocol is to find the best path between a sender node and a destination node. Performing this task by creating a table of directions, a protocol tries to find the smallest and most efficient route according to the performance criterion adopted for the network. In general, the protocol is assigned the function of establishing communication between nodes, tracing the route, organizing the network structure and defining the next hop directing the message to the recipient. In this way, a routing protocol has four arrangements to be defined: Form of operation; Next-hop selection; Path Establishment; Network Structure. Within each of the arrays it is possible to allocate different ways of designing an RP, this protocol being formed by the combination of characteristics of each array. Cites some of the possible types of protocols within the arrangements, as can be seen in Figure 3.2. Below is a list of protocol characteristics, some of the listed protocols that are relevant to the work. The form of operation is related to the way a WSN prioritizes and directs the operation of the network. A QoS protocol, for example, aims to operate the network in such a way that it presents favorable performance in relation to predefined metrics here the multipath and QoS based protocol are presented. Multipath protocols discover more than one route to forward messages from a sender to a receiver. The same message is sent by the discovered routes, without evaluating the routes as the best possible. As the main positive point is the reliability provided by multiple routes, the

main disadvantage is the fact that much of the energy consumed by the network goes to route discovery, scaling with the size of the network.



**Figure 3.2:** WSN Routing Protocols

QoS is defined as a set of requirements that a network needs to fulfill to guarantee the quality with which messages are exchanged between nodes. Among the metrics that define QoS are: Minimum network throughput (bps); Maximum tolerable delay for the message to go from sender to receiver; balancing the energy consumption of the network; Maximum tolerable packet loss rate. The prioritization of these metrics varies according to the use of WSN, but for a protocol to be considered based on QoS, it must meet at least one of these metrics. Among the QoS-based routing methods, two are highlighted here: routing that maximizes WSN lifetime and a protocol that performs message forwarding at the lowest possible cost. Routing is intended to set costs to possible paths formed between nodes. For energy-aware routing protocols, this cost is based on the energy remaining in the sensor node and the energy required to transmit a packet along this path. As a solution, the role of routing is to maximize the battery life of the

sensor nodes in the WSN. Message forwarding tries in a simple and scalable way to find the shortest path within a WSN of many sensor nodes. The cost function uses QoS metrics to determine the routes with the lowest costs. The protocol uses these costs to set up multipaths for a message, which can be discarded if the network detects that it is not preferable to continue forwarding it through the network. Thus, through efficient message routing, the number of hops over the network must be minimized, which affects, for example, the maximum delay between the messages being sent by the sensor node and being received by the sink. As the name suggests, next hop selection focuses on the way the protocol determines the next hop of the message from one sensor node to another, or to the sink. The most basic form is by broadcasting messages and consists of transmitting to all nodes indiscriminately within its coverage radius in order to guarantee that the message reaches the destination module. Point out the advantage of broadcasting for networks in which the nodes work synchronously, as there is a greater guarantee that the nodes are up and running at the time the message is broadcast, generating less energy cost for the WSN. However, the most common and most viable case is the network operation asynchronously, generating an uncertainty that can be quite costly for the use of broadcast-based protocols. For location-based hop selection, it is necessary that the component nodes of the network know the distance between it and the rest of the network nodes. From the position information, the route is traced so that the message travels the shortest distance. This arrangement acts mainly on the execution of the routing algorithm. Lists some location-based protocols, such as GEAR (Geographic and Energy Aware Routing), which uses a geographic information system to determine the location of nodes, and forwards messages according to the energy level of the nodes. Neighbors. Protocols based on probabilistic approximations for selection use mathematical methods or heuristic algorithms for optimal route calculation. The objective is to generate a route that optimizes network quality parameters, mainly providing an improvement in the energy consumption of the network, although other QoS parameters can be optimized. an example of hop selection based on genetic algorithm optimization is presented, in which the focus is to elaborate an elitism strategy to improve the performance of the routing protocol.

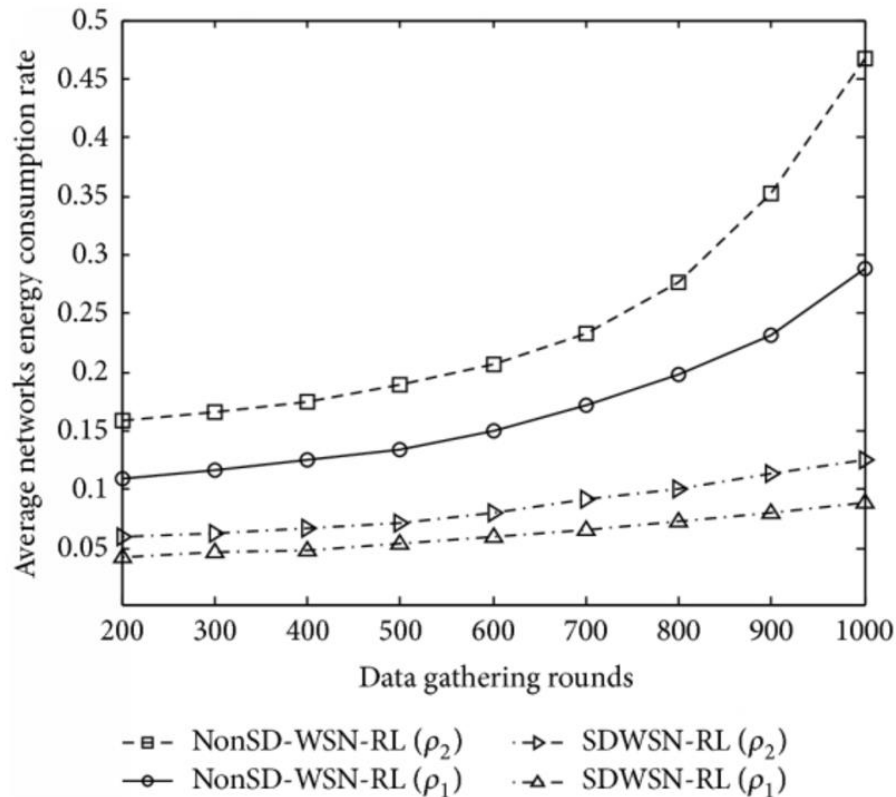
### 3.1.2 Energy Efficiency In WSN

Of all the restrictions associated with a WSN, the power limitation of the sensor node is one of the most impacting in the design of a network. Therefore, the optimal use of the energy sources of the sensor nodes is vital. The models presented in this section are proposed to equate the energy consumption both internally to the sensor node, as well as to the transmission and reception of messages, referring to the processing and communication subsystems respectively. As mentioned in Section 2.1, the processing subsystem is generally composed of micro processing units such as microcontrollers and FPGAs. According to Sinha and Chandrakasan (2000), the power consumed by a microprocessor system during the execution of a subroutine<sup>3</sup> can be expressed according to Equation 2.1. Where total power ( $P_{tot}$ ) is the sum of dynamic power ( $P_{dyn}$ ) plus static power ( $P_{stat}$ ). Dynamic power is represented by the ratio between the average of the total capacitance being switched in the execution of the subroutine per clock cycle ( $CL$ ), with the square of the transistor supply voltage ( $V_{dd}$ ) and the frequency at which a clock cycle (provided that there are no bias currents in its core) ( $f$ ). Static power is the ratio between the power dissipated by the transistor in the form of leakage current<sup>4</sup> ( $I_{leak}$ ) and  $V_{dd}$ .

$$P_{tot} = P_{dyn} + P_{stat} = C_L V_{dd}^2 f + I_{leak} V_{dd} \quad (2.1)$$

Taking into account a subroutine whose execution has a time interval  $\Delta t_{sub}$ , it is possible to calculate the energy consumed during an entire execution of this subroutine. During the interval  $\Delta t_{sub}$ , there is a certain number of clock cycles, ie the execution time value is the total number of cycles ( $N_{tick}$ ) divided by the duration of each cycle ( $f$ ), in the form  $N_{tick} f$ . If we take into account that  $CL$  is the average total capacitance per cycle, the total capacitance switched during the execution of a subroutine ( $C_{tot}$ ) is the value of  $CL$  times the total number of  $N_{tick}$  cycles. That said, it is possible to obtain the equation that determines the energy consumed ( $E_{tot}$ ) through Equation 2.1, according, in the form of  $P_{tot}$  times the time interval  $\Delta t_{sub}$  (SINHA; CHANDRAKASAN, 2000). Taking into account a subroutine whose execution has a time interval  $\Delta t_{sub}$ , it is possible to calculate the energy consumed during an entire execution of this subroutine. During the interval  $\Delta t_{sub}$ , there is a certain number of clock cycles, ie the execution time value is the total number of cycles ( $N_{tick}$ ) divided by the duration of each cycle ( $f$ ), in the

form  $N_{\text{tick}} f$ . If we take into account that  $CL$  is the average total capacitance per cycle, the total capacitance switched during the execution of a subroutine ( $C_{\text{tot}}$ ) is the value of  $CL$  times the total number of  $N_{\text{tick}}$  cycles. That said, it is possible to obtain the equation that determines the energy consumed ( $E_{\text{tot}}$ ) through Equation 2.1, according to Equation 2.2, in the form of  $P_{\text{tot}}$  times the time interval  $\Delta t_{\text{sub}}$  (SINHA; CHANDRAKASAN, 2000). An example that can be given is: the processing unit makes a request for data collected by the sensing subsystem, the data converted by the ADC is transmitted to the processing subsystem, the processor sets the data in the format of the network message protocol by the processor, the message is then encapsulated in the protocol format, to be then forwarded to the communication subsystem via SPI. The total switched capacitance, for all transistors that participated in the execution of all these actions is  $C_{\text{tot}}$  and the total elapsed time of the operation is  $\Delta t_{\text{sub}}$ . Figure 3.3 is used to show a temporal diagram that presents all the tasks executed and their respective execution times of the example cited in each subsystem, in addition to pointing out the total execution time  $\Delta t_{\text{sub}}$ .



