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Mémoire

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Parcours : **Réseaux et Technologies de l'Information et de la Communication (RTIC)**

Titre : Conception d'un protocole de routage hiérarchique efficace en énergie pour les réseaux de capteurs sans fil

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Acknowledgments

First of all, we have to say thanks to **Allah** that I have been and I am good enough physically and mentally to study and reach this place, peace upon our prophet Mohammed. And I wish I will meet my died **mother** in the Jannah “rahimaha Allah w askanah Jannat annaaim”.

I would also like to thank my project supervisor **Dr. Imene Aloui** for guiding, giving the helping hand and being a good listener to me, without her supervising I wouldn’t do that project to the fullest.

Finally, I would like to acknowledge my family and friends who supported me during mytime here at the university. I would like to thank my father **“Lakhder”,** two brothers **“Houssam, Chaker”** and my two sisters **“Imane, Aicha”,** And I want to thank my friends that can’t be only friends, they are my brothers which were my support in the university **“CHADLI Mohammed Isaac and MAAMOULI Abd El Wahab”,** without forgetting my faithful cousin **“ADOUANE Rabie”.**

Sofiane.

ملخص:

منذ العقد الماضي، شهدت أعيننا أدلة على استخدام شبكات الاستشعار اللاسلكية (WSNs) في العديد من المجالات مثل الرعاية الصحية والزراعة والدفاع والجيش والمناطق المنكوبة بالكوارث وما إلى ذلك. تم تجهيز المستشعرات بواجهات لاسلكية يمكنهم من خلالها التواصل مع بعضهم البعض لتشكيل شبكة.

نظرًا لأن المصدر الوحيد للطاقة لعقد المستشعر هو البطارية. من الصعب جدًا إعادة شحن هذه البطارية أو استبدالها، لذا فإن استهلاك الطاقة يعد أمرًا مهمًا للغاية في WSN .

في هذه الأطروحة، نهدف إلى زيادة عمر شبكة WSN من خلال تقليل استهلاك الطاقة للعقد. نختار بروتوكول يسمى SPIN لتحسينه، بروتوكول SPIN له مزايا وعيوب. نقترح بروتوكولًا جديدًا أطلقنا عليه اسم DC-SPIN يحافظ على المزايا ويعمل على العيوب.

الهدف الرئيسي من هذا العمل هو اقتراح بروتوكول هرمي يعتمد على الاستدلال الفوقي. لقد اخترنا الخوارزميات الجينية التي تقدم العديد من المزايا لتحسين أداء بروتوكولات التوجيه. فهي فعالة في إيجاد الطريق الأمثل لاستعادة البيانات.

الكلمات الرئيسية: شبكات الاستشعار اللاسلكية ، DC-SPIN ، الخوارزمية الجينية ، SPIN ، استهلاك الطاقة ، بروتوكولات التوجيه ، البروتوكول الهرمي ، الاستدلال الفوقي..

Abstract

Since last decade, our eye witnessed proofs that Wireless Sensor Networks (WSNs) have been used in many areas like health care, agriculture, defense, military, disaster hit areas and so on. Sensors are equipped with wireless interfaces with which they can communicate with one another to form a network.

We can see that the only source of the energy of the sensor nodes is the battery. This battery is very hard to be recharged or replaced, So the energy consumption is very important issue in WSN.

In this thesis, we aim to increase network lifetime of WSN by reducing energy consumption of the nodes. We choose protocol called SPIN to optimize it, SPIN protocol has advantages and drawbacks. We propose new protocol that we named it DC-SPIN that keeps the advantages and works on the drawbacks.

The main objective of this work is to propose a hierarchical protocol which is based on meta-heuristics. We have chosen the genetic algorithms which offer several advantages improving the performance of routing protocols. They are effective in finding the optimal route to take to recover data.

Keywords: Wireless Sensor Networks, DC-SPIN, Genetic algorithm, SPIN, energyconsumption, routing protocols, hierarchical protocol, meta-heuristics.

Résumé

Depuis la dernière décennie, nos yeux ont été témoins de preuves que les réseaux de capteurs sans fil (WSN) ont été utilisés dans de nombreux domaines tels que les soins de santé, l'agriculture, la défense, l'armée, les zones sinistrées, etc. Les capteurs sont équipés d'interfaces sans fil avec lesquelles ils peuvent communiquer entre eux pour former un réseau.

Puisque la seule source d'énergie des nœuds capteurs est la batterie. Cette batterie est très difficile à recharger ou à remplacer, la consommation d'énergie est donc un problème très important dans WSN.

Dans cette thèse, nous visons à augmenter la durée de vie du réseau de WSN en réduisant la consommation d'énergie des nœuds. Nous choisissons le protocole appelé SPIN pour l'optimiser, le protocole SPIN a des avantages et des inconvénients. Nous proposons un nouveau protocole que nous avons nommé DC-SPIN qui garde les avantages et travaille sur les inconvénients.

L'objectif principal de ce travail est de proposer un protocole hiérarchique basé sur des méta-heuristiques. Nous avons choisi les algorithmes génétiques qui offrent plusieurs avantages améliorant les performances des protocoles de routage. Ils sont efficaces pour trouver le chemin optimal à emprunter pour récupérer les données.

Mots-clés : Réseaux de capteurs sans fil, DC-SPIN, Algorithme génétique, SPIN, consommation d'énergie, protocoles de routage, protocole hiérarchique, méta-heuristique.

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List of Abbreviations

WSN	Wireless sensor network
ADV	Advertise
RQS	Request
msg	Message
GA	Genetic algorithm
CH	Cluster-Head
SPIN	Sensor Protocols for Information via Negotiation
DC-SPIN	Dynamic Clustered SPIN
MAC	Media Access Control

General Introduction:

In nowadays, we are facing a huge use in wireless sensor networks in this world. Wireless Sensor Networks enjoy great benefits due to their low-cost, small-scale factor, smart sensor nodes.

A WSN (Wireless Sensor Network) consists of sensor nodes deployed over a geographical area for monitoring physical phenomena like temperature, humidity, vibrations, seismic events, and so on. Those nodes can communicate with each other or directly to the sink. Each sensor has four essential parts which are “sensing unit”, “processing unit”, “transceiver unit” and “the power unit” although we can find some kind of sensors that have other optional units such as the mobilizer.

The only way to supply the sensor node with power is the battery “the power unit” which is almost impossible to be replaced or recharged. Thus, we are facing a huge problem which is the energy consumption of the sensor. So, we have to ask this question “what is the best way to conserve and save the energy of sensors in WSN so we can maximize the network lifetime?”. For the seek of getting the best and the most maximized network lifetime, a lot of research have been done and suggested several technics to reach that goal such as reducing the sensing energy consumption, reducing the processing energy consumption and reducing the communication energy and this one is the most important cause of the huge energy consumption by this unit.

From the best ways to conserve the energy is the routing of the messages between the nodes or we can say the routing protocol. So, the main objective of this work is to propose a new hierarchical protocol which is based on meta-heuristics based on SPIN protocol and we named it DC-SPIN. We have chosen the genetic algorithms which offer several advantages improving the performance of routing protocols. They are effective in finding the optimal route to take to recover data, so that makes us conserve our energy.

The structure of this thesis is as following:

Chapter 1: This chapter explains generally the wireless sensor network and its routing protocols, its classification … etc. Between all of these, we talked also about sensor node including its definition, architecture characteristics and more.

Chapter 2: In this chapter we'll talk about power consumption of the sensor node and the rating of the energy consumption on each unit and the energy consumption model, we will present also the energy conservation technics.

Chapter 3: This chapter introduces DC-SPIN protocol and its working mechanism. This chapter explained DC-SPIN steps globally and with detailed description also. It presents also general architecture a general diagram of this protocol.

Chapter 4: At the end will present in this last chapter the simulation tools, network model and the results of the simulation by evaluating the performance of DC-SPIN compared to the basic SPIN protocol.

Chapter 1: Wireless Sensor Network

1. Chapter 1: Wireless Sensor Network (WSN)

1.1. Introduction:

Originally, sensors were electromechanical detectors for measuring physical quantities. Their first use can be traced back to 1933, in the first room thermostats.

Recent advances in MEMS and integrated circuits (IC) have enabled the development of small-scale sensors and the integration of its actuators and electronics into one cost-effective high-performance chip [1].

A wireless sensor network (WSN) is a wireless network that contains distributed independent sensor devices that are meant to monitor physical or environmental conditions. A WSN consists of a set of connected tiny sensor nodes, which communicate with each other and exchange information and data.

1.2. Wireless Sensor Network:

A WSN consists of spatially distributed sensors, and one or more sink nodes (also called base stations). Sensors monitor, in real-time, physical conditions, such as temperature, vibration, or motion, and produce sensory data. A sink or base station acts like an interface between users and the network [2][3]. Like you can see below its schema in (figure 1).

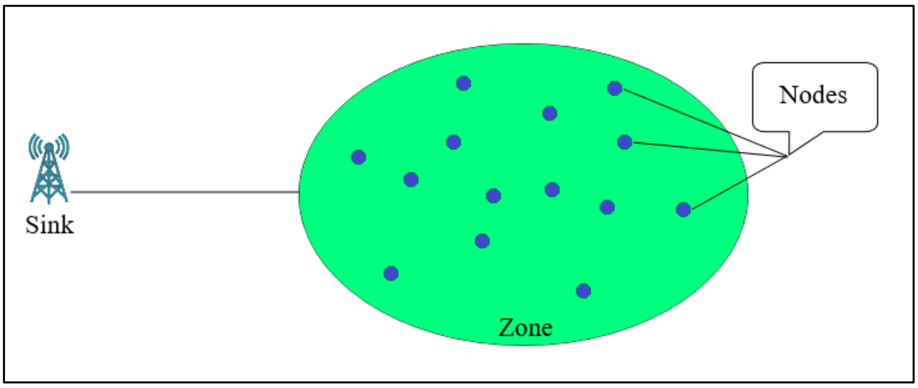

Figure 1: WSN architecture.

1.2.1. Sensors:

Sensors are input devices that record data about the physical environment around it.

Sensors send data to a microprocessor (computer). They do not make judgements, decisions or control any output devices [4]. And there are some examples as you can see below in (Figure 2).

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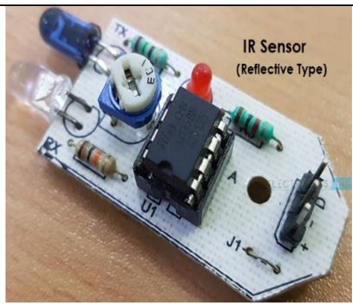
<td>
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<tr>
<td>Proximity Sensors</td>
<td>Infrared Sensor (IR Sensor)</td>
<td>Ultrasonic Sensor</td>
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Figure 2: Examples about sensors [5].

1.2.2. Units of a sensor:

A wireless sensor node is equipped with sensing and computing devices, radio transceivers and power components as we can see in the architecture in (figure 3) below. The individual nodes in a wireless sensor network (WSN) are inherently resource constrained: they have limited processing speed, storage capacity, and communication bandwidth [3].

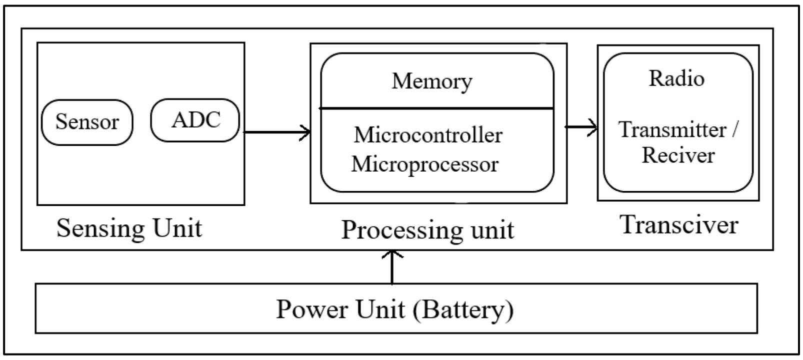


Figure 3: Sensor node architecture [3].

So, we have 4 units of the sensor node which are:

- **Sensing Unit:** it's a unit that has to subunits which are the sensor and the analogue-to-digital converter (ADC). The first unit, produces the analogue signals, and the second one converts them to digital signals then it sends them to the processing unit [3].

- **Processing Unit:** is a unit that has the most important job in the sensing node which is processing the captured data and storing it in the memory [3].
- **Transceiver (Communication Unit):** that unit used to transmit and receive data to and from other nodes [3].
- **Power Unit:** it's an important unit that used to supply the node with the energy [3].

1.3. Protocol stack:

The protocol stack implemented for the set of communication protocols of the sensor network.

The protocol stack comprises 5 layers which have the same functions as those of the OSI model (Open Systems Interconnection). Each layer of the stack communicates with an adjacent layer (the one above or the one below). Each layer thus uses the services of the lower layers and provides them to the higher level one.

It thus includes 3 plants for energy management, mobility management and task management.

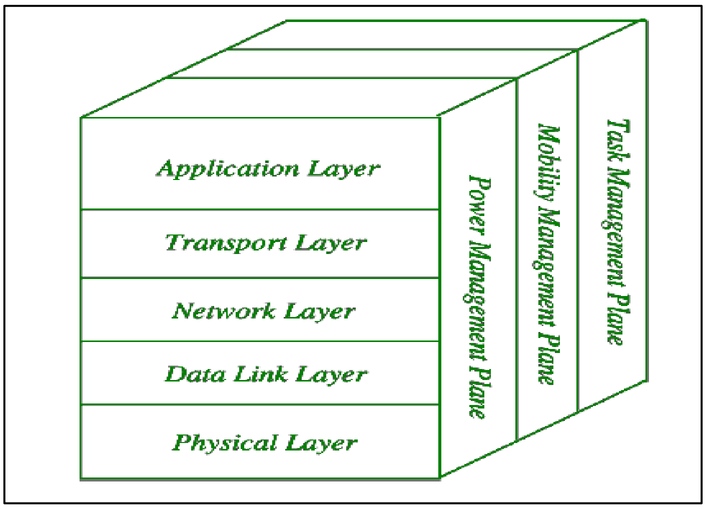


Figure 4: Protocol Stack.

1.4. WSN applications:

There are many applications of WSN we will describe some of them in this part:

1.4.1. Health applications:

Nowadays, the health care system is highly complex. The proposed system is designed to provide ultimate solutions to healthcare using wireless sensor networks [15].