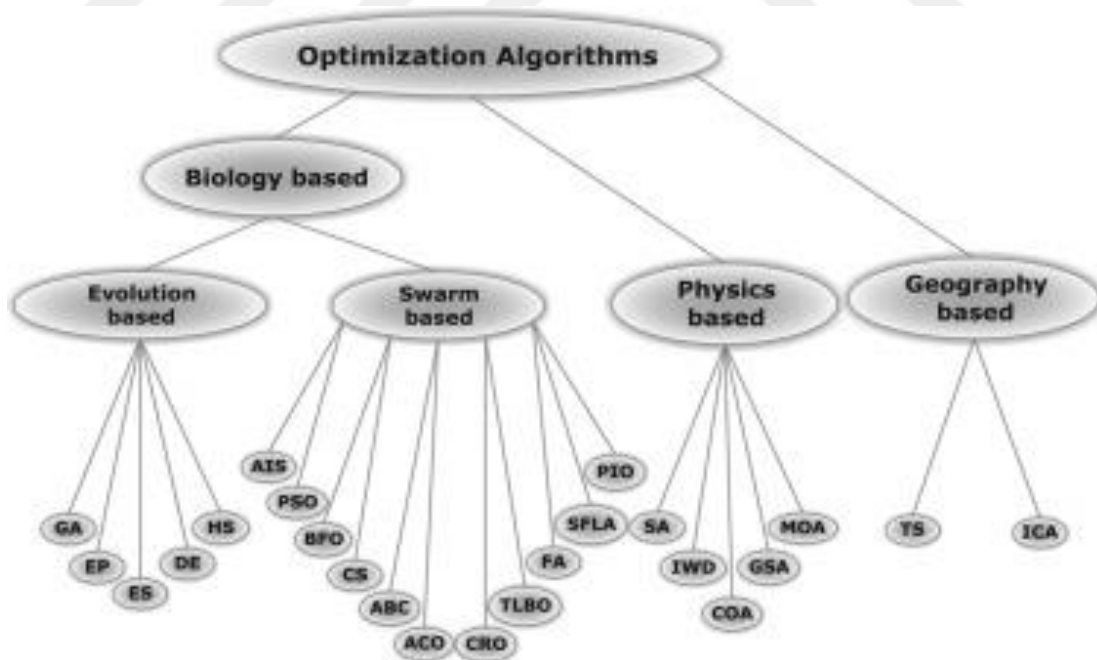
**Figure 3.3:** Energy Consumption in WSN

### 3.2 OPTIMIZATION ALGORITHMS

The optimization issues that emerge in practice are frequently too complicated to be solved analytically. The dimensions of the issue, the number of variables & constraints, and the existence of non-linear functions in the functions  $f$ ,  $g_i$ ,  $h_j$  influence the complexity of the problem. Only a few variables and very basic functions allow for an analytical solution, and even then, only in the examples and exercises provided in the literature and on the chalkboard. You'll need a calculating program that uses the current approximation of the answer ( $x_k$ ) as the basis for the next iteration ( $x_{k+1}$ ) to solve the optimization issue. This is known as the "iterative method," and it's often used to solve optimization problems. A sequence  $x_k$  is therefore determined with an initial approximations  $x_0$ . At this point, however, it is necessary to highlight an intrinsic limitation of the optimization algorithms, which consists in the fact that, due to the way they are constructed, they are able to determine only points which, for a given problem,

satisfy the necessary conditions of optimality. A: that is, only points of the set  $\Omega$  introduced in §7.1. If we denote by  $X$  the set of local solutions of the problem, it is evidently  $X \subseteq \Omega \subseteq F$ . The performance of an algorithm must therefore be evaluated in relation to its ability to determine points of  $\Omega$ , which, in this context, is called the target set, rather than in relation to the ability to determine points of  $X$ . By convergence of the algorithm, we mean precisely its ability to center, with the sequence  $\{x_k\}$  it generates, the target set  $\Omega$ . The algorithm is said to be convergent if it provides a point of  $\Omega$  after a finite number of iterations, or at least, at the limit, for  $k \rightarrow \infty$ . In the first case we speak of finite convergence, in the second of asymptotic convergence. Finite convergence is achieved only for particular problems and specific algorithms for these; for example, the simplex algorithm for Linear Programming has finite convergence. The algorithms for Nonlinear Programming generally have asymptotic convergence. Obviously, for an algorithm with asymptotic convergence, it will not be possible in practice to perform an infinite number of iterations, and it is therefore necessary to provide a stopping criterion, i.e., a rule that interrupts the execution of the algorithm after a finite number of iterations. The stopping criterion is usually based on recognizing that you have found, if not a point of  $\Omega$ , at least a good approximation of it. For example, for Problem, we know that  $\Omega = \{\omega \in \mathbb{R}^n: \nabla f(\omega) = 0\}$ ; therefore, given a sufficiently small  $\epsilon$ , one can think of stopping the algorithm at the first value of  $k$  for which  $\|\nabla f(x_k)\| < \epsilon$  results. , depending on the behavior of the sequence  $\{x_k\}$  for  $k \rightarrow \infty$ . A first case occurs if the entire sequence is convergent to a point  $\omega \in \Omega$ ; that is, if  $\lim_{k \rightarrow \infty} x_k = \omega \in \Omega$ . Such behavior, although desirable, is not always achievable. A second case occurs when the sequence  $\{x_k\}$  has at least one limit point (or accumulation point)  $\omega \in \Omega$ , and that is when it is possible to extract from the sequence at least one subsequence (also called extracted sequence)  $x_{k_j}, j = 1, 2, \dots$ , which is convergent to a point  $\omega \in \Omega$ . Since if a sequence converges to a point  $\omega \in \Omega$  also all its subsequences must converge at the same point  $\omega$ , it is evident that in the first case the algorithm must satisfy much more stringent requirements than in the second. However, in practice, even the second behavior is more than satisfactory; in fact, taking into account what has been said about the stopping criterion, we have that, if  $\{x_k\}$  has at least one limit point in  $\Omega$ , it is always possible to find, for  $k$  sufficiently large, a point  $x_k$  that approximates a point of  $\Omega$  with the desired accuracy. Obviously, the sequence  $\{x_k\}$  can then have more than one limit point, both in  $\Omega$  and outside  $\Omega$ . to solve not a particular problem, such as Problem, but

a whole class of problems: for example an unconstrained optimization algorithm must be able to apply to all problems, whatever the function  $f(x)$  continuously differentiable; and the properties of convergence and speed of convergence of the algorithm must hold for the whole class. The algorithms Alg1, Alg2, Alg3 have been introduced purely by way of example with reference to Problem, but none of them can be considered an optimization algorithm: in fact none of them is able to solve the problem  $\min_{x \in \mathbb{R}} (x - 1)^2$ , which is evidently of the same type as Problem. We also note that, from a practical point of view, analytical considerations on the speed of convergence are not sufficient to establish that one algorithm performs better than another, as they only take into account the number of iterations, and not how much each iteration is computationally expensive. As we will see below, in general the single iteration of an algorithm with linear speed requires much simpler calculations than those required by an algorithm with quadratic speed. In practice, therefore, a convenient compromise must be sought, between the need not to carry out too many iterations, and that of having iterations that are not too onerous.



**Figure 3.4:** Types of Optimization Algorithms

### 3.2.1 Metaheuristic Clustering

It has expanded dramatically in the previous two decades. This pattern is seen in several media and data sources, such as social media and online transactions, network sensors, satellite data, and astronomical data. A growing data volume makes decision-making more challenging. The statistical method allows for more exact data analysis and conclusions. As a result, cutting-edge data processing techniques and tools are required. We'll start by examining some common data analysis tasks and jargon. Then we'll go more into the clustering problem and the possible solutions. The last section summarizes the various clustering techniques and their uses. This approach identifies and extracts important knowledge (information) from data. It is also known as database knowledge discovery (KDD). The term "useful information" varies depending on the end user's expectations. KDD is used in marketing, finance, security, telecommunications, and engineering. Keep in mind the following KDD stages:

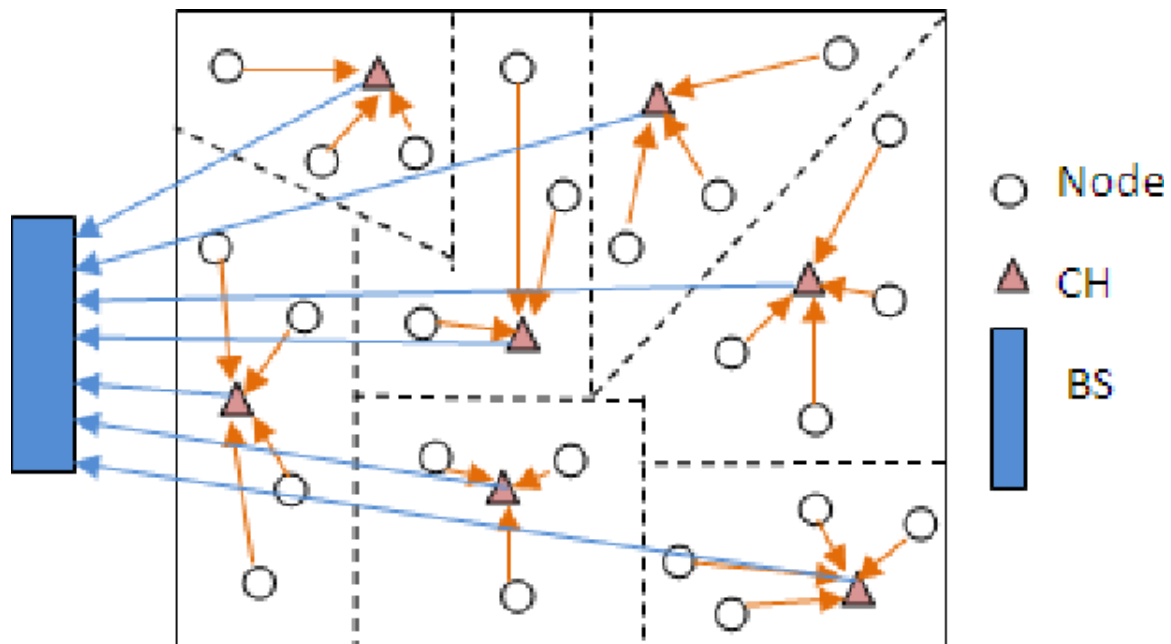
- a. data collection and selection;
- b. Pre-processing includes purifying and preparing data, as well as:
- c. data transformation
- d. data mining is a subset of data mining;
- e. understanding based on prior knowledge

This technique's key components are data analysis and information presentation. Data mining is a computational process for identifying and extracting information (knowledge) from large data sets. After all, it's part of the KDD process. The terms "data mining" and "knowledge discovery" are sometimes used interchangeably (KDD). While KDD uses data mining to extract previously unknown information from data, it is seen as a technique rather than a method (algorithm). Data mining is used to safeguard internet websites, retrieve information, examine biological pictures, and assess signals. Data mining includes several steps, such as:

- a. Classification by a qualified person
- b. Corporate laws
- c. Finding and obtaining desired properties
- d. to run a regression

e. human grouping

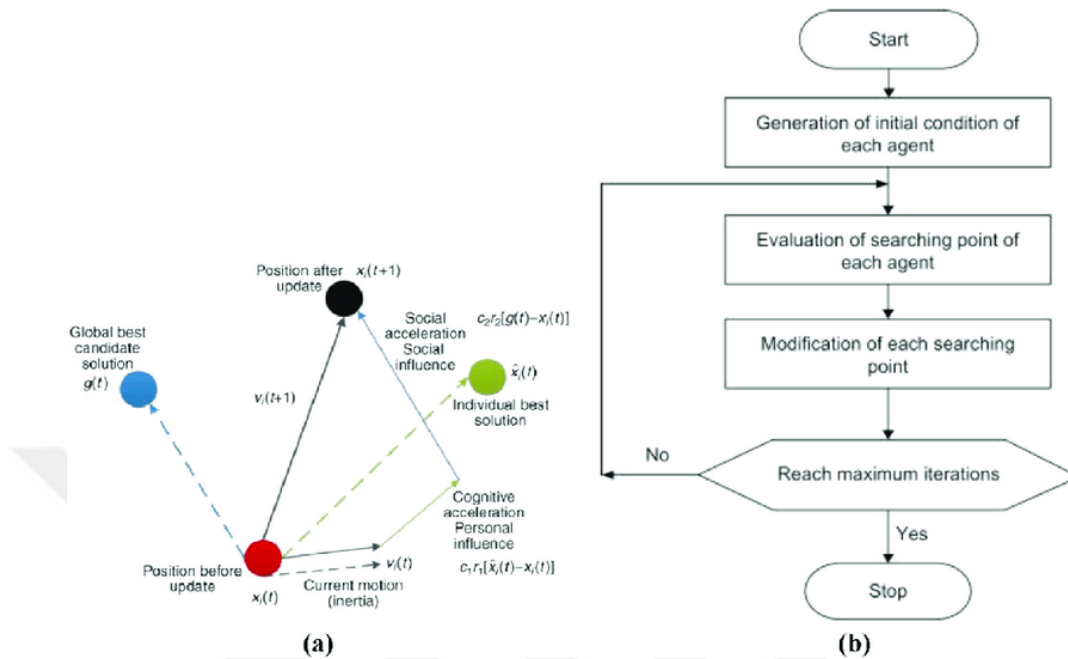
Provides statistics on the quantity collected, the attributes collected, and the number of groups or classes generated. For text data, you may call each document "a bag of words." The order of the words is unimportant since they are used as features rather than sentences in this case. Data categorization with a human observer is called "supervised data classification" or "supervised learning." This is achieved by integrating class-defined objects in the training and learning process (labels). Aside from the aforementioned components, the training program includes: The supervised data classification approach is used to categorize new items in a test set into one or more of these groups. Association analysis identifies common patterns, connections, links, and causal structures in a data set. I work at a rule mine. Using association rule mining, we can uncover rules that predict the existence of a specific item in a transaction based on the presence of other things in the transaction. Feature selection is the process of selecting the most important, useable, and relevant data attributes for data clustering and supervised classification. To keep the discourse concise, feature selection algorithms seek for qualities that are both informative and discriminative or predictive. Feature extraction or combination alters the original features to discover a smaller collection of new features with greater data quality. Techniques like clustering and supervised data classification benefit from both feature selection and extraction, say the authors. Regression analysis is a statistical method for predicting the relationship between a dependent variable and one or more independent variables (predictors). Other regression models exist than linear and logistic regressions.



**Figure 3.5:** MetaHeuristic based Clustering Techniques in WSN

### 3.2.2 PSO Algorithms

James Kennedy & Russell Eberhart initially presented Particle Swarm (PSO) in 1995 as a newer computational learning approach. It resembles evolutionary computation in certain respects. For any multidimensional (often nonlinear) function, PSO seeks to identify the global optimum. Many issues can be solved using this approach. A swarm with particles may be imagined as traversing problem space in PSO (points in space). The goal is to bring the particles together in a way similar to how a group of geese converges on a certain location. The initial distribution of the particles in the problem space is random and they are given a velocity. During flight, each particle retains a record of the best place (and related suitability) it has met thus far, as well as its current location as well as appropriateness. This stochastic movement toward the optimal location for one particle as well as the best position for another particle in the vicinity occurs over time. The neighborhood of a particle is the group of particles with whom it has direct contact in the swarm. It is called sociometry, or swarm topology, because of the interconnectedness of all the particles in the system.



**Figure 3.6:** PSO algorithm: (a) Main phases of PSO, and (b) The general diagram of PSO search method

### Principle of PSO

- It has agents with limited perception, memorization and calculation capacities.
- It is dynamic induced by local interactions.
- Observation of “emerging” global behaviors.
- A population of agents (here particles).
- Cooperation rather than competition.
- Efficient on a continuous search space.
- Dynamics defined on a discrete space time.

PSO is effective in a variety of areas:

- Regulation of electrical systems.
- Design of aircraft wings.
- Image analysis.

We assume all the particles arranged (symbolically) in a circle and, for the particle studied, we gradually include in its informants, first itself, the nearest wells to its right and to its left, so as to reach the total required. There are, of course, many variations, including choosing informants at random. But this one is both simple and effective.

Once the best informant is detected, the change in velocity is a simple linear combination of three trends. Using confidence coefficients:

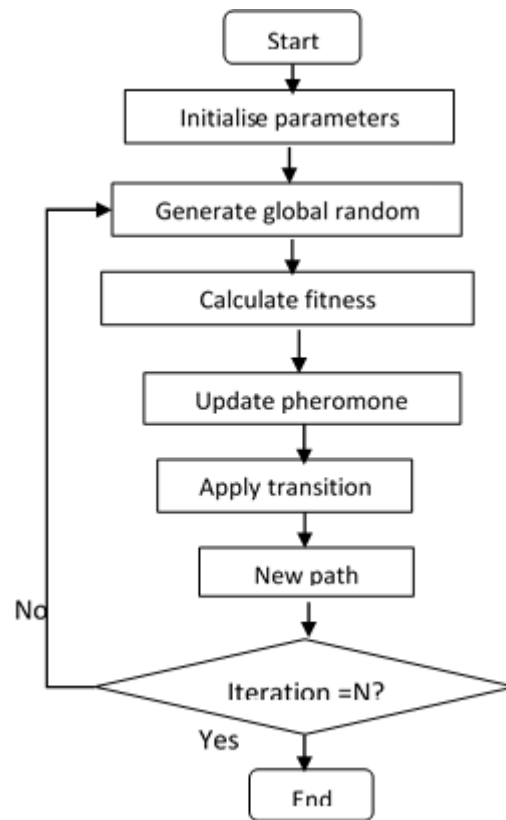
- a. The “adventurous” tendency, consisting in continuing according to the current speed.
- b. The “conservative” tendency, bringing more or less towards the best position already found.
- c. The “panurgism” tendency, orienting approximately towards the best informant.