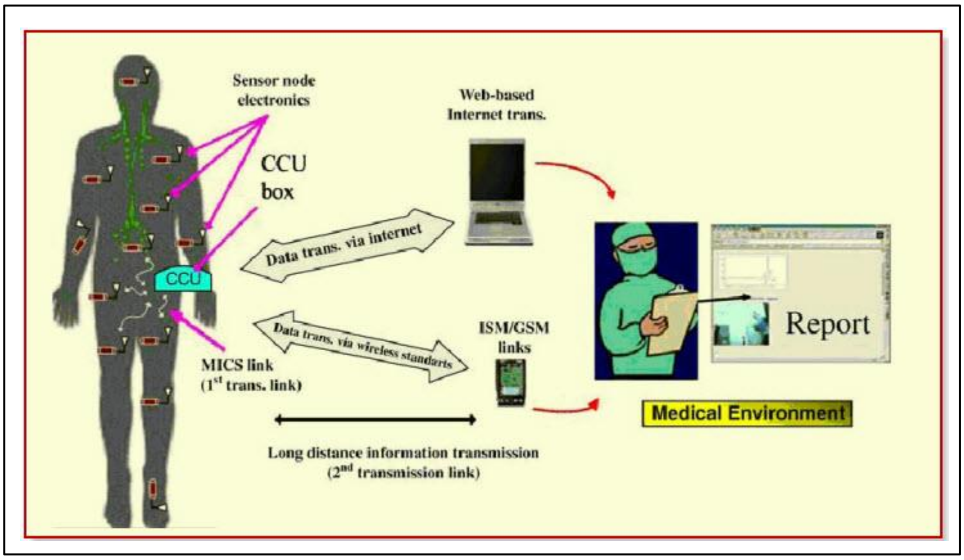


Figure 5: Example about health applications [15].

1.4.2. Agricultural sector Applications:

Soil moisture and temperature monitoring is one of the most important application of WSNs in agriculture. When monitoring the environment [16].

Figure 6: Example about agriculture in WSN [16].

1.4.3. Military application:

This Is the first WSN ever deployed. As the WSNs can be deployed rapidly and are self-organized therefore they are very useful in military operations for sensing and monitoring friendly or hostile motions. The battlefield surveillance can be done through the sensor nodes to keep a check on everything in case more equipment, forces or ammunitions are needed in the battlefield. The chemical, nuclear and biological attacks can also be detected through the sensor nodes [14].

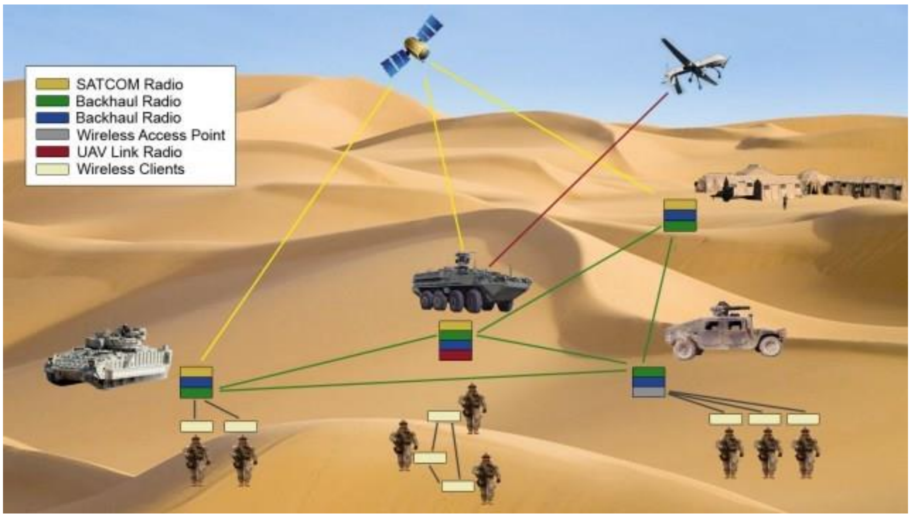


Figure 7: Example about military application in WSN [14].

An example of 'sniper detection system' which can detect the incoming fire through acoustic sensors and the position of the shooter can also be estimated by processing the detected audio from the microphone.

1.4.4. Home Applications:

As the technology is advancing, it is also making its way in our household appliances for their smooth running and satisfactory performance. These sensors can be found in refrigerators, microwave ovens, vacuum cleaners, security systems and also in water monitoring systems. The user can control devices locally as well as remotely with the help of the WSNs [14].

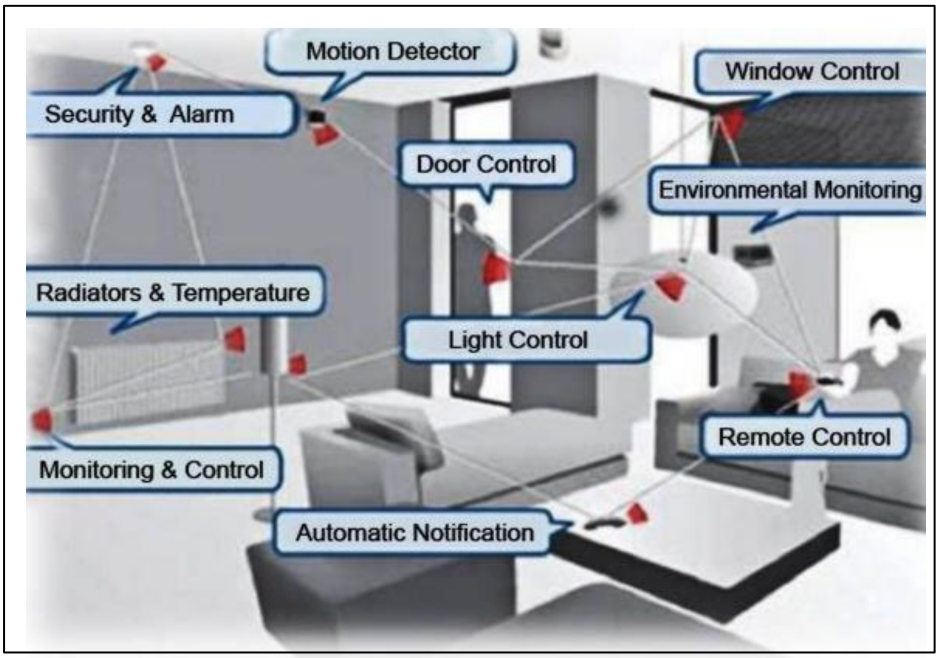


Figure 8: Example about home applications [14].

1.4.5. Environmental Applications:

These sensor networks have a huge number of applications in the environment. They can be used to track movement of animals, birds and record them. Monitoring of earth, soil, atmosphere context, irrigation and precision agriculture can be done through these sensors. They can also be used for the detection of fire, flood, earthquakes, and chemical/biological outbreak etc [14].

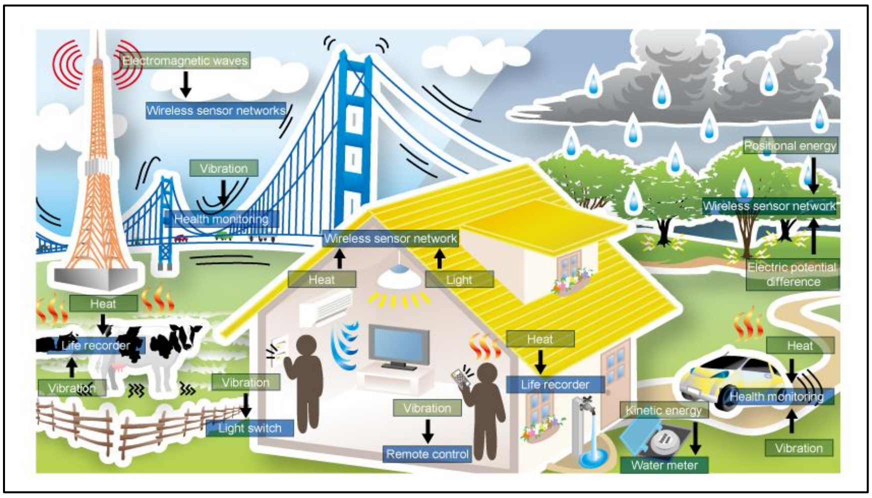


Figure 9: Example about environmental applications [14].

An example of 'Zebra Net'. The purpose of this system is to track and monitor the movements and interactions of zebras within themselves and with other species also.

1.5. Communication models:

In WSN we can talk about four kinds of architectures:

1.5.1. Directed communication model:

In this kind of architectures each node is connected with the sink directly. But, because it's unscalable it can't be used in a wide WSN application [7].

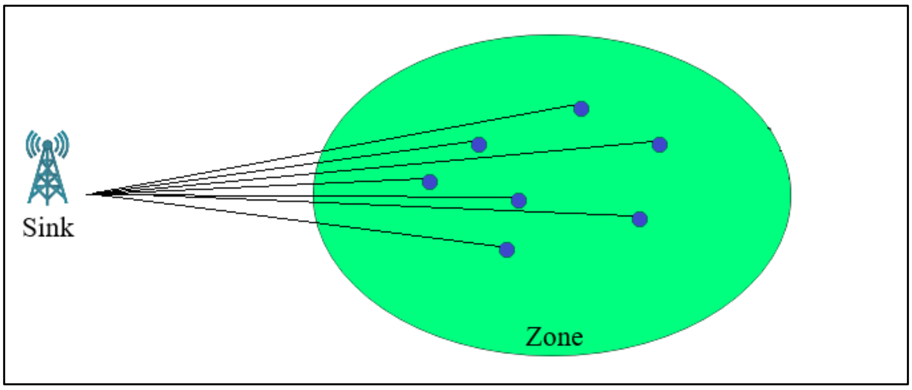


Figure 10: Directed communication model.

1.5.2. Multi-hop and peer-to-peer model:

Sensor nodes are placed nearby the sink, those nodes are usually used for packets routing between other nodes and the sink [7].

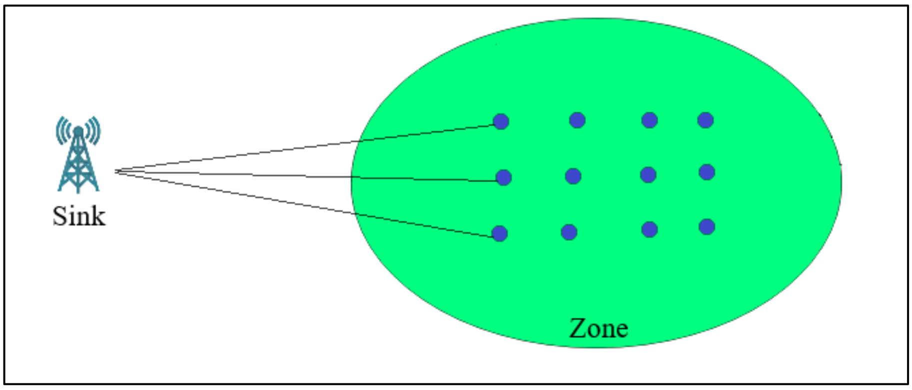


Figure 11: Multi-hop and peer to peer model.

1.5.3. Multi-hop based on clustering model:

In this architecture we have sink, cluster-heads and sensor nodes. The sink is connected to every cluster-head in the network and the cluster-head is connected to a bunch of nodes, but each cluster-head can be connected to one and only one cluster-head [6].

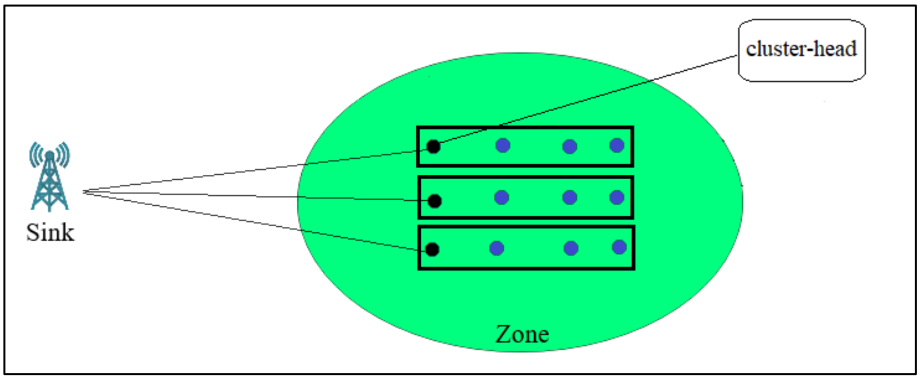


Figure 12: Multi-hop based on clustering model.

1.5.4. Multi-hop, clustering and dynamic cluster-heads model:

This architecture is similar to the previous one but in this one we have the cluster-head are dynamic so the other corresponding nodes can change the role with the cluster [6].

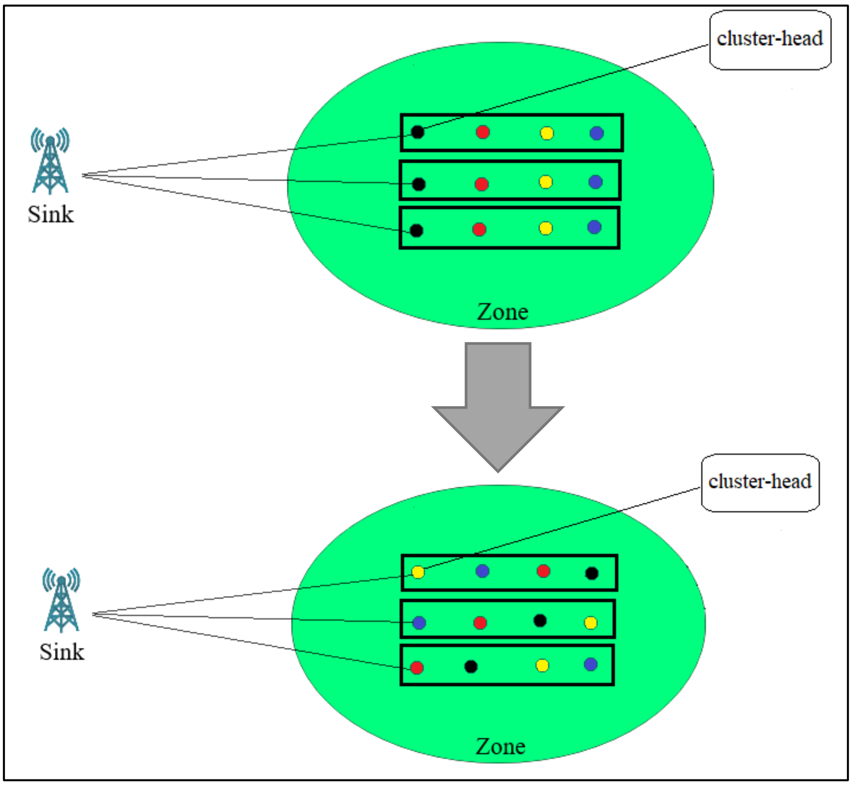


Figure 13: Multi-hop clustering and dynamic cluster-heads model.

1.6. WSN Characteristics:

The wireless sensor network has many characteristics such as mobility, switching character and the limit capability of the battery power. The characteristics of WSN is shown as following [10]:

- **Communication capabilities:** Because of the sensor which is easy to influence by the impact of natural environment, sensor networks' communication bandwidth is narrow and changeful.
- **Dynamic:** The WSN topology must have the function of dynamic self-adjustment and reconfiguration because sensor nodes can exit the networks because of the battery exhausting and other failures, so it is possible that some new sensors can be moved or added to the network and that makes the topology change.
- **Battery energy:** In the seek of saving the power and maximizing the lifetime of nodes we should consider the protocols and algorithms for battery energy conservation in advance, but that's not enough because computing algorithms cost lower than the wireless communication and that's the biggest problem that we are facing.
- **Computing capabilities:** sensors have very limited memory space, low performance CPU and low program space because those nodes have limited size and battery consumption.
- **No centre, self-organization:** sensor nodes can collaboratively adjust itself and perform and distribute algorithm and it can rapidly and automatically form an independent network after nodes switch on.
- **Multi-hop communications:** When a node want to communicate with another node which is out of his coverage range of it radio frequency, it must be via multi-hop route through the intermediate nodes.

1.7. WSN advantages and disadvantages:

WSN have many advantages, at the same time WSN have disadvantages too, in the following table we will list the advantages and the disadvantages of WSN:

Advantages	Disadvantages
1- Ease of deployment. 2- Extended range of sensing. 3- Improved lifetime. 4- Fault tolerance. 5- Improved accuracy. 6- Lower cost. 7- Actuation. 8- Collaborative objective.	1- Security issues. 2- Reliability. 3- Less speed. 4- Less control.

Table 1: Some of advantages and disadvantages of WSN [8][9].

1.8. Routing protocols in WSN:

The data in any network is routed from one node to another to travel from source to the destination. The routing path must be shortest for the high throughput of the network [12]. There is three different categorizes of routing protocols according to network structures which are: Flat, Hierarchical and Location based [13].

1.8.1. Flat based routing:

This kind of routing category is a multi-hop routing where all nodes operate in the same time, like when a sink or base station can ask for data in a region, so all the nodes in this region will send this data. That makes this kind of routing leads to high energy consumption. There are some of flat routing schema that we will mention bellow [13]:

- Sensor Protocol for Information via Negotiation (SPIN).
- Directed Diffusion (DD).
- Rumor Routing (RR).
- Gradient based Routing (GBR).
- Constrained Anisotropic Diffusion Routing (CADR).
- Energy Aware Routing (EAR).

1.8.2. Hierarchical based routing:

The importance of this routing protocol is implemented data aggregation causing decreasing energy consumption, where the packets are sent to the sink, because it is based on clustered routing. And here are some of the hierarchical based routing [13]:

- Low energy adaptive clustering hierarchy (LEACH).
- Minimum energy communication network (MECN).

- Power efficient gathering in sensor information systems (PEGASIS).
- Self-Organizing Protocol (SOP).
- Threshold Sensitive Energy Efficient Protocols: TEEN and APTEEN.

1.8.3. Location based routing:

In this scheme the location of nodes is known through a low power GPS on every node. So, nodes are addresses by their location. At the same time in this scheme nodes are not obliged to work together which means that idle nodes will remain to sleep. There are some location-based schemes that we will mention bellow [13]:

- Sequential assignment routing (SAR).
- Ad-hoc positioning system (APS).
- Geographic adaptive fidelity (GAF).
- Greedy Perimeter Stateless Routing (GPSR).
- Graph Embedding for Routing (GEM).
- Location Aided Routing (LAR).
- Geographic distance routing (GEDIR).
- Geographic and energy aware routing (GEAR).

1.9. Conclusion:

This chapter was about concept of WSN and some definitions. And we talked about what is WSN, what does mean sensor and sensor nodes in WSN, WSN architectures, some of WSN applications, and finally its routing protocols with their classification according to network structures.

In the next chapter, we will see energy consumption, its problems and the techniques to reduce consumption.

Chapter 2: Energy consumption of a sensor node

2. Chapter 2: Energy consumption of a sensor node

2.1. Introduction:

WSN uses are growing by time, especially in nowadays we are using WSN more often than before. And in the same time, we are facing a huge issue which is energy constraints and problems. Nodes use the energy to make any activity, and in WSN each node has a battery which is the only source of energy which we can't change if it run out of energy, So the lifetime of a node depends on lifetime of the battery and the energy that can be provided by it.

At the same time, we know that one failure in any node can Frustrate the hole application, So the energy consumption has become a huge problem in WSN.

2.2. Network lifetime definition:

It is the time span from network deployment to the instant when the percentage of alive and connected irredundant sensor nodes and relay nodes fall below a specific threshold. Notice that the remaining nodes, in addition to being alive, need to be connected to the sink (base station) either directly or indirectly [17].

The life time is an important thing in WSN, so we have mainly prolong that time span because it is one of the controlling factors of WSN performance.

2.3. Sensor node energy consumption:

The WSN energy consumption in any node is distributed by percentages which is shown as bellow in (figure 14):

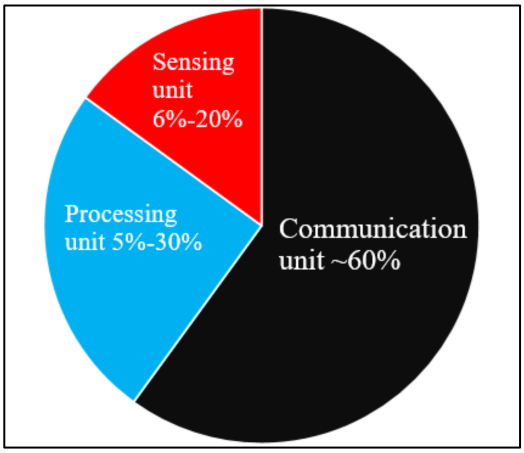


Figure 14: Distribution of energy in a node [18].

2.3.1. Capturing energy consumption:

A node can be equipped with multiple sensors (humidity, heat, movements, position …). Therefore, the sources of energy consumption for detection or capture are: sampling, analog-digital conversion (ADC), signal processing and activation of the capture probe [18].

2.3.2. Computing energy consumption:

Process energy is made up of two kinds of energy: switching energy and leakage energy. Switching energy is determined by the supply voltage and the total capacity switched at the software level (by running software). In contrast, leakage energy is the energy consumed when the computing unit is not performing any processing. In general, the processing energy is low compared to that required for communication [18].

2.3.3. Communication energy consumption:

Communication energy comes in three parts: receive energy, transmit energy, and standby energy. This energy is determined by the amount of data to be communicated and the transmission distance, as well as by the physical properties of the radio module. The emission of a signal is characterized by its power; when the transmit power is high, the signal will have a large range and the energy consumed will be higher. Note that the communication energy represents the largest portion of the energy consumed by a sensor node [18].

2.4. Energetic consumption model in WSN:

The energetic model is the consumption of the energy by the sensor node (**E_S**) as it is presented in the following equation **(1)** [11]:

$$\mathbf{E_S} = E_{s/sensing} + E_{s/processing} + E_{s/communication} \quad \mathbf{(1)}$$

Where:

$E_{s/sensing}$: the energy consumption of sensing unit

$E_{s/processing}$: the energy consumption of processing unit

$E_{s/communication}$: the energy consumption of communication unit, it equals the sum of two values: E_{TX} which is energy transmission and E_{RX} which is energy reception, as shown in the equation **(2)** bellow:

$$\mathbf{E_{s/communication} = E_{TX} + E_{RX} \quad (2)}$$

Where:

$$E_{TX}(k, d) = (E_{elec} * k) + (E_{amp} * k * d^2) \quad (3)$$

$$E_{RX}(k) = E_{elec} * k \quad (4)$$

And:

K: the packet size (bits).

d: the distance between the transmitter and receiver.

E_{elec}: energy to run the transmitter or receiver circuitry.

E_{amp}: Transmit Amplifier.

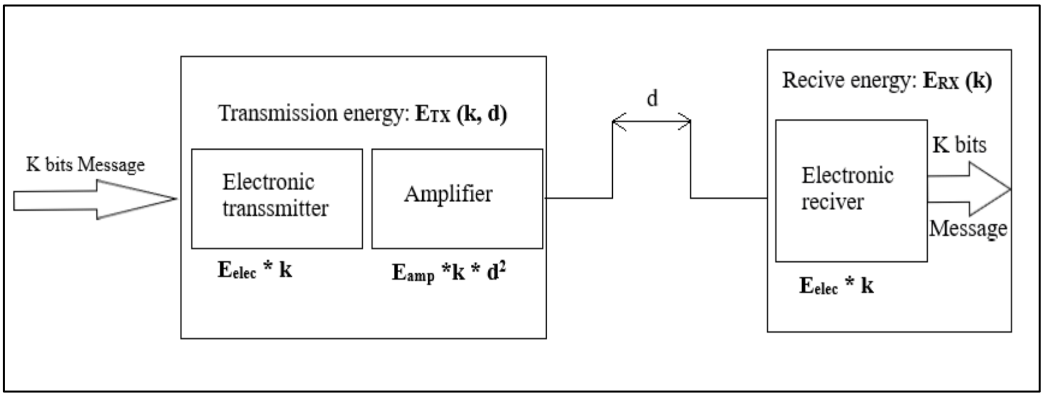


Figure 15: Energy consumption model [11].

According to this model, just the distance "d" between the transmitter and receiver and the packet size "k" are dominant factors in energy consumption [11].

2.5. Energy dissipation factors:

Energy consumption depends on several factors that are explained below.

2.5.1. State of the radio module:

The radio module is the component of the sensor node that consumes the most energy, it is he who ensures communication between the nodes. There are four states of radio components (transmitter and receiver): active, receiving, transmission and sleep [19].

- **Active state:** the radio is on, but it is not used. In other words, the sensor node is neither receiving nor transmitting. This state causes a loss of energy due to unnecessary listening to the transmission channel.
- **Sleep state:** the radio is switched off.

- **Transmission state:** the radio transmits a package.
- **Reception status:** the radio receives a package.

It should also be noted that the frequent transition from active to sleep may have resulting in a higher energy consumption than leaving the energy radio module in active mode. This is due to the power required for the voltage of the radio module. This energy is called transition energy.

It is therefore desirable to shut down the radio completely rather than transiting through the sleep mode. The change in the state of the radio module must be managed by a MAC layer protocol.

2.5.2. Access to the medium of transmission:

The MAC layer plays an important role in the coordination between the nodes and the minimisation of energy consumption. In this section, we will analyse the main causes of energy consumption in the MAC layer [20].

2.5.2.1. Retransmission:

Sensor nodes typically have a single radio antenna and share the same transmission channel. In addition, the simultaneous transmission of data from multiple sensors can produce collisions and thus a loss of information transmitted.

The transmission of lost packages can result in a significant loss of energy [20].

2.5.2.2. Active listening:

Active listening (idle listening) to the channel for a possible package reception that will not be received may result in a significant loss of the capacity of the nodes in energy [20].

To avoid this problem, you need to switch the knots into the most sleep mode for a long time to come [20].

2.5.2.3. Overhearing:

The phenomenon of overhearing occurs when a node receives packages that are not intended for it (Figure 16). Over-listening leads to a loss additional energy due to the involvement of other sensors in the reception data [20].

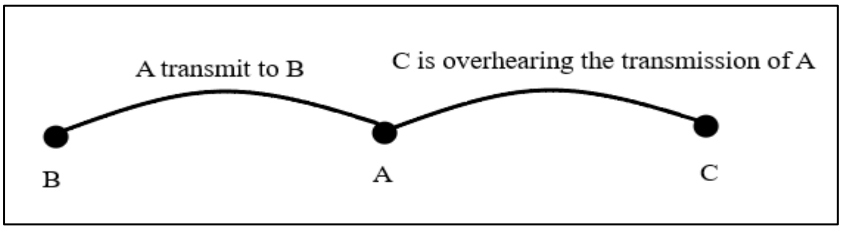


Figure 16: The overhearing in a transmission [20].

2.5.2.4. Overload:

Several mac layer protocols work by exchanging messages from control (overhead) to provide various features: signage, connectivity, access planning and collision avoidance. All of these messages require additional energy [20].

2.5.2.5. Over-emission:

The phenomenon of over-emitting occurs when a sensor node sends the data to a recipient who is not ready to receive it.

Indeed, messages sent are considered useless and consume energy Additional [20].

2.5.2.6. Packet size:

The size of the messages exchanged in the network has an effect on consumption energy from the transmitting and receiving nodes. Thus, the size of the packets should not be not too high or too low. Indeed, if it is small, the number of packets of control (acquired) generated increases the overhead. Otherwise, High power transmission is required for large packages [20].

2.5.3. Radio Propagation Model:

The propagation model represents an estimate of the average power radio signal at a given distance from a transmitter. The propagation of the signal radio is generally subject to different phenomena: reflection, diffraction and dispersal by various objects. Generally, the power of the signal received is 1/d n, where **d** the distance between the transmitter and the receiver is between, **n** an exhibitor loss of a path [21].

2.5.4. Date routing:

Routing in WSN is a multi-jump routing. The delivery of packages from a given source to a destination is done through several nodes intermediate. Thus, a node consumes energy either to transmit these data to relay data from other nodes. In this context, a poor routing policy can have serious consequences for the duration of the life of the network [21].

2.6. Energy consumption sources:

Sources of power consumption at the network layer are diverse [21].

2.6.1. Paths' length:

Data packets follow paths in a number of hops. The cost of a hop in terms of energy is measured by the distance between the two nodes involved in the communication, and the overall cost of the routing is the sum energies consumed at all jumps. The longest paths consume the most energy [21].