### **3.2.3 ACO Algorithm**

Pheromones, chemical agents that ant colonies use to communicate, have been shown to have a major role in their behavior. Some pheromones are deposited just on ground, among the many sorts of these scents. Ants travel a course indicated by such pheromones from a food source to a nest, for example, with random variations or according to the ant's perception and reaction to its surroundings. These pheromones are likewise prone to depletion and degradation. As they fade away, new routes might be discovered, or old ones can be retraced. Ants employ these pheromones to discover the quickest way to a food source, and so solve an optimization issue, according to biological investigations and theoretical conclusions. New resolution algorithms may be developed by studying ant behavior. Ant Colony Optimization is a metaheuristic for discrete optimization problems that was developed from the original method. A full and up-to-date evaluation of ACO is presented here.

Modeling is based on preset variables and open domains in a broad context of the setup. These challenges consequently lie beyond the scope of a ACO definition, nor could they be handled using a conventional CSP technique. Since a solution's components aren't constrained, an a priori construction graph can't be shown. This graph may be used to identify a commonality: the component connection graph. As a result, we've established a key tenet of our strategy. It's

possible to see a configuration's structure as a graph. The vertices and edges of this structural graph depict the components as well as the connections that link them together. A graph is also produced by superimposing all prior efforts at a random-restart algorithm's graphs of structures. For an artificial ant, the choosing of a component (existing) as a port is represented by pheromones being deposited on arcs. If it is decided to dynamically build a new target again for port, an ant may not only follow one or even more arcs, but it can also establish new arcs to components at a particular vertex of this graph. The cardinality of a port decides the amount of arcs (i.e. the destinations of a port) that an ant follows or creates. Classify it and provide a numerical value to each of its characteristics. These choices may be represented mathematically by instantiation of standard CSP variables, as we have shown. Vertices attached to the component's top may be used to add types and attributes to the building graph. Similar to that presented by, this final depiction provides a uniform perspective on the building of a solution. As a result, throughout the search, the ACO building graph for the configuration is dynamically formed by overlaying every previously produced instance. As pheromones and heuristics lead them along this network, ant-like robots may assemble possible solutions. Setting up variables to be used later Each choice an ant makes in ACO is linked to a specific variable on a specific domain. Variables that closed domains may likewise be configured using this concept (CSP or set). Certain variables (ports & their cardinalities, for example) may be configured to have a wide range of values. The simu-finite sets are a novel approach for dealing with the related probabilistic decision. A simul-finite set has a fixed number of realm values, as well as a developing value (or payoff spot) that represents all of the additional values that might exist in the domain. Each time the ant selects a wild card value, the set grows (i.e., the following ACO iteration gets a boost). The concept of employing wild cards in the first place is widely accepted.



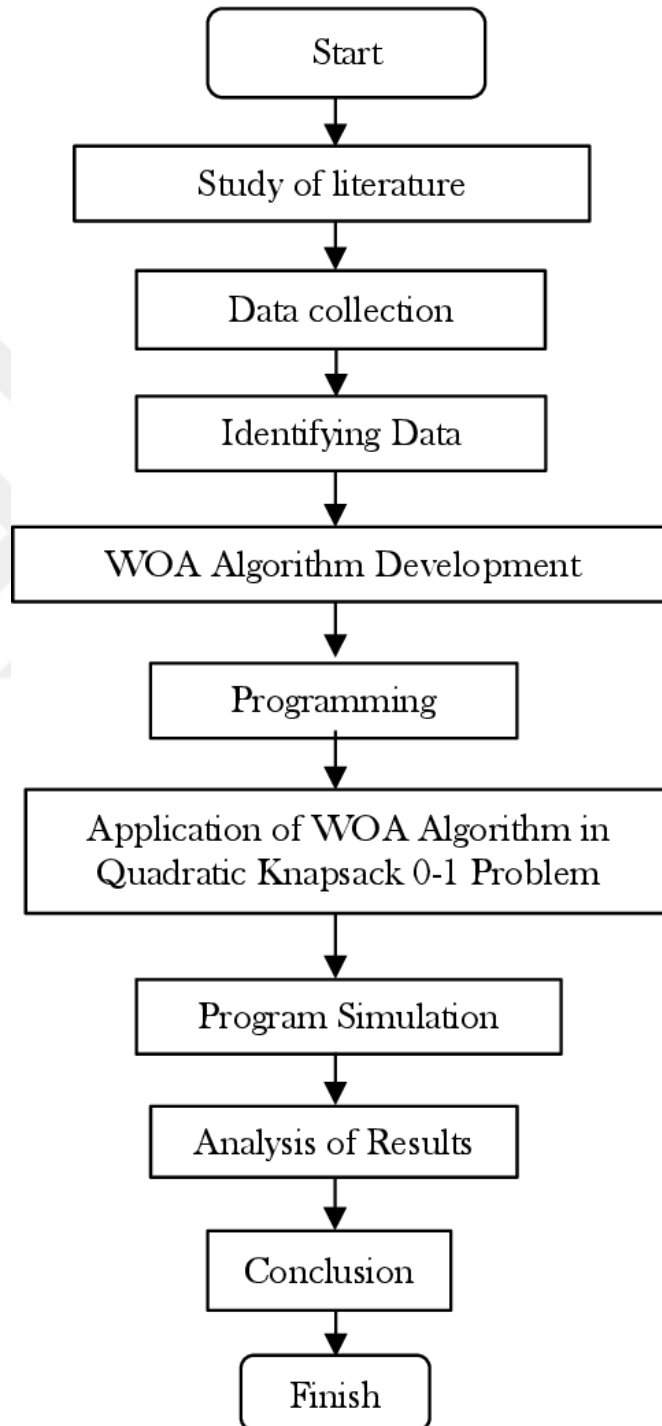
**Figure 3.7:** Flowchart for The Ant Colony Optimization Algorithm

### 3.2.4 WOA Algorithm

The developed with the objective of determining the parameters that generate the minimum or maximum value of a given function, that is, to determine the value of the optimization variables that generate the minimum or maximum value for the objective function of the problem. In general, optimization algorithms can be classified into two main categories: (a) function gradient-based optimization algorithms and (b) heuristic optimization algorithms. Gradient-based optimization algorithms are algorithms that use information related to the derivatives of the analyzed function to determine the behavior of the function. These characteristics make the gradient-based optimization method complicated to apply in complex functions, often nonlinear, with many local minima, discontinuous or defined by mixed variables (discrete and continuous). As the modeling of the application of friction dampers in dynamic systems results in generally non-convex functions with discrete and continuous input variables, this method does not

represent a good approach to the problem proposed in this work. Heuristic optimization algorithms are algorithms based essentially on the trial and error method and on the intention of traversing the entire domain of possibilities for a given problem. However, more modern algorithms, such as meta-heuristics, are usually considered to be of a higher level when compared to heuristic algorithms because they are not simply based on trial and error, but also because they are built in a way that learns from previous solutions, for select the best solutions and have sophisticated search engines. Within the category of meta-heuristic optimization algorithms there are already popularly known and widely used algorithms. However, new optimization algorithms are developed regularly, introducing new features and concepts that seek methods with higher performance. In this context, meta-heuristic algorithms that have been recently developed were researched in order to use an algorithm with the most up-to-date methods. Thus, the chosen algorithm was the WOA (Whale Optimization Algorithm) developed. WOA, according to Mirjalili and Lewis is an optimization algorithm that replicates the social behavior of humpback whales, in particular the hunting method used by this species based on the generation of a curtain of bubbles that concentrates the group of prey nearby. To the surface, facilitating the final attack. The whale species is known for its collective hunting habit of schools of small fish, and the hunting process can be divided into three stages: (1) the exploration or search for prey phase, (2) the approach phase whales to the region where a shoal is found and (3) the prey restriction and attack phase. For the implementation of the algorithm, the phases were changed in order to better cover the domain of solutions. The algorithm starts by composing a group of agents, representing the initially random values for the optimization variables, and the variable that generates the lowest value for the objective function is considered the prey. Thus, the other agents have their values altered to approach the agent that produced the lowest objective function result, this is the phase of approaching the whales. The second phase also represents an approximation of the other agents towards the agent that generated the lowest value for the objective function, but the approximation is performed in order to traverse the domain in a spiral movement, this is the phase of restriction to prey and attack. . The last phase is the random search phase, where an agent is forced to move away in order to add variability to the search for the optimal configuration, this is the exploration or prey

search phase. As the algorithm is executed successively, it is expected that the search agents will focus closer and closer to the minimum value of the objective function.