2.6.2. Links' quality:

The retransmission of the data following the interruption of the path between the source and the destination is an operation which generates an additional energy cost [21].

2.6.3. Communication mode:

Point-to-point routing is inefficient for WSNs because it consumes a lot of power at sensor nodes. Moreover, the appropriate communication modes are in fact the "one-to-many" mode and the "many-to-one" mode [21].

2.6.4. Routing unnecessary packets:

Certain data packets become useless if the time limits for transmissions, set either by the sender or by the receiver, are not respected. Routing data that has expired causes unnecessary energy consumption [21].

2.6.5. Choosing a path:

Failure to take into account the energy of the node during the path establishment process can cause the depletion of the energy capacities of some node [21].

2.7. Energy conservation technics:

After we made a description of the main causes of energy consumption in WSN, we will present in this section (figure 17) an overview of the different techniques used to minimize this consumption.

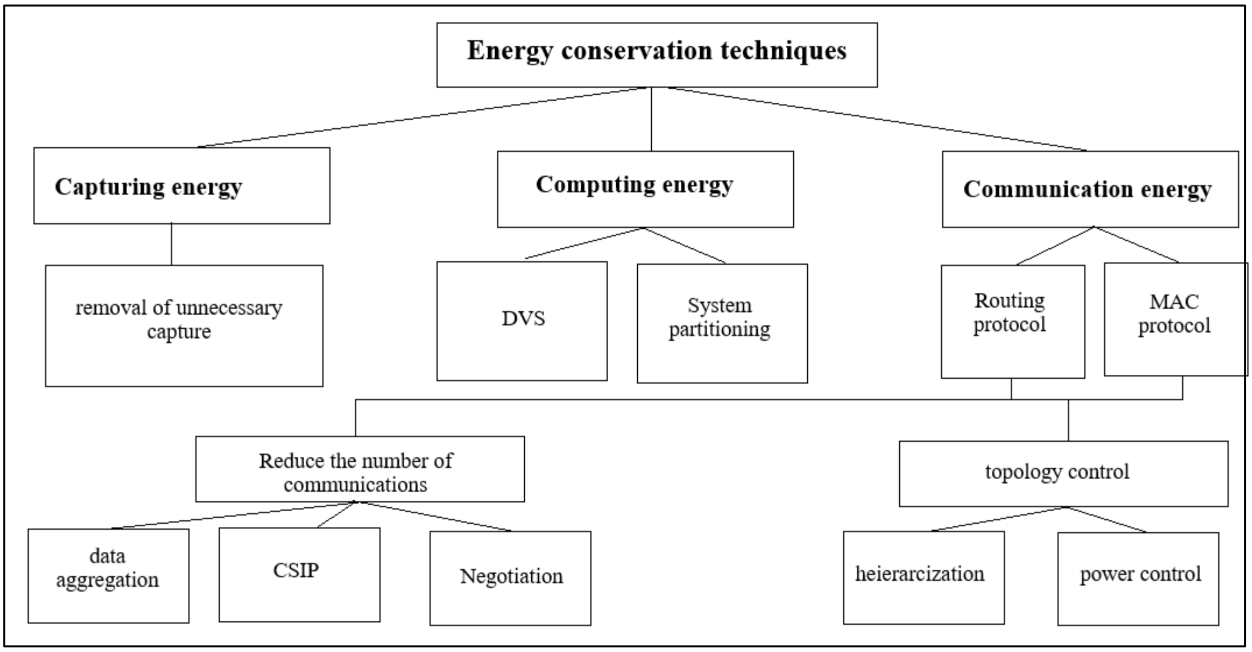


Figure 17: Energy conservation techniques [21].

Sensor energy can be saved at either (a) capture level, (b) processing level, or (c) communication level.

a. The only solution provided for minimizing energy consumption at the capture level is to reduce the capture times.
b. The computational energy can be optimized using two techniques:
   - The DVS (Dynamic Voltage Scaling) approach [22], which consists of adaptively adjust the supply voltage and frequency of microprocessor to save computing power without degradation performs.
   - The system partitioning approach, which involves transferring a prohibitive calculation in calculation time towards a base station which has no energy constraints and which has a high computing capacity [23].
c. The minimization of energy consumption during communication is closely related to the protocols developed for the network layer and the MAC layer. These protocols are based on several techniques: data aggregation, negotiation and CSIP (Collaborative Signal and Information Processing). This last technique is a discipline which combines several fields [24]: communication and low power computing, signal processing, distributed algorithms and fault tolerance, Adaptive systems and fusion theory of sensors and decisions. These

techniques aim to reduce the number of sending/receiving messages. On the other hand, the control of the topology [23] allows the adjustment of the transmission power and the grouping of the sensor nodes (Hierarchy).

- Transmit power control not only affects the battery life of a sensor node, but also the traffic carrying capacity which is characterized by the number of packets successfully transmitted to a destination. In addition, it influences connectivity and density management (the number of nearby nodes). Thus, it can conserve energy on two levels: explicitly by applying low transmit powers and implicitly by reducing contention with other transmitter nodes. The power control module is often integrated into either network layer or MAC layer protocols [25].
- Hierarchy protocol consists of organizing the network into a structure several levels. This is the case, for example, with clustering algorithms, which organize the network into groups (clusters) with cluster heads and member nodes [26]
- Another technique has been proposed in [27]. This technique takes advantage of the high density of the deployed sensors to allow some of them to fall asleep, so that not all the sensors are active at the same time.

A variety of protocols have been proposed in the literature. Most of these protocols are intended for the network and MAC layer.

Network layer protocols in WSN can be divided according to the network structure into linear routing, hierarchical routing, and location-based routing. In linear routing, all nodes typically have the same roles or functionality. However, in hierarchical routing nodes will play different roles in the network. In location-based routing, the positions of sensor nodes are used to route data in the network. Furthermore, these protocols can be classified according to their operations, into multi-path, question-based, coherence, negotiation or quality-of-service-based routing techniques [28].

Likewise, there are several MAC layers protocols that are developed for WSN.

Several classifications of these protocols have been proposed in the literature. The authors of [29] classify these MAC protocols into two classes: centralized access protocols and random-access protocols.

2.8. Related work:

From a lot of technics that can be used to save the energy in WSN, we choose to modify the SPIN protocol and optimize it.

2.8.1. Traditional SPIN protocol:

SPIN (Sensor Protocols for Information via Negotiation) is a data-centric routing protocol. It fits under event-driven data delivery model in which the nodes sense data and disseminate it through the network by means of negotiation. SPIN nodes use three types of messages for communication [30]:

- **ADV:** whenever the source node has a new data to share it will send an advertisement to all its neighbour nodes in the network.
- **REQ:** the nodes who are interested in receiving the data will send a request to the source node by saying that I am interested in that data. But if the node is not interested in receiving that data or the node may have same data already then it will ignore the data and will not send any message to the source node.
- **DATA:** upon getting the request the node will send the original data to the nodes and this process will continue till all the nodes in the network get the data.

2.8.2. SPIN working Mechanism:

Nodes can communicate in this kind of protocols by three phases [30]:

- **Phase 1:** when a node wants to send data, that node will advertise by sending an ADV message containing a description of the data.
- **Phase 2:** when any other node received an ADV then he can request the data if this node is interested by sending a REQ message to the sender of the ADV message.
- **Phase 3:** after getting a REQ, the sender of ADV sends the data to the requester of this date.

The table below (table 2) explain this mechanism more:

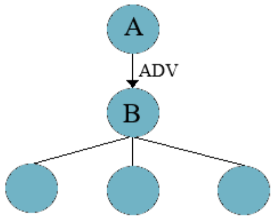
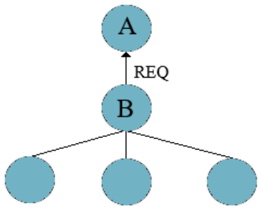
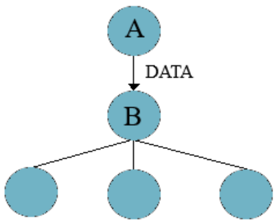
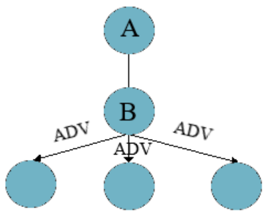
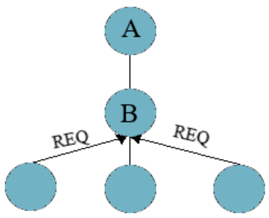
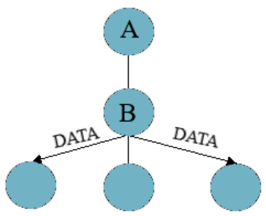
	Figure	Description
1		Node A advertises that he has data to node B.
2		Node B requests that data from node A because he needs it.
3		Node A sends data to node B.
4		Node B advertises that data to his neighbours.
5		The nodes that are interested to that data request and receive it from the node B as node B do before with node A and it goes like that till the access to all the nodes.
6		

Table 2: Steps of the communication of SPIN [30]

2.8.3. SPIN advantages:

SPIN has advantages that can simplify our work and make it easy like [31]:

- The node has to know only his neighbours with a single hop so it makes it simple.
- The negotiation mechanism helps to minimize the redundant data.
- It solves the implosion and overlap problem in the classic flooding protocol.

2.8.4. SPIN disadvantages:

The SPIN protocol has disadvantages the same as he has advantages that we should be working on so we make that protocol better:

- **Blind forward problem:** sending DATA from the source node to the destination will be done by broadcasting ADV message to all his neighbours then the node who needs this data will send back REQ so the source node can send this DATA to this node till it reach the destination. This operation will be done again and again every time the network has a new data, so that's it the "Blind forward" and that's problem leads to waste of energy and doesn't consider the balance of energy consumption of networks' nodes [31].
- **Data inaccessible issue:** Sometimes in this protocol there are some nodes which have the collected DATA from the source node so those nodes don't need the DATA which make it stop in the way because the nodes which have the DATA won't send a REQ message or sometimes due to the energy problems the nodes can't request the data, so the operation will be stopped and makes the "DATA inaccessible" for the destination [31].
- **Collision:** When the network collect DATA from a lot nodes at the same time, it will be a lot of messages in the network at the same time which causes the "Collision", which leads to a huge packet loss in the network [31].

2.8.5. Studies:

There are a lot studies about SPIN Protocol. In the next table we will mention some of those studies:

Title of the study	Author	Proposed protocol	Description of the study
SPIN-IT A Data Centric Routing Protocol for Image Retrieval in Wireless Networks	Edward Woodrow & Wendi Heinzelman (2002)	SPIN-IT	In this paper, authors proposed a protocol which considers image as data and by using spin techniques data received will be chosen as optimal sources. Example, Based on robustness or perceived longevity of route record. In this route record, each data is being Rout-Reply packet header and source closest to the requesting node is chosen for data transfer.
A Modified SPIN for Wireless Sensor Network	ZeenatRehna, Sarbani Roy, Nandini Mukherjee (2011)	Modified SPIN	Authors suggested that data must be circulated towards the sink node. In this protocol a new phase is added in existing phases to find distance of each sensor node in the network from sink to sensor node and vice versa, i.e. the more number of hops in between increases the distance between sink and nodes, that phase iscalled distance discovery, i.e. total phases in modified spin are: –Distance Discovery. –Negotiation. –Data Transmission.
Adaptable Protocol for Time Critical Information	M.Tabibzadadeh , M.Sarram & M.Ghasemzadeh , (2009)	Cluster Based SPIN (CBS)	The authors suggested that SPIN can be modified with the property of clustering for saving time and energy. It was named as Cluster

Dissemination via Negotiation in Large scale Wireless Sensor Network			Based SPIN (CBS). The rotation of Cluster head leads to a balanced energy consumption of all nodes and hence to larger lifetime of network. Rest of the procedure will be performed by cluster heads.

Table 3: Studies about SPIN protocol

2.9. Conclusion:

In order to solve energy consumption in wireless sensor networks problems, there are several researches are being working on to reach that goal by using different technics.

In the second chapter we talked about network lifetime, energy consumption in WSN, energetic model, Energy dissipation factors, energy consumption sources and some of the technics can be conserve the energy.

In the next chapter, we proposed an optimized and modified SPIN protocol which is a dynamic cluster-head spin protocol a genetic algorithm to select the best pathing from each source in each cluster to his Cluster-Head then to the sink.

Chapter 3: Preposed protocol DC-SPIN (Dynamic Cluster-Head SPIN)

3. Chapter 3: Preposed protocol

3.1. Introduction:

We saw in the previous chapter network lifetime, energy consumption in WSN, energetic model, Energy dissipation factors, energy consumption sources and some of the technics can be conserve the energy. Also, we talked about SPIN protocol and the studies protocol. In this chapter we will explain more deep our proposition to optimize SPIN protocol using clustering with k-means and routing by Genetic algorithm (GA) and we named this protocol DC-SPIN.

The objective of DC-SPIN is to minimize the energy consumption of all the nodes within the network and this leads to maximize the network lifetime by clustering our network using k-means, those clusters have cluster-heads that can be changed by the sink when they get lower than 50%. Then, to make the pathing between source node and the sink passing by the Cluster-Heads (CHs) we use GA. Those modifications reduce sensor activity and messages number which make the SPIN protocol overstep the drawbacks of “Blind Forward Problem”, “Data Inaccessible Issue”, “Collision” and “Flooding”. Therefore, those modifications make sensor nodes consume less energy as much as possible compared to SPIN protocol which leads to maximize the network lifetime.

3.2. Global description:

Initialization:

Randomly deploy sensor nodes in the network zone then we can divide it to clusters.

- **Step 00: Partitioning:**

  In this step, the sink makes the partitioning of the network to clusters each cluster have its Cluster-head with the algorithm “K-means”.

- **Step 01: Data advertising:**

  This step is responsible to send the ADV message which has the information of the DATA from the source node to the sink passing by the CHs.

- **Step 02: Data requesting:**

  In this step, the sink after receiving the list of the adv messages will decide the nodes that will send them back a REQ message to request the data, but before sending the REQ message the sink will find the route back to the source node first passing by the CHs.

- **Step 03: Data transmission:**

In this last step, any source node that receives a REQ message will send the data to the sink.

All these steps are repeated on each cluster and each until the end of clusters. Then this whole operation will be repeated on each task, and we mean by the "task" the process of collection of all the data from all clusters.

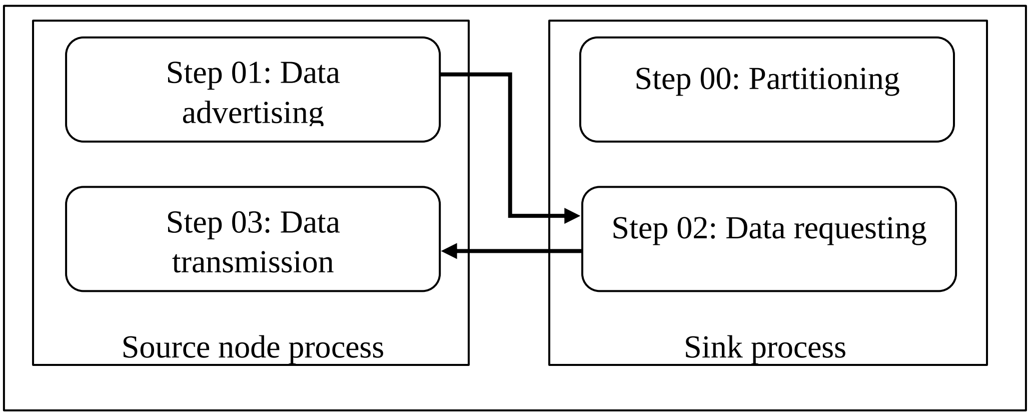


Figure 18: Global process of DC-SPIN

3.3. Detailed description:

We will present in this section more details about the four steps that we talked about before.

3.3.1. Step 00: Partitioning

Based on the geographic location, this phase is responsible for the distribution of the network. This partitioning is carried out in accordance with the distance between the sensor nodes (the closest nodes are grouped together). Our strategy allows the separation of the network into k clusters by the use of the "k-means" algorithm [13]. It is a simple and effective method. It can be used with large databases (thousands of sensors). The k-means algorithm aims to partition the n sensor nodes Si: i∈ [1, 2, ..., n] in k

clusters Pj ∈ [1,2, ..., K] (k ≤ n) using k centres of ―Cj" chosen arbitrarily. This algorithm aims to minimize the distance between the sensor nodes "Si" inside each cluster "Pj

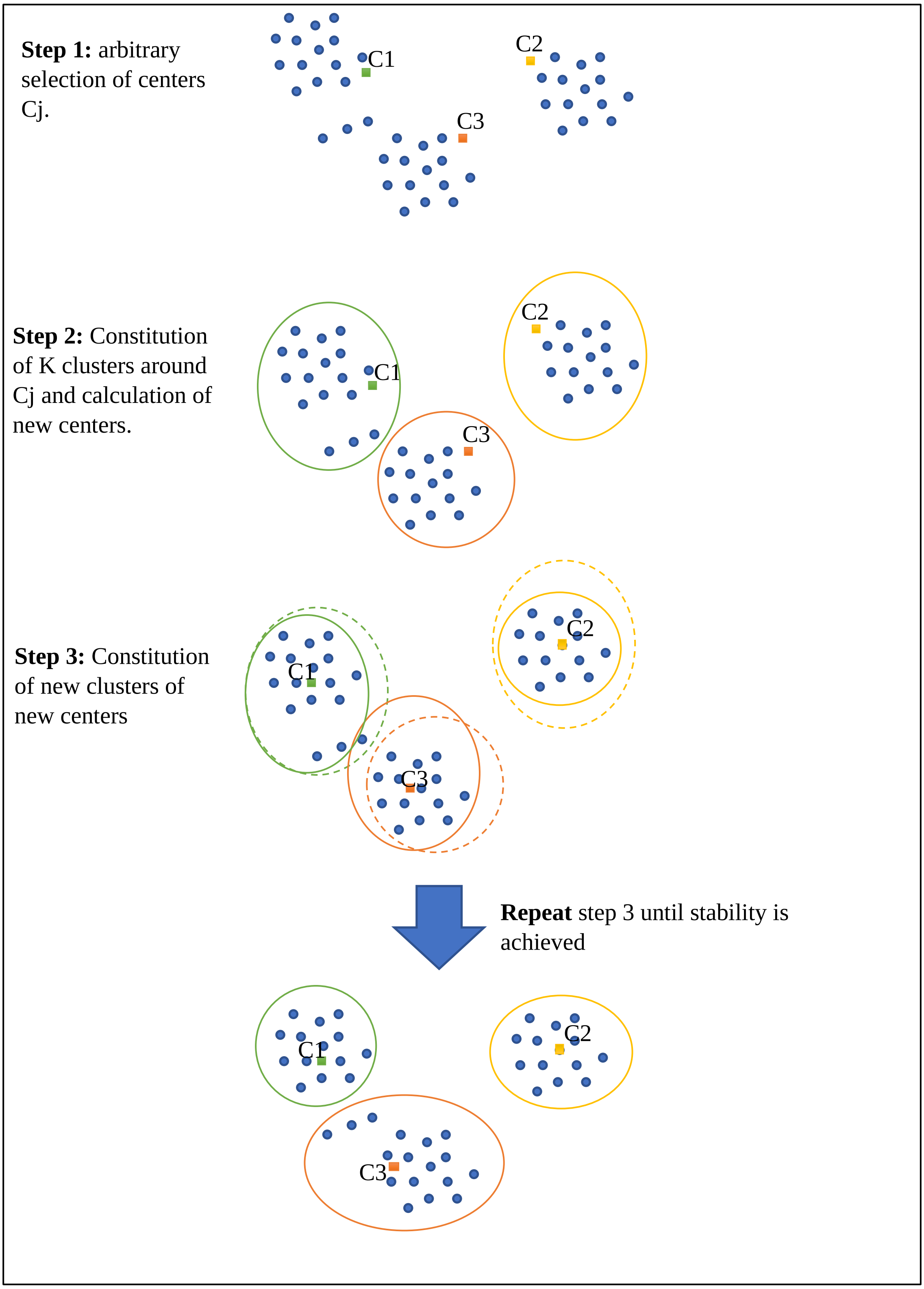


Figure 19: General process of k-means method

3.3.2. Step 01: Data advertising

To make this step clearer, we will explain it in the **"figure 20"** below:

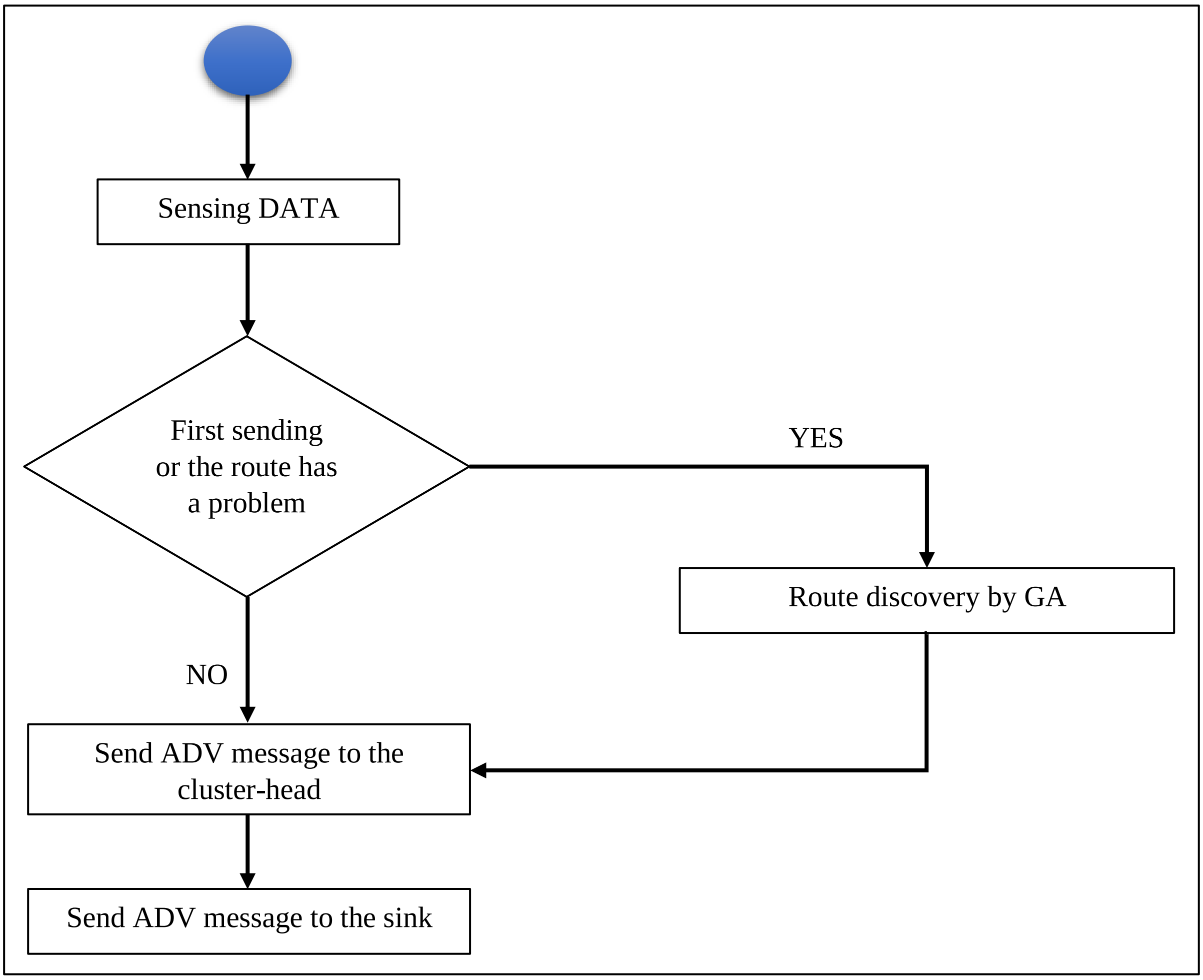


Figure 20: General process of data advertising step

In this step, the source nodes in each cluster sense the data from the sensing zone. Then, the cluster-head will discover the route from the source node to the sink passing by it, and then the source node will send the ADV message to the Cluster-head. After that, it sends a list of adv messages to the sink.

The following description will explain more this step:

- **Sensing data:**

In our proposition we have three types of data "Temperature, Humidity and Light". The values are as following: Temperature from -40°C to 123.8°C, Humidity from 0% RH to 100% RH, Light from 320nm to 730nm. Source node choose one data with its value randomly.

- **Route discovery:**

This task is responsible for determining the order of nodes (including source nodes) to be followed from a source node to the sink or vice versa, according to the genetic algorithm.

A source node performs this operation only in two cases; the first one is the first sending of a source node (a source node did not send any message to the sink), the second one when the route from a source node to the sink has a problem.

The genetic algorithm procedure, will be done in 6 operations:

- ✓ **Operation 01: generation of initial population:** we generate randomly an initial population of N solution, where N is equal to 20% of node.
- ✓ **Operation 02: Evaluation of each of the individuals of the population:** This operation is responsible for calculating the smoothness for each path of the initial population.

  The fitness function can be calculated using the formula given in the equation (1).

  $$f(x) = \sum_{i=1}^{i=k} d_{iK} \qquad (1)$$

  Where, d_{ik} is the distance between two sensor nodes.
- ✓ **Operation 3: Selection:** in this work we select the best individuals (the parent paths) according to their evaluation by rank (selection by rank)

  Selection by rank:

  This selection technique always chooses individuals with the best adaptation scores, so chance does not enter into this selection mode. In fact, if N individuals constitute the population, the applied selection consists in conserving the K best individuals (within the meaning of the evaluation function) where number of parents k = N / 2

  In our case the best individuals have a minimal Min (f) evaluation.
- ✓ **Operation 4: new population generation:** in this operation we must generate new solutions where we apply the crossing and mutation operators for reproduction.

  In this work we have chosen the crossing at a point from the second gene.

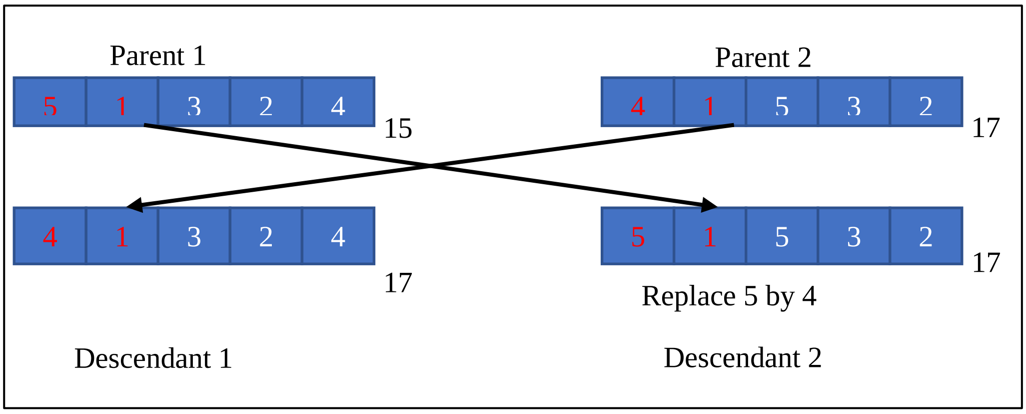


Figure 21: Crossing operation

Regarding the mutation is carried out with a very low probability (in the case of the local optimum), and it consists for example of exchanging two consecutive nodes in individual.

- ✓ **Step 5: population replacement:** when K new individuals have been generated, they then replace the old population. The individuals of the new population are evaluated in turn.

- ✓ **Step 6: Stopping criteria:** The genetic algorithm operations are applied until a iteration number adapted “100”.

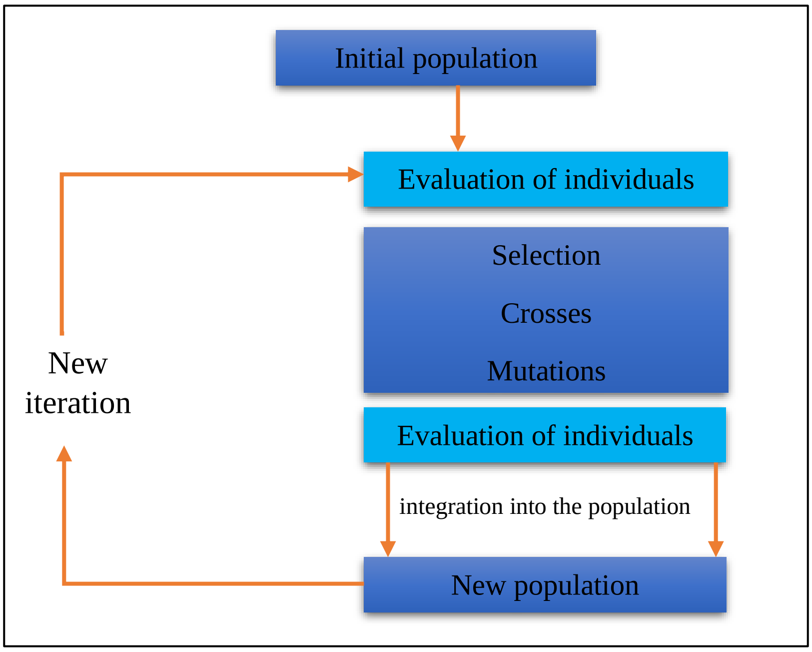


Figure 22: General process of GA

- **Send ADV message:**

After the discovery of the route, the source node sends the ADV message to the sink passing by its Cluster-Head.