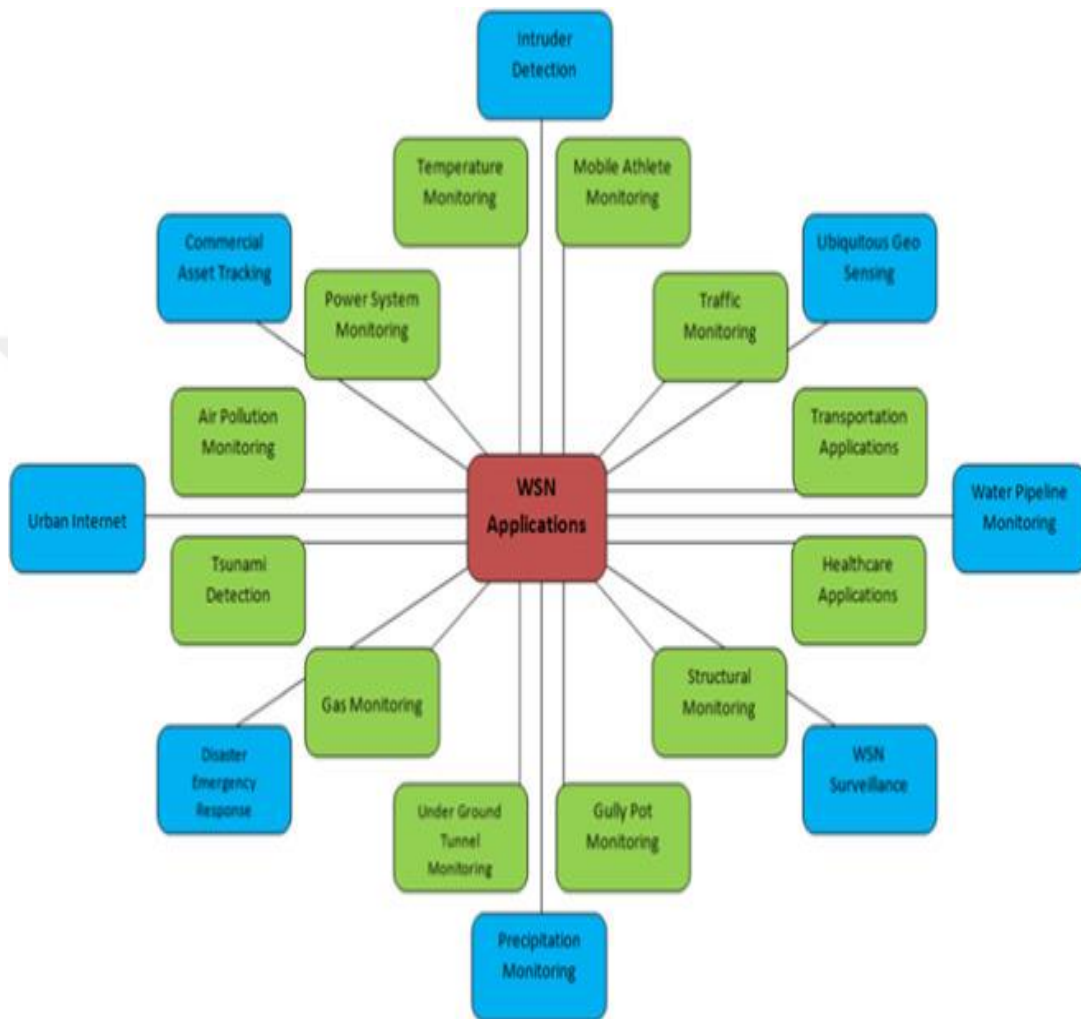
**Figure 3.8:** Application of Whale Optimization Algorithm

### 3.3 WSN CLUSTERING

Fs are data centric as WSNs as distribution data should not be defined as application level, so they will only be relayed, aggregated with other data and data as data and data as data or just implemented. presents the differences between the traditional routing process and a routing (spreading) with data aggregation. we identified sensors A, B and C sending data to the sink sensor S. data, only 6 messages changed. The first sensor highlighted messages A and B in ab. Then, the second highlighted sensor aggregates message ab with message c, generating a single message ABC. In addition to reducing network traffic, the data aggregation process provides energy savings for WSN. References highlight that sensor networks can consist of several types of sensors in order to monitor numerous phenomena, such as:

- a. **Military Applications** – The ease with which sensor networks can be constituted, added the characteristics of self-organization, coordination and fault tolerance make sensor networks suitable for military use. Sensors can be dropped from aircraft onto battlefields, making it possible to identify and/or monitor the actions of friendly or enemy troops. As sensor networks are typically densely populated, the destruction of some sensors by enemy actions, loss of energy, etc, will not possibly imply a loss of connectivity.
- b. **Environmental Applications** – Monitoring the migratory process of birds, insects or small animals can be carried out through sensor networks. In addition, millions of sensors arranged in a forest allow the identification of floods and the exact identification of the origin of fires (natural or criminal) and of fires before the fire can get out of control, events that can cause countless damages to the population and the community. Nature. The use of pesticides above the permitted limit or the presence of harmful insects to the culture of a particular crop are events that can be monitored through WSNs.
- c. **Medical Applications** – Vital organs of living beings can be monitored by introducing sensors into organisms, identifying the presence of a specific substance or the emergence of a biological problem.
- d. **Miscellaneous Applications** – In industrial production, WSNs can be used to control important metrics, such as flow, pressure, temperature, humidity, level, enabling the

identification of leakage, heating, etc. These metrics are essentially useful for suppliers and distributors of water, gas, electricity, etc.



**Figure 3.9:** application of wireless sensor network

## **4. PROPOSED METHOD**

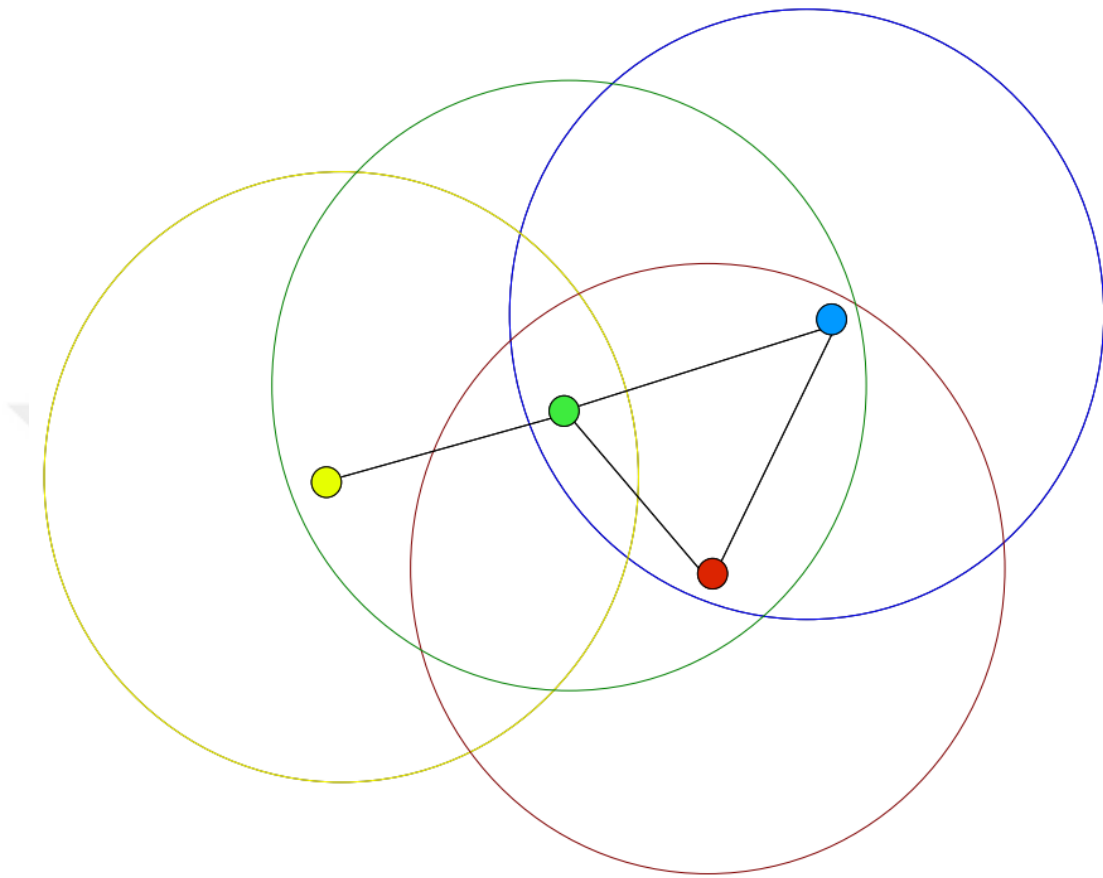
### **4.1 CHAPTER OVERVIEW**

The next section summarizes our suggested distributed clustering technique, which is based on the biological principles behind the honeybee nest site selection process. This method, which is implemented locally by each sensor, enables the network to display features of self-organization and self-adaptation. In the case of WSNs, a large one has emerged in which numerous solutions may be devised, both in terms of protocol and energy and time consumption. There are several ways that may be used to address network design and protocol dependability concerns. The management of residual energy in networks of independent nodes and, above all, its distribution through election leader techniques does not find much literature. The problem has already been addressed in other articles and solved quite simply. we propose as a solution to uniformly unload the network while the fact that, in a given configuration, the root is the node that consumes the most leaves unload less. Under this hypothesis they assign the root role to each sensor in a random way.