3.3.3. Step 02: Data requesting

This step is done by the sink, and here is the **"Figure 23"** to explain it more clearly.

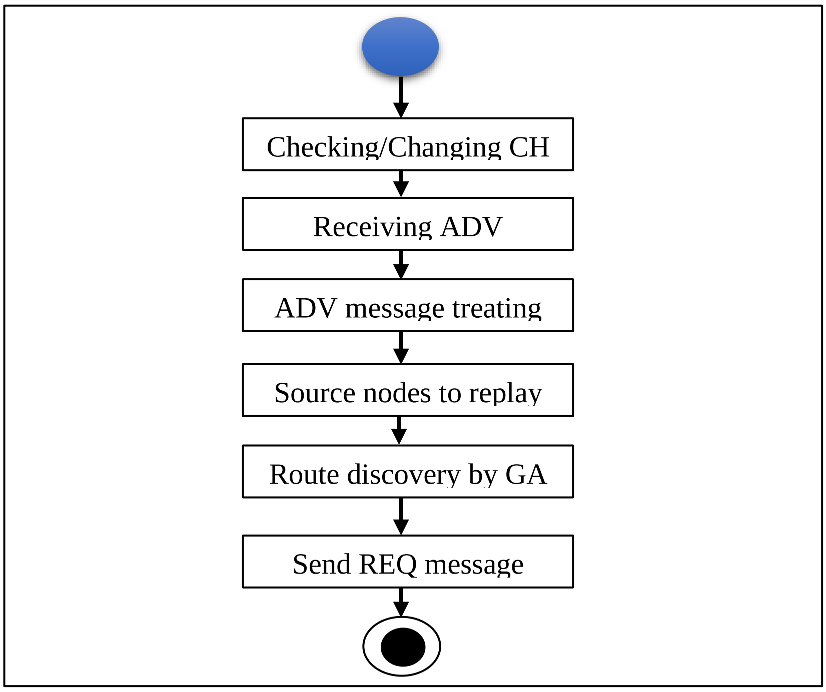


Figure 23: General process of data requesting stage

And to make this step clearer we will explain it as following:

- **Checking/Changing CH:**

After receiving the ADV message from the source node passing by the cluster-head, the sink will check the energy of each cluster-head, if the energy is lower than 50% the sink will make another node in the same cluster which have the biggest energy a cluster-head and change the old cluster-head to a normal node.

- **REQ message treating:**

After checking/changing the cluster-heads and receiving all ADV messages from the source nodes of each cluster, when the adv message has the name of the data and the energy rate of the sender adv message. The sink needs to treat them and decide the set of source nodes to send request massages.

This task will realize as following:

For each cluster, the sink classes the name of data with source nodes with its type of data, and then we have three possibilities:

✓ **First possibility:** none of the source nodes sent this type of data, in this case the sink does not send request message, it moves to the other types.

- ✓ **Second possibility:** just one source node sent one type of data, in this possibility the sink checks if it needs this data or not. If the sink needs the data, it will send REQ message to the source node.
- ✓ **Third possibility:** more than one node send ADV message about one type of data, in this case the sink checks if he needs this data or not. If it needs this data and for the balance of energy consumption, the sink will choose the highest energy rate and will send REQ message to the chosen one.

This operation repeated for all types of data.

- **Send REQ message:**

After determining the source nodes to reply, the sink implement the operation route discovery by GA and send REQ message to them.

3.3.4. Step 03: Data transmission

This step will be done in the source nodes as it shown in the **"Figure 24"** bellow:

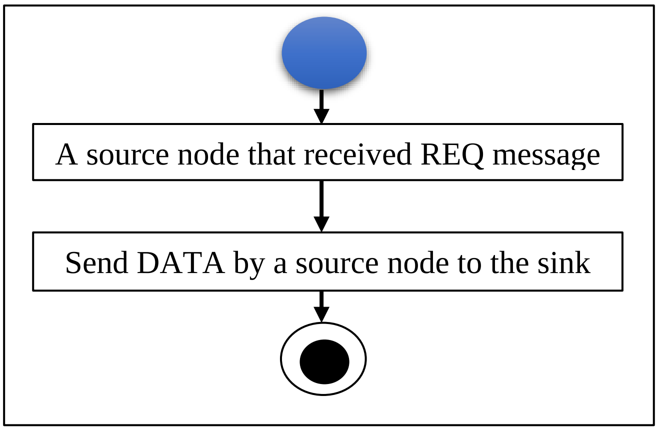


Figure 24: general process of Data transmission stage

As this figure is not enough to explain this step, we will explain it more as following:

Send data by source node to the sink:

As we explained above, the REQ message contains the route from the sink to the concerned source node. Therefore, any source node receives REQ message is able to use the same route without discover the route again. We used this method to conserve energy of source nodes as much as possible.

Finally, the source nodes send the data to the sink. Then the sink saves these data.

The following architecture "figure 25" explains more our proposition:

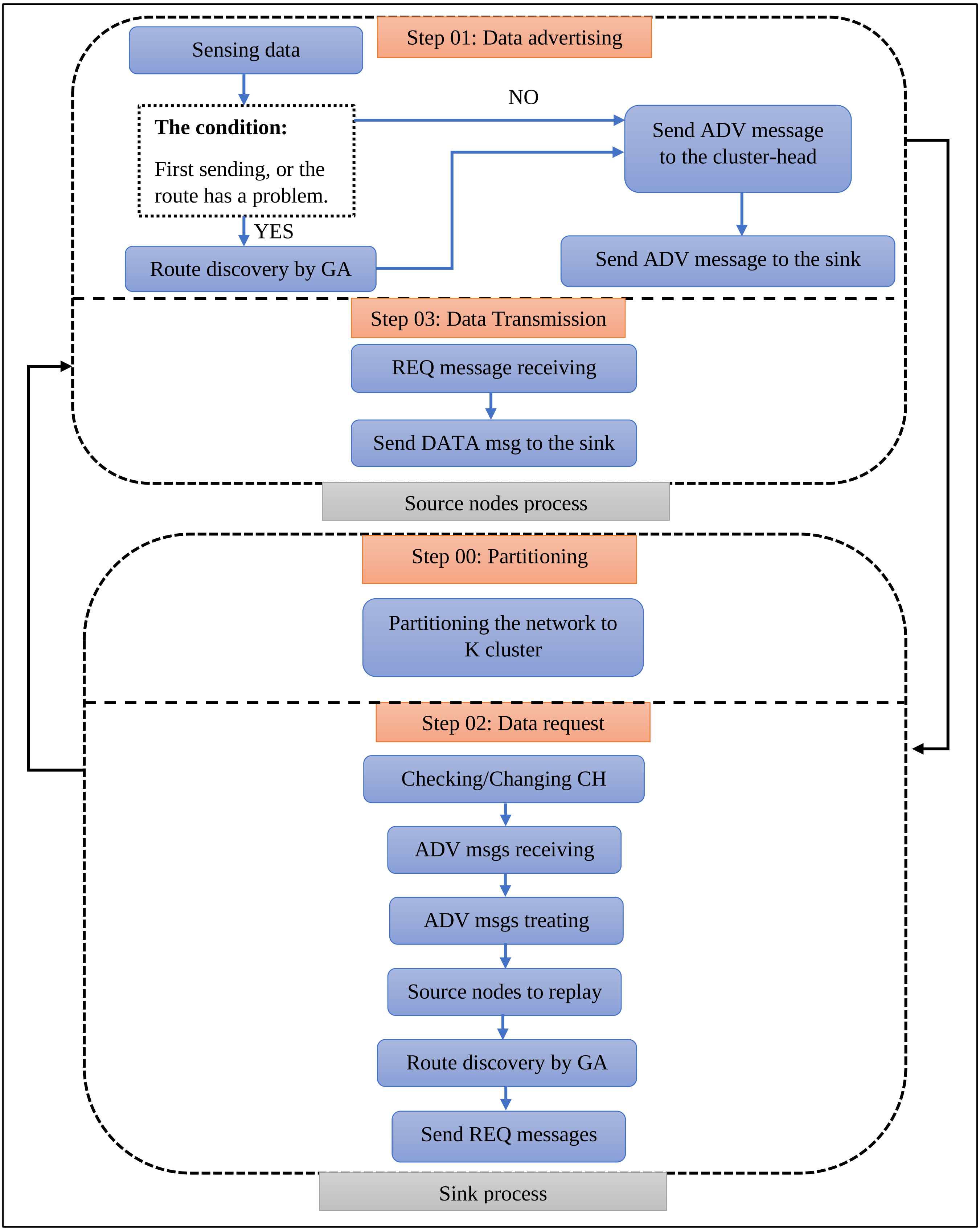


Figure 25: global architecture of our proposed protocol

3.4. General operation:

The general process of DC-SPIN presented by the sequence diagram bellow:

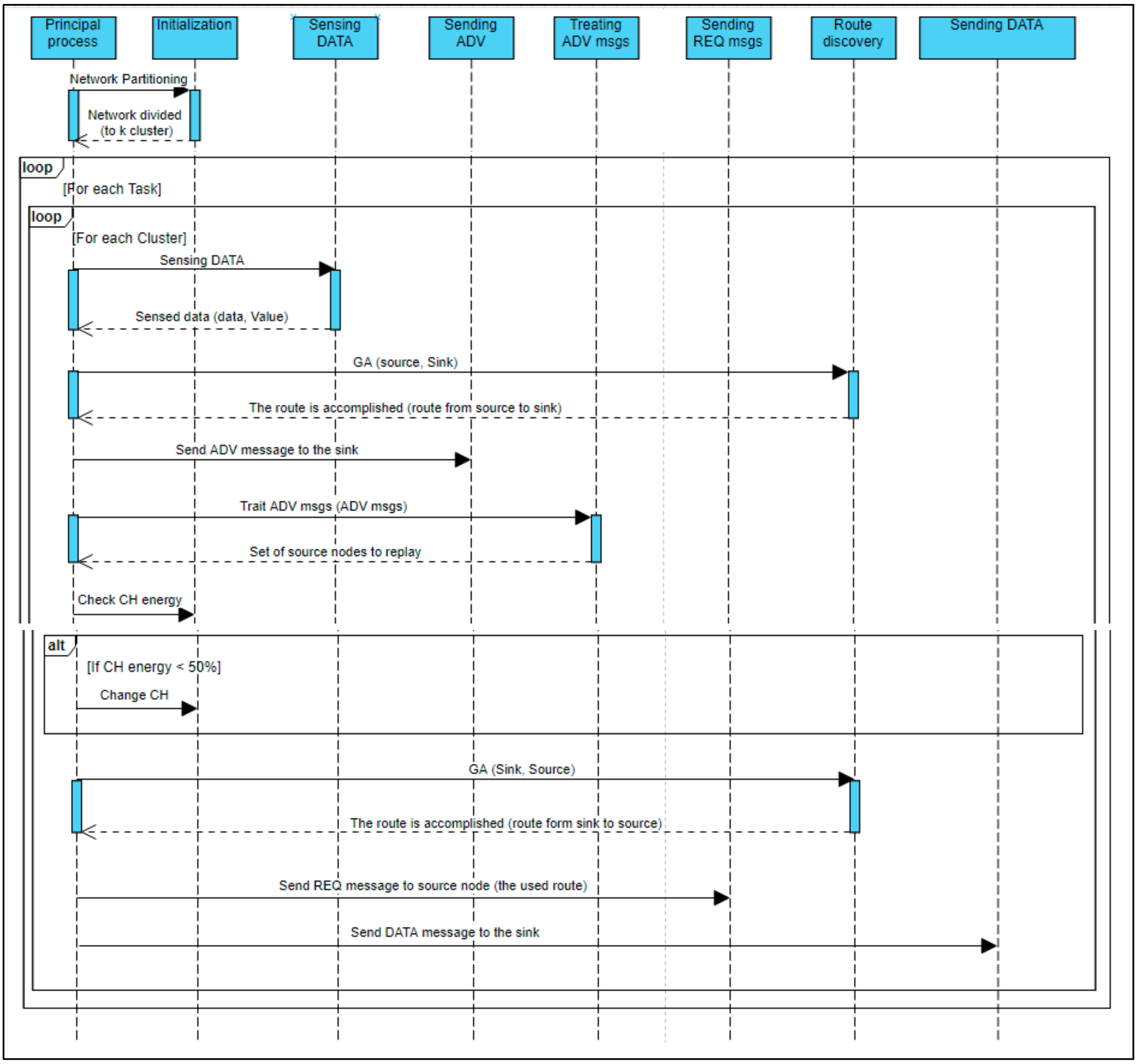


Figure 26: Sequence Diagram

- The sink starts partitioning the network to k cluster, and select their cluster-heads.
- Source nodes sense the data with its value.
- Source nodes discover the route to the sink by GA.
- Source nodes send the data to CH after sending all of the ADV messages to the CH, the CH will send it to the sink.
- The sink receives ADV messages and trait them to select the set of source nodes to

replay.

- The sink checks if the cluster-head under 50% of its energy, the sink will change it.
- The sink discovers the route to the source nodes passing by their cluster-heads.
- Then the sink will send REQ messages to the source nodes.
- Any source node receiver REQ message will send back to the sink within the same route a DATA message.

This operation will be repeated in k cluster for each task.

3.5. Conclusion:

In this chapter, we explained our proposed protocol which is DC-SPIN and its working mechanism, so we talked about it globally at the beginning, then we talked about it more deeply, after that we ended our explaining for that protocol by a general architecture and a general operation explanation.

Our proposition is made for many advantages compared to SPIN such as reducing the activity of nodes as much as possible, we gave the biggest job to the sink since it hasn't energy problem and we decreased the number of messages because we make the transmission between the source nodes to the sink passing by the cluster-head on each cluster or from the sink passing by the cluster-head on each cluster to the source nodes only using the GA, and we made the cluster-heads change when they are lower than 50%. Those features can increase the network lifetime.

We aim in the next chapter to implement our proposed protocol and make its simulator.

Chapter 4: Implementation and results

4. Chapter 4: Implementation and results

4.1. Introduction

Like we talked previously in the last chapter, we saw the conception and the modelling of the DC-SPIN where we route between the source node and the sink with GA passing by the CHs.

In this chapter we will see the implementation of our program with its analysis and validation, and the simulation that resulted from it and the results from the simulation as well. Also, we presented in this chapter the platform and tools that we used to implement this project.

To reach our goal, we deployed randomly in the sensing zone, sensor nodes and we clustered them with k-means algorithm to K cluster and this zone is centred by a sink. Then, we used the GA algorithm to make the pathing by identifying the route from a source node to his Cluster-Head then to the sink and from the sink back to the Cluster-Head then to the source node. We executed DC-SPIN for many iterations to obtain the optimal results.

4.2. Simulation tools:

To realise the simulation of our DC-SPIN (Dynamic Clustered-heads SPIN), we used the next tools:

- **Software:**

  Programming language: We used a MATLAB language because of its features for the simulation like the ease of use, robustness and the provided libraries that can be used for simulation … etc.

Figure 27: MATLAB’s icon

- **Hardware:**

We used a "LENOVO" laptop with the following characteristics:

- ✓ **Processor:** Intel(R) Core(TM) i5-2430M CPU @ 2.40GHz.
- ✓ **RAM:** 3.92 GB
- ✓ **Operating System:** **"**Windows 10 Pro" with the version "20H2" and the type "64-bit operating system, x64-based processor"

4.3. Network Model:

The network dimension in 150m × 150m, we deployed the sensor nodes randomly then we clustered the network to k clusters given by the user with a Cluster-Head on each cluster. The source nodes are 20% from the total number distributed to a 5% on each cluster. The sink located on the centre of the sensing zone as we will present it in the "figure 26". To verify the performance of our protocol, we determined three cases, small scale with 100 nodes, medium scale with 200 nodes and the last one is a large scale with 300 nodes.

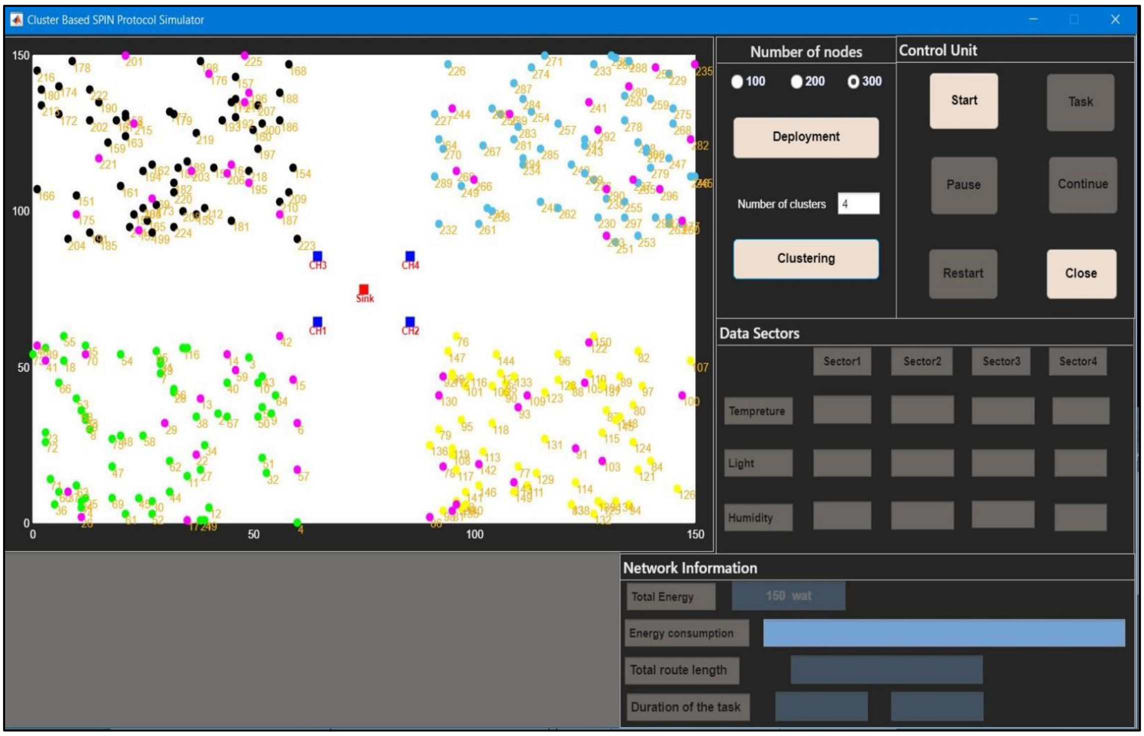


Figure 28: Network visualization

4.4. Sensor Model:

We used in our project the simulation of the sensor node that is defined in IEEE 802.15.4 (standard ZigBee). It is called TelosB sensor.

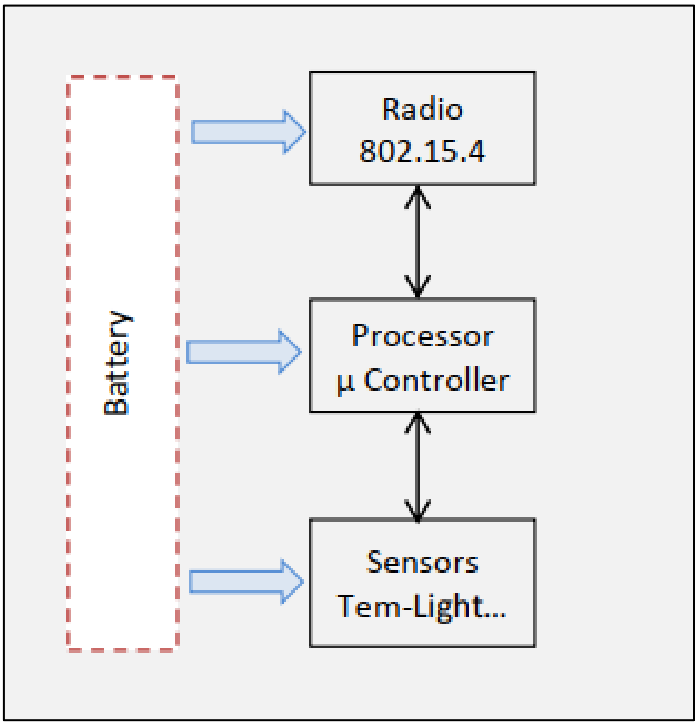


Figure 29: Block diagram of TelosB sensor

The TelosB mote is constitute of the component's basic sensor, processor and radio devices. It also can have additional application-dependant components.

TelosB sensor's settings	
Processor's performance	16-bit RISC
RAM	10 KB
Frequency band	2400 MHz to 2483.5 MHz
Outdoor range	75m to 100m
Indoor range	20m to 30m
Sensors	Light-IR-Humidity- Temperature … etc.
Battery	2×AA Batteries
User interface	USB

Table 4: Settings of TelosB sensor

4.5. Simulation Settings:

We will present the nominal values of the used settings in the tables below (Table 5, Table 6).

These tables include essential settings for the network and the number of clusters and the number of their Cluster-Heads, type of nodes and settings of simulation for GA. Knowing that K is number of clusters/cluster-heads.

Network Settings	
Size of the network area	150m × 150m
Clusters' number	k Clusters
Cluster-Heads' number	k Cluster-Heads
Deployment of the nodes	Random
Range of radio transmission	20m
Size of packet	120 bits

Table 5: Network simulator settings

Nodes' number					
Cases	**Total**	**Source nodes**	**Source nodes on each cluster**	**Cluster Heads**	**Sensor nodes**
Case 1	100	(20%)	(5%)	k	(80%)-k
Case 2	200	(20%)	(5%)	k	(80%)-k
Case 3	300	(20%)	(5%)	k	(80%)-k

Table 6: Nodes' Type

Settings of Genetic Algorithm	
Iterations' number	100
Probability of crossing	0,9
Probability of mutation	0,2

Table 7: Setting of simulation for GA

4.6. Project structure:

We can divide our project structure to two parts, functions and buttons that will be performed by those functions and that what we will present bellow.

4.6.1. Functions:

Our project can be performed only if we perform it within those functions that will be shown in the figure 30, and we will highlight the most important functions:

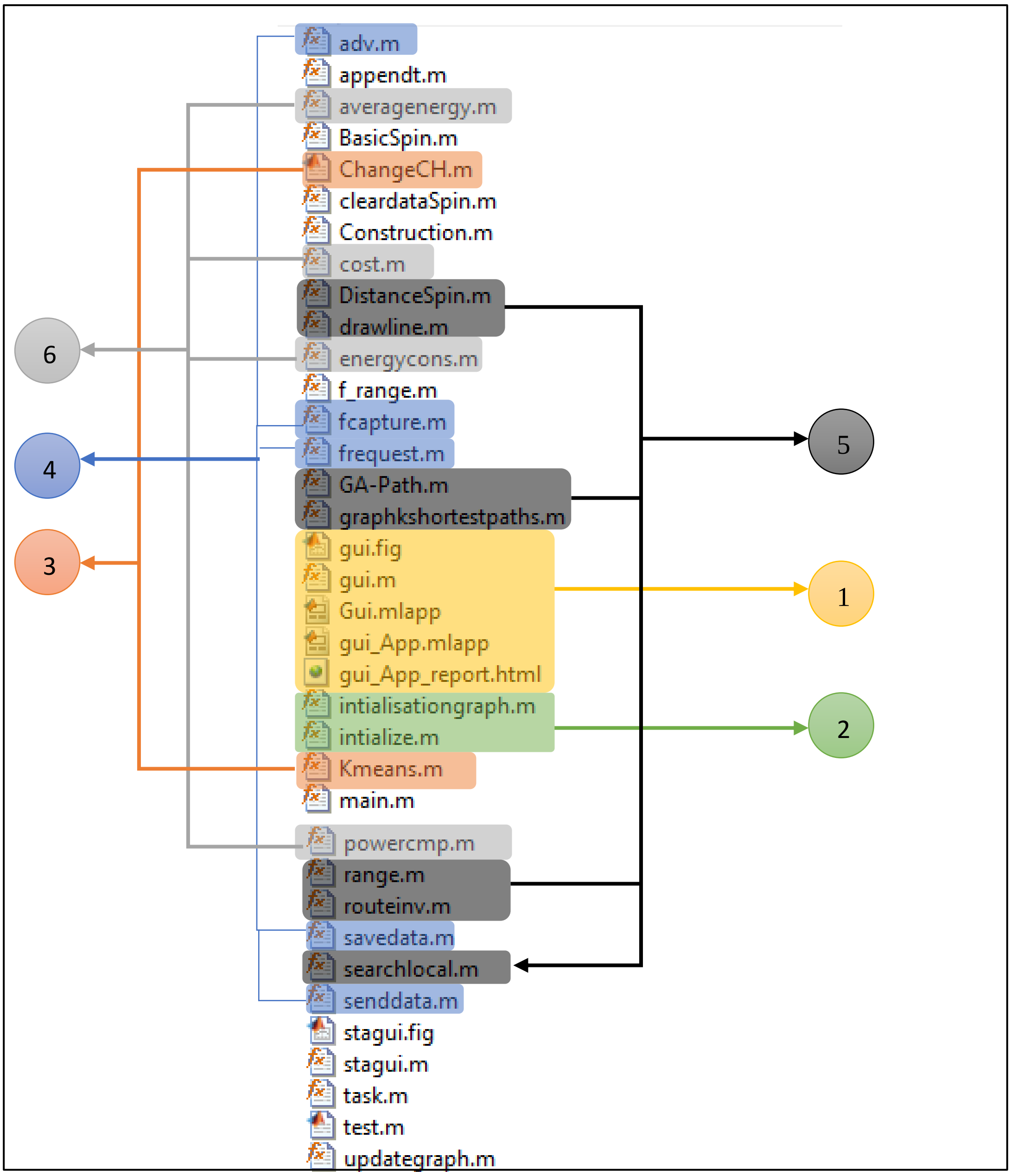


Figure 30: Application functions

1- **Application GUI functions:** those functions used to make our interface work well.

2- **Initialization functions:** those functions made to initialize our graph and deploy the nodes randomly.

3- **Clustering functions:** those functions have been done to divide our network to clusters in each cluster has its cluster-head that will be changed after it is less than 50%.

4- **Messages functions:** those functions are made to create and make our ADV, REQ and Data message and to perform data sending and saving.

5- **Discover path functions:** those function made to find, calculate and draw the best path from the source node to the sink passing by the CH.

6- **Energy functions:** those function made to calculate energy consumption.