### **4.2 LEACH MULTI-HOP PROTOCOL**

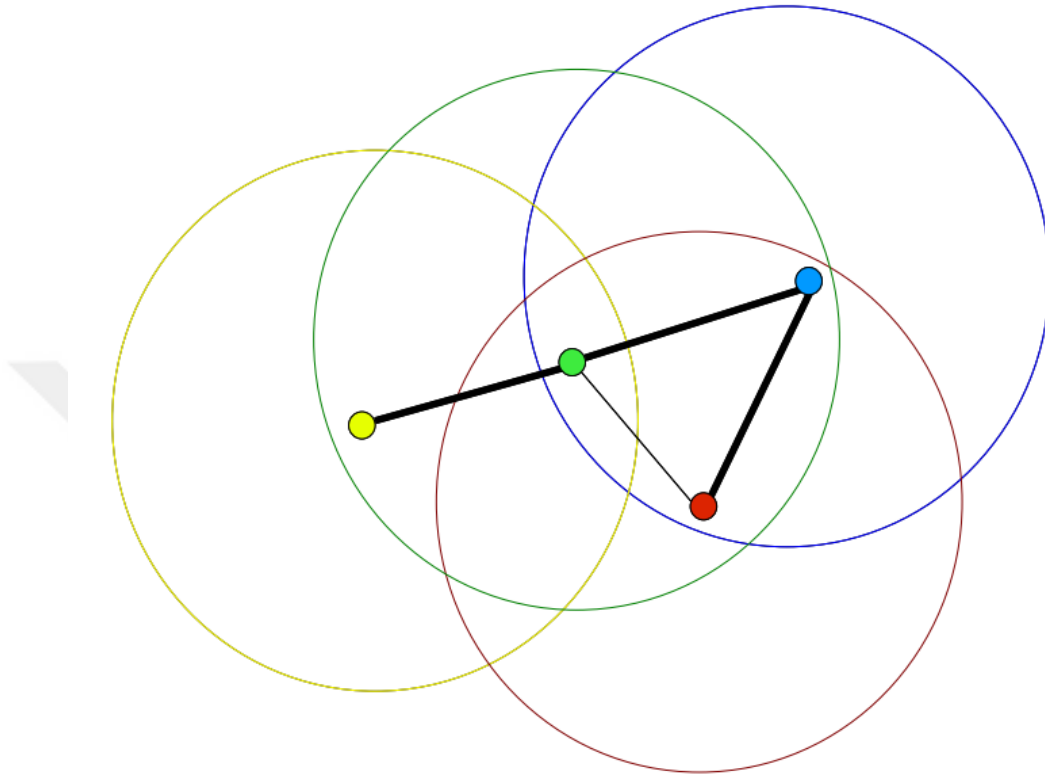
A fundamental aspect of multi-hop networks is that unlike star types, the nodes use the other nodes to get the data to the root, thus increasing the range of the network. To do this it is necessary that each sensor identifies a "path" through the other sensors that leads to the root. This task is carried out precisely by the routing algorithm. Since the choices at each hop can be multiple, a link cost function must be set. The chosen algorithm will try to identify the path that leads to the root, minimizing the total cost of the path. As a cost function, we have chosen to minimize the energy consumption of the network, which has the direct consequence of limiting the power used in communication by the transmitters. However, by decreasing the power of the transmitters, the communication cells of the devices decrease their diameter causing an increase in the number of hops necessary to get the data to the root. As for the arrangement of the wireless sensors, we have assumed to be able to place them on a planar space of given dimensions, placing them inside it in randomly chosen positions satisfying the only constraint that each

sensor is able to communicate with at least one other sensor. This hypothesis, which coincides with what happens in reality, allows us to obtain graphs that are always connected. To check if the  $i$  - th sensor is able to communicate with at least one other sensor we have defined a single communication range assuming that all the sensors under examination are identical. The communication range corresponds to the maximum distance a sensor can transmit / receive using the maximum transmission power. With this beam, assuming that the sensor is able to communicate in an omnidirectional manner, the relative circular communication area has been constructed as shown in the figure 4.1. A graph of the connectivity between the various nodes is thus created. The most convenient way to handle this graph is to use a node-node adjacency matrix. Taking into account the possibility of the sensors to communicate on both sides, that is, if the two see each other, one can think that the first can transmit and the second receive or vice versa. The result obtained is that the adjacency matrix is symmetric by construction.



**Figure 4.1:** Initial WSN clustering

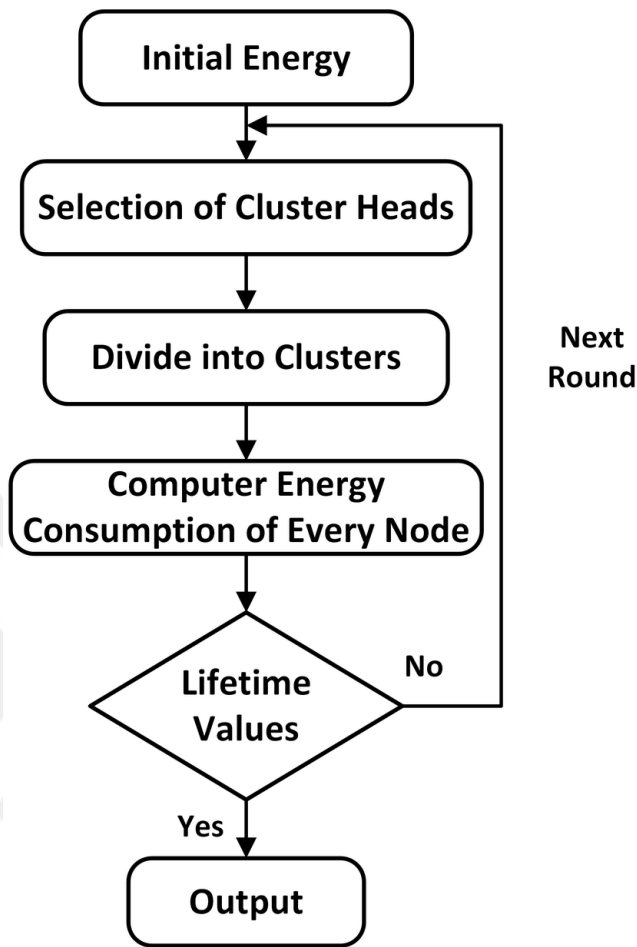
When a sensor examines itself, it fills its diagonal with one. This leads in confusion when selecting which route to follow at the end of the tree is the best choice in the case of a tree of packets created at node I. To produce adjacency matrices, we've chosen to set these entries to zero on the diagonal. The construction of a tree may begin immediately by selecting a parent and child for each vertex in accordance with a defined rule, but always bearing in mind the adjacency matrix's intrinsic constraints. The matrices in the figure 4.2 reflect the adjacencies of a hypothetical tree:



**Figure 4.2:** Path finding in WSN clustering

### **4.3 PROPOSED MODIFICATION**

According to Garnier et al. [73], social insect collective behaviors are classified into four categories: coordination, cooperation, deliberation, and collaboration. Our method incorporates all four of these functions. The selection of CHs satisfies the coordination, cooperation, and deliberation functions, whereas the scheduling of network connections satisfies the collaborative function. The suggested approach is based on the same core notions as previously proposed distributed clustering algorithms for WSNs, such as those now in use:



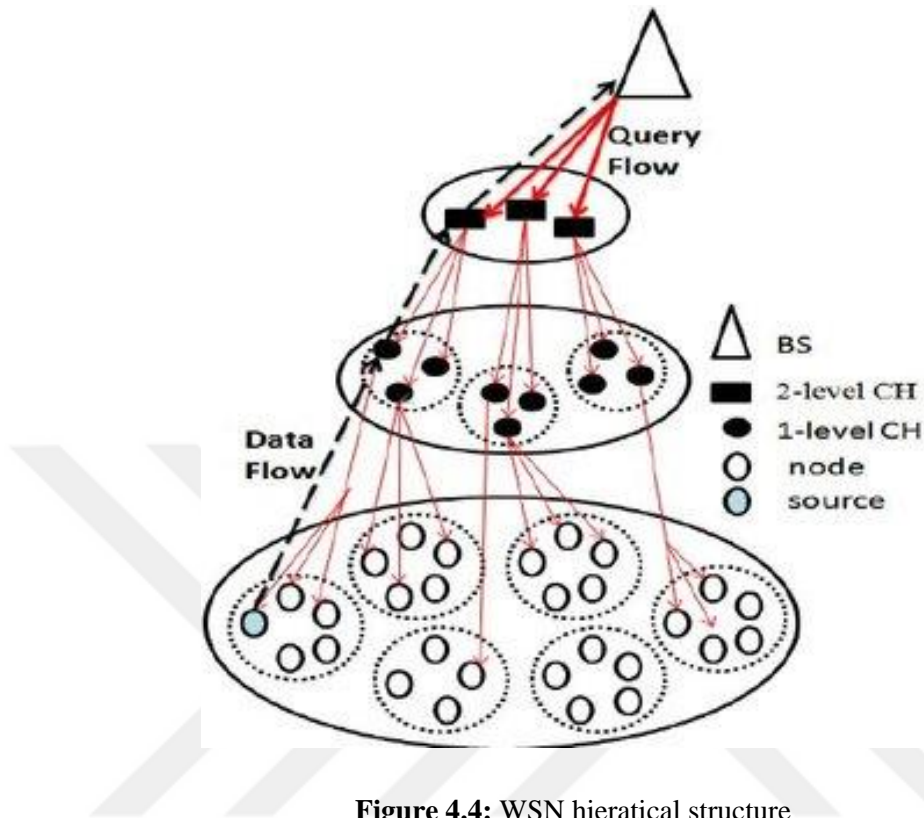
**Figure 4.3:** Clustering scheme diagram

Sensors engage in competitive bidding to become CHs, with other sensors picking the best candidates based on the bids received from other senses. On the other hand, our strategy introduces a significant innovation in the way normal nodes choose the best CHs. Honeybees do cluster in a temporary spot during the PSO nest-site selection process to see waggle dances done by scout bees in search of potential nest places. Clusters are established and cannot be updated over the network's lifespan when a node competition is held and a CH is picked. Finally, a new CH is chosen when a CH dies as a result of the cluster. This is where our suggested approach with its distinctive twist comes into play. When a CH's energy level drops below the threshold, it alerts its CH f and begins the process of choosing a new CH within the cluster.

**Table 4.1:** CH system parameters

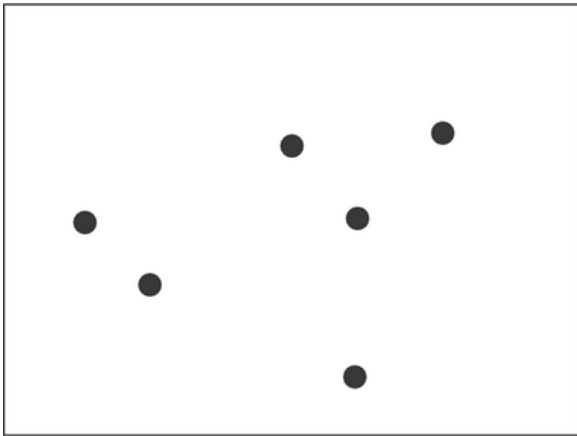
| <b>Parameter</b>                            | <b>Value</b>                                |
|---|---|
| Square ( $m^2$ )                            | $500 \times 500$                            |
| <i>BS</i> location                          | (250, 575)                                  |
| Number of sensor nodes                      | 100   |
| Initial Energy (J)                          | 40 (80% of sensors)<br>100 (20% of sensors) |
| Number of iterations                        | 5000  |
| $E_{elec}$ (nJ/bit)                         | 50  |
| $\epsilon_{fs}$ (pJ/(bit.m <sup>-2</sup> )) | 10  |
| $\epsilon_{mp}$ (pJ/(bit.m <sup>-4</sup> )) | 0.0013                                      |
| $d_0$ (m)                                   | 87  |
| $E_{agg}$ (nJ/bit)                          | 5   |
| $E_{sen}$                                   | 0   |
| Packet size (Kbit)                          | 512   |
| Message size (kbit)                         | 2   |
| Bandwidth of channel (Kbit/s)               | 250   |

When LEACH, HEED, or another distributed clustering technique is used, CH elections cannot begin until the CH energy level falls below a threshold value  $l$ . (see Figure 1). As a consequence, the proposal's overall quality is increased by one notch.

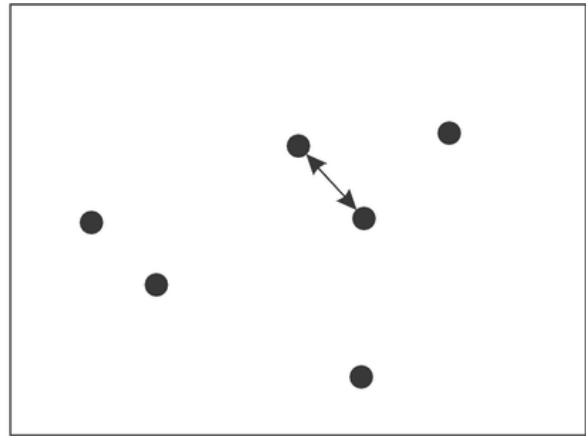


**Figure 4.4:** WSN hieratical structure

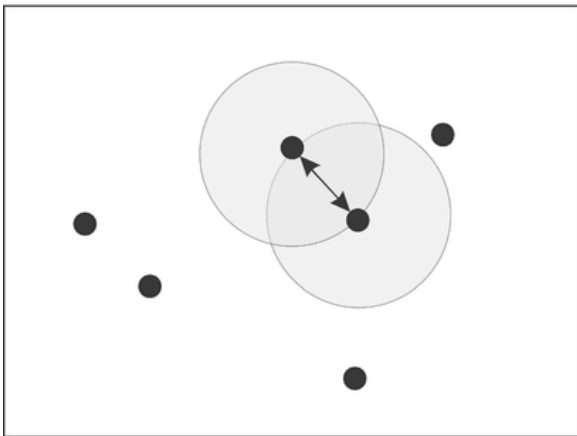
While a sensor meets a set of characteristics and is uniformly distributed according to the discrete uniform probability distribution, the suggested clustering technique takes this aspect into consideration when designing its design. The quality of each sensor is determined using the cost function established at the start of  $s_1$ . When the sensor's quality exceeds the threshold  $t$ , it is identified as a CH  $c$  and broadcasts a CH $c$  MSG to alert the user of the change in status. After the setup step is complete and all of CH  $c$  is known, it will be feasible to begin the election process. If a sensor gets just one candidate for CH status, the sensor will send the candidate a CH FOLLOW message.



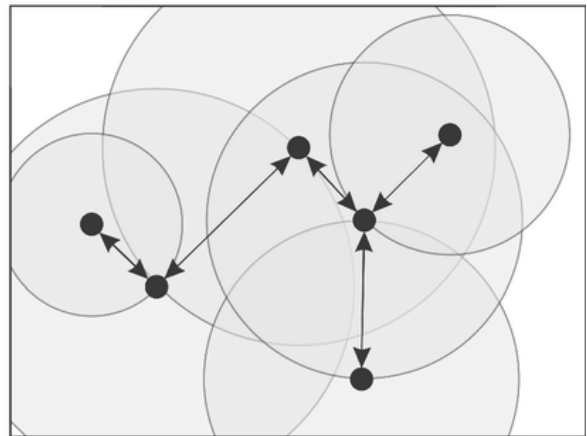
**(a)** Given a set of nodes located in the Euclidean plane



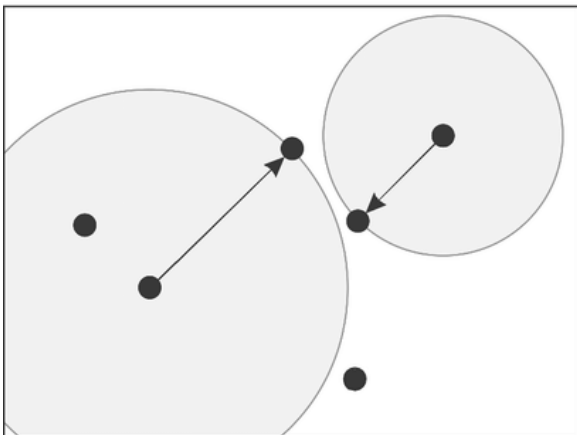
**(b)** Select the edge with minimum greedy cost function



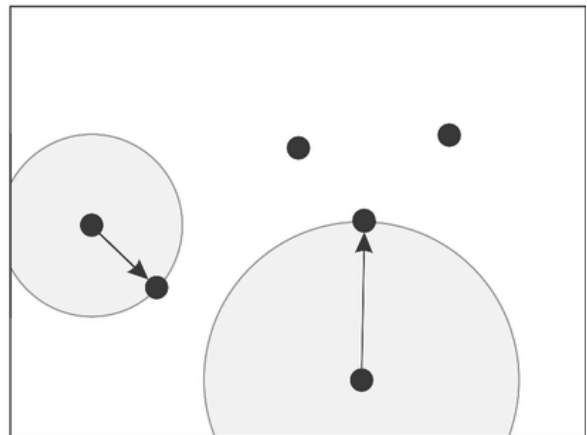
**(c)** Update transmission power



**(d)** The final connected communication graph solution used as scheduling input



**(e)** interference-free time slot  $s^1$



**(f)** interference-free time slot  $s^2$

**Figure 4.5:** steps of cluster-based routing in the proposed system from (a) to (f)

### 4.3.1 Cost Function

The fundamental aspect to solve the proposed problem is to find a structure of the solution that allows to perform the choice of the tree using a certain cost function  $C$ . The objective of the cost function is to give the algorithm for calculating the change network a characteristic parameter for each single node that allows the comparison and the choice of the solution with lower consumption. We have tried to construct a function that allows us to have a general view on the degree of goodness of each solution adopted. Before giving a quantitative description of the equations seen for  $C$ , the components that influence the energy consumption of a generic node are identified. A node consumes energy mainly to transmit its information ( $E_c$ ), for the activity of the device ( $E_p$ ) and to carry out the measurements ( $E_s$ ). Generally,  $E_p$  is negligible compared to  $E_c$  and  $E_s$ . Therefore,  $E_c$  is the energy expended by the node to transmit its own generated data  $E_t$  together with the forwarding energy  $E_f$ , i.e. the energy expended to transmit the data of the descending nodes to the father. You could also consider the consumption to transmit all the data collected from the root to an  $E_{ext}$  external unit such as a PC or other external network, but in this case, we will assume it is equivalent to any other transmission. It is clear that a cost function, even if very general, can satisfy a wide range of requests but not all specific cases of real projects. In practice it will be very likely that additions of parameters will be necessary that take into account the particular characteristics of the project, for example the degree of tolerance to interference due to neighboring but not directly connected nodes which lead to a high rate of loss of information. Ultimately, the parameters to build the cost function are:

- a. The maximum battery level for each node  $B$ , possibly normalized to the unit.
- b.  $E_f$  varies during the construction of the tree at minimal cost.
- c. An energy that takes into account the generation of data by the sensor  $E_g = E_s + E_t$  could be considered to evaluate its proximity to the root node. In fact, if a node had many operations to perform and communicate, its proximity to the root is essential to load the smallest possible number of intermediate nodes. However, this parameter is not included in the simulations as it is assumed that each node performs a single measurement without adding other weight to the transmission.

- d. The energy spent in the network change ( $E_r$ ) that is the consumption that each node faces for the management of the transmissions related to the change of the network configuration both in terms of packet transmission and for internal operations such as resetting the transmission power. The general objective of the optimization algorithm is obviously the minimization of the cost.

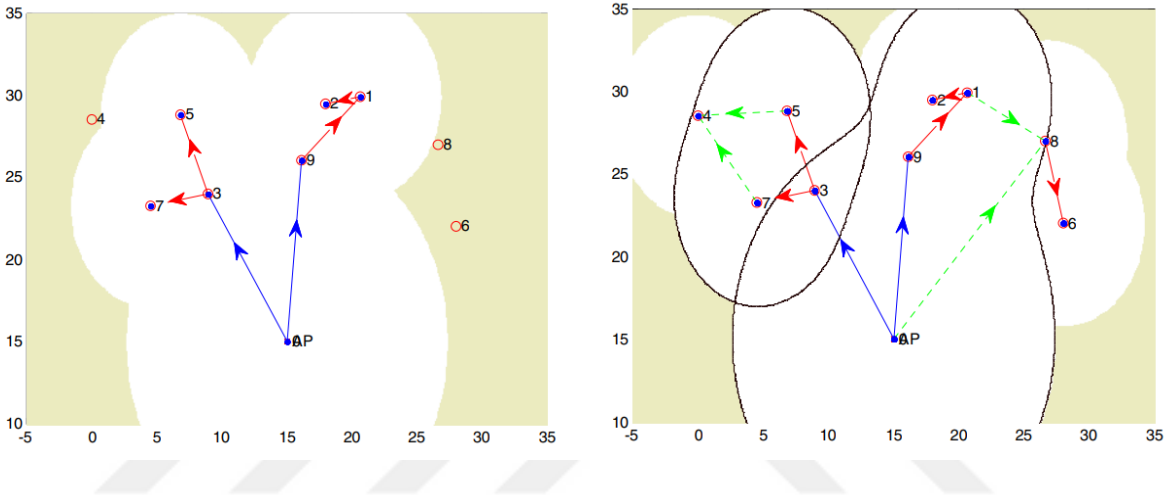
In the first analysis, a simple cost function was used in which it is assumed that the energy spent by a node during the activation of the network is substantially that spent in reception to acquire the measurements of its children, plus the energy used to transmit this data, with the addition of its own, to the parent node.

**Table 4.2:** Simulation parameters

|                 |  |               |
|-----------------|--|---------------|
| Length          | Length of the field Area                   | 100 m         |
| Width           | Width of the field Area                    | 100 m         |
| Num_Nodes       | Total number of nodes                      | 100           |
| bsX             | x coordination of base station             | 50 m          |
| bsY             | y coordination of base station             | 200 m         |
| max_Round       | No. of Max Round                           | 9999          |
| ctrPacketLength | Length of packet that sent for nodes to CH | 200 bits      |
| PacketLength    | Length of packet that sent for CH to BS    | 6400 bits     |
| initEnergy      | Initial energy of each node                | 0.5nJ         |
| transEnergy     | Energy for transferring of each bit (ETX)  | 50 nJ/bit     |
| recEnergy       | Energy for receiving of each bit (ETX)     | 50 nJ/bit     |
| fsEnergy        | Energy of free space model                 | 10e-12 J/bit  |
| mpEnergy        | Energy of multi path model                 | 1.3e-15 J/bit |
| aggrEnergy      | Data aggregation energy                    | 5e-9 J/bit    |

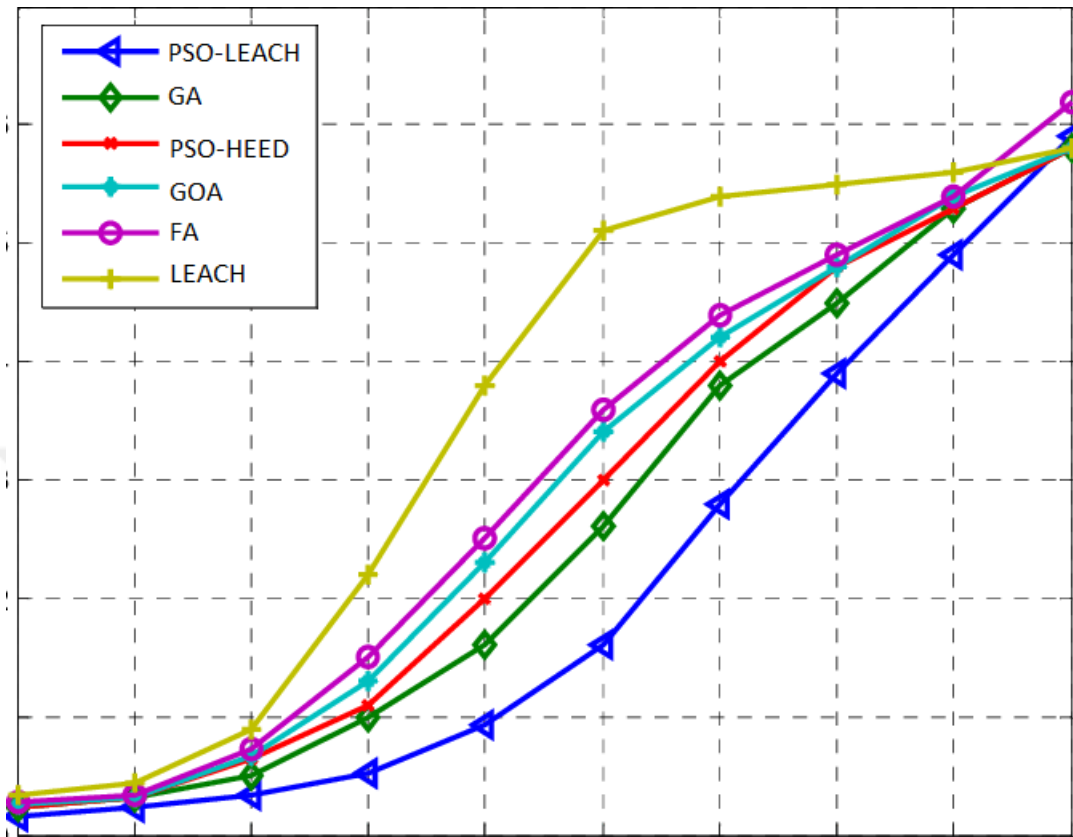
Considering that the energy used to receive one measurement packet is comparable to that expended to send another, this is of course a simplified version of the cost that provides a simple but good model of consumption at the node. In fact, during the life of the sensor, the energy expended is in a much greater proportion to receive and transmit information than for the other

functions of the device. In a first version of the algorithms this relationship has been implemented in order to calculate the residual energy of each node step by step in order to be able to choose the configuration of the tree that leads to having the residual energy in the larger node. u discharge as high as possible by essentially making a one-step prediction for the energies.



**Figure 4.6:** initial clusters and the routes taken

That said, it is possible to obtain the equation that determines the energy consumed ( $E_{tot}$ ) in the form of  $P_{tot}$  times the time interval  $\Delta t_{sub}$ . An example that can be given is: the processing unit makes a request for data collected by the sensing subsystem, the data converted by the ADC is transmitted to the processing subsystem, the processor sets the data in the format of the network message protocol by the processor, the message is then encapsulated in the protocol format, to be then forwarded to the communication subsystem via SPI. The total switched capacitance, for all transistors that participated in the execution of all these actions is  $C_{tot}$  and the total elapsed time of the operation is  $\Delta t_{sub}$ . is used to show a temporal diagram that presents all the tasks executed and their respective execution times of the example cited in each subsystem, in addition to pointing out the total execution time  $\Delta t_{sub}$ .



**Figure 4.7:** the proposed LEACH-PSO compared to the common routing algorithms

## **5. CONCLUSION AND FUTURE WORK**

### **5.1 CONCLUSION**

Over the time of research on the subjects that involve this work, some contributions were achieved in the area of WSN and optimization algorithms. A new routing algorithm was developed for WSN where a PSO is executed to calculate the routes. The main contributions are in the execution of the PSO with a form of coding that generates valid solutions for any topology in WSN meshes. Apart from that, two fitness functions that evaluate the generated solutions according to some of the main WSN performance parameters (distance traveled, energy consumption and packet loss). The contributions achieved in this work also add value to the research project carried out by the Inovathys team, which has been developing solutions in the area of home automation and wireless communication since 2016. It is expected that the results obtained, together with the developed system, will serve as a basis for the expansion and modernization of the solutions provided by the Inovathys team. In the academic field, the research resulted in a publication in the month of May 2019 at the international congress I2MTC that took place in New Zealand of an article entitled: "Evaluation of the Performance of a Wireless Mesh Network built with Sub-GHz Transceivers". The article shows an experimental approach to wireless communications, which deals with physical parameters of a transceiver module, and performance in terms of routing. Publications that report the results obtained from the system proposed in this work are also planned.

### **5.2 FUTUER WORK**

As a suggestion for future work, we can mention the application of the algorithm in a real environment with sensor nodes built for some application and observe how it behaves; another point that can be worked on is the improvement of the algorithm itself, making an analysis of the optimization method used in order to improve its performance. Improving PSO performance can be done by testing new objective functions, adjusting rules in the coding of individuals and applying new parameters for genetic operators: such as the number of generations and individuals and mutation crossover rates. The purpose is to find a balance between the accuracy

of the method and its execution time. For application in a real environment, it is necessary to define some operational characteristics, in addition to the application of the WSN and its purpose. The proposal is to make a real processing unit run the PSO to trace routes of a physical network that collects data of interest within an environment of a WSN.



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