4.6.2. Buttons:

The interface of the project some buttons that we will show and explain them bellow:

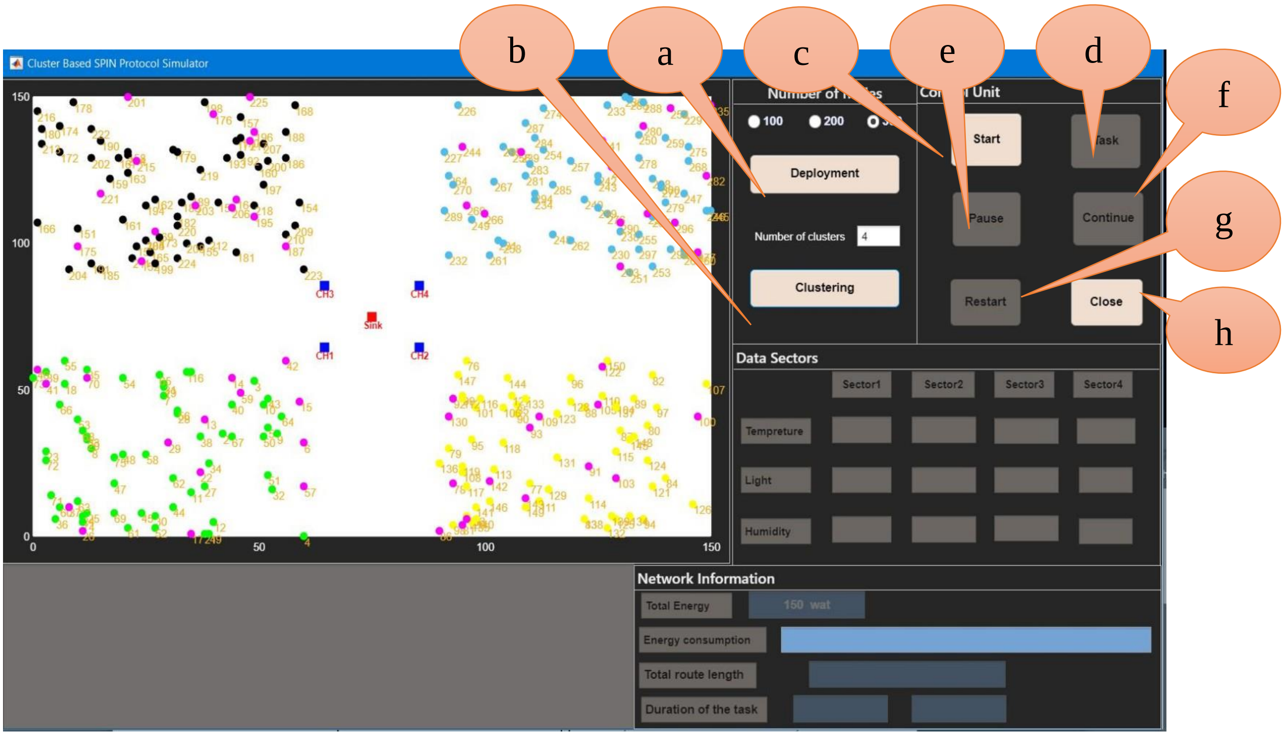


Figure 31: Application interface and its buttons

a. **Deployment button:** This button will deploy Nn number of nodes that will be checked from radio buttons that have three values “100,200 and 300” randomly in the network zone that will be centered by sink with the function “initialize.m” bellow:

```
function  intialize(handles,width,higth,Nn)
global Eintial
global S
global close
global gaspitiration
global clusters
global c1
global c2
global c3
global c4
gaspitiration = 300;
close = false;
Eintial = 0.5;
cla(handles.axes1);
% Creation four clusters
clusters = containers.Map;
clusters('1')= [];
clusters('2')= [];
clusters('3')= [];
clusters('4')= [];
% Set the Dimensions of the network area
handles.axes1.XLim = [ 0  width ];
handles.axes1.YLim = [ 0   higth];
% Creation the nodes with their properties
for i=1:1:Nn
if i <= 0.25*Nn
S(i).x = randi([0,width]);
S(i).y = randi([0,higth]);
S(i).E =  vpa(Eintial);
S(i).status = 'active';
```

```
S(i).radio = 20;
S(i).route = [];
S(i).inrange = [];
S(i).dataspin = false;
plot(handles.axes1,S(i).x,S(i).y,'o','MarkerEdgeColor','#808080, 'MarkerFaceColor','#808080')
text(handles.axes1,S(i).x,  S(i).y2,  num2str(i),'color','#EDB120');
    hold on;
end
% Total initial energy
Tenergy = Eintial * Nn;
set(handles.Tenergy,'String',[ num2str(Tenergy) '  wat']);
% Creation the Sink with its property
S(i+1).x = 0.5*width;
S(i+1).y = 0.5*higth;
S(i+1).radio = 15;
S(i+1).advs = [];
plot(handles.axes1,S(i+1).x,S(i+1).y,'--gs',...
    'LineWidth',0.2,...
    'MarkerSize',10,...
    'MarkerEdgeColor',[0.271,0.408,0.49],...
    'MarkerFaceColor','#FF0800');
text(handles.axes1,S(i+1).x-2,  S(i+1).y-3, 'Sink','Color','r','FontWeight','Bold','FontSize',10);
hold on;
% Set the color of axes1
set(handles.axes1,'XColor','white');
set(handles.axes1,'YColor','white');
end
```

Figure 32: “Initialize.m” code

b. Clustering button: this button will cluster our nodes with the function "Kmeans.m" to K node given by the user as we choose as an example before 4 clusters. Those clusters have K cluster-heads that will be changed after being lower than 50% by the sink with "ChangeCH.m":

```
function [ cluster, centr ] = Kmeans( k, P )
Nn = size(P,2); % number of points
dimP = size(P,1); % dimension of points
%% Choose k data points as initial centroids
% choose k unique random indices between 1 and size(P,2) (number of
points)
randIdx = randperm(numP,k);
% initial centroids
centr = P(:,randIdx);
%% Repeat until stopping criterion is met
% init cluster array
cluster = zeros(1,numP);
% init previous cluster array clusterPrev (for stopping criterion)
clusterPrev = cluster;
% for reference: count the iterations
iterations = 0;
% init stopping criterion
stop = false; % if stopping criterion met, it changes to true
while stop == false
    % for each data point
    for idxP = 1:numP
        % init distance array dist
        dist = zeros(1,k);
        % compute distance to each centroid
        for idxC=1:k
            dist(idxC) = norm(P(:,idxP)-centr(:,idxC));
```

```
        end
        % find index of closest centroid (= find the cluster)
        [~, clusterP] = min(dist);
        cluster(idxP) = clusterP;
    end
% Recompute centroids using current cluster memberships:
% init centroid array centr
    centr = zeros(dimP,k);
% for every cluster compute new centroid
    for idxC = 1:k
% find the points in cluster number idxC and compute row-wise mean
        centr(:,idxC) = mean(P(:,cluster==idxC),2);
end
% Checking for stopping criterion: Clusters do not chnage anymore
    if clusterPrev==cluster
        stop = true;
    end
    % update previous cluster clusterPrev
    clusterPrev = cluster;
    iterations = iterations + 1;
end
% for reference: print number of iterations
fprintf('kMeans.m used %d iterations of changing centroids.\n',itera
tions);
end
```

Figure 33: “Kmeans.m” code

c. **Start button:** This button will start the simulation by capturing and sending ADV, REQ and DATA message that will be routed by GA and will calculate the route length, energy consumption and task duration and will show the results in the task area. As we can see in the following figures (figure 34, figure 35, figure 36) the simulation of the pathing of the ADV, REQ and DATA message as a green line for the ADV message, blue line for the REQ and a red line for the DATA message:

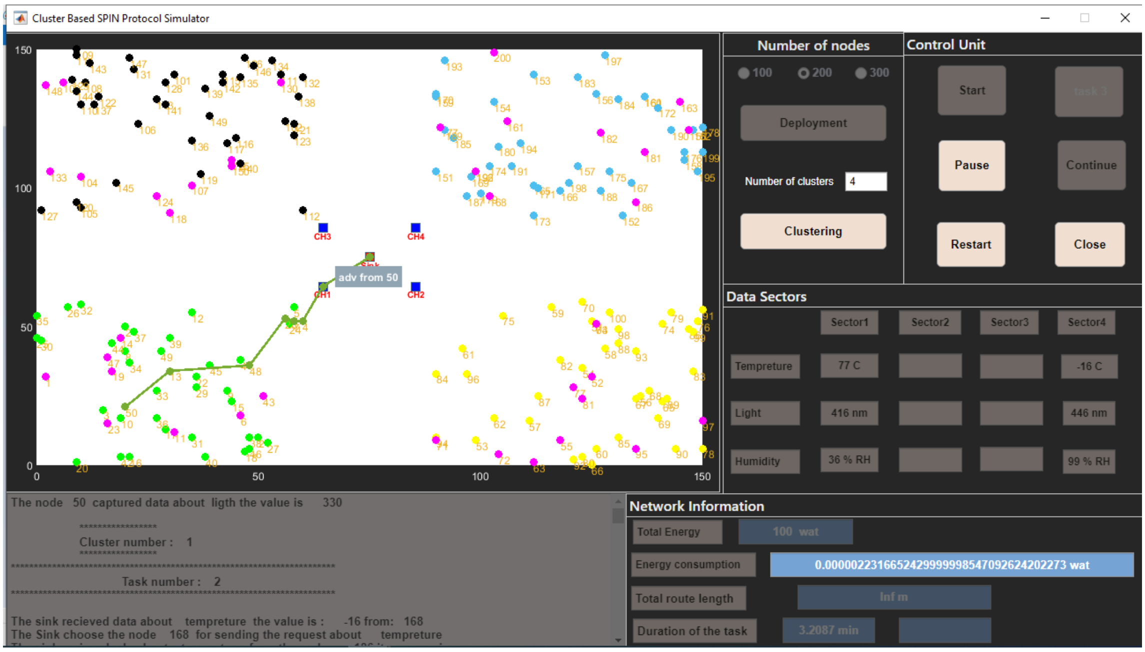


Figure 34: Simulation of the pathing of ADV message

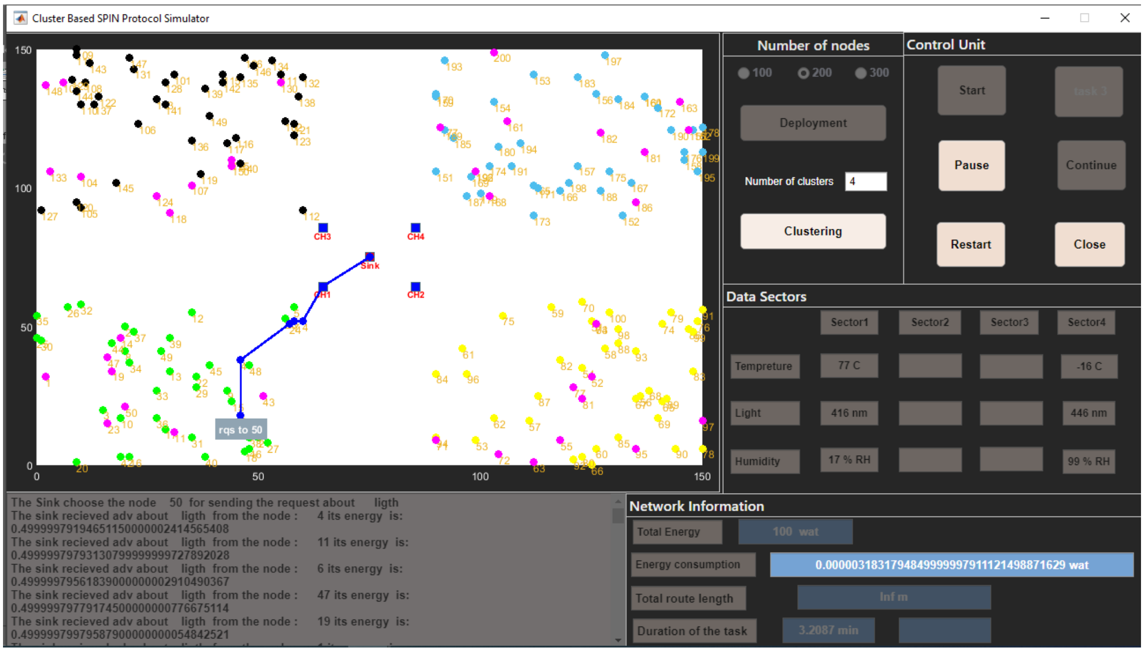


Figure 35: Simulation of the pathing of REQ message

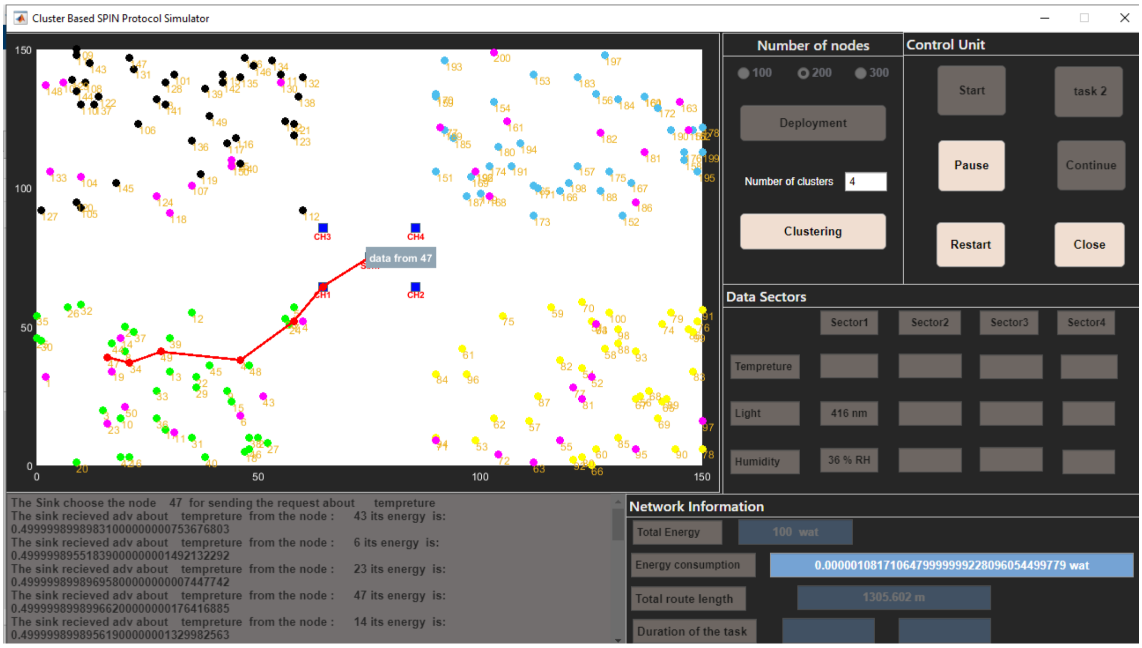


Figure 36: Simulation of the pathing of DATA message

- **d.** **Task button:** this button made to go to the next task after finishing the current task.
- **e.** **Pause button:** this button will pause the simulation and make continue enabled.
- **f.** **Continue button:** after pausing the simulation by the user, the continue button will be enabled to make the user continue the simulation when he wants to.
- **g.** **Restart button:** this button made to restart our application from the beginning so the user can deploy and start over.
- **h.** **Close button:** this button made to close our program.

4.7. Performance metric:

In order to evaluate our suggested and simulated protocol, we define the following performance measures:

4.7.1. Route's total length:

This is the sum of all sending messages routes such as ADV message, REQ message and DATA message.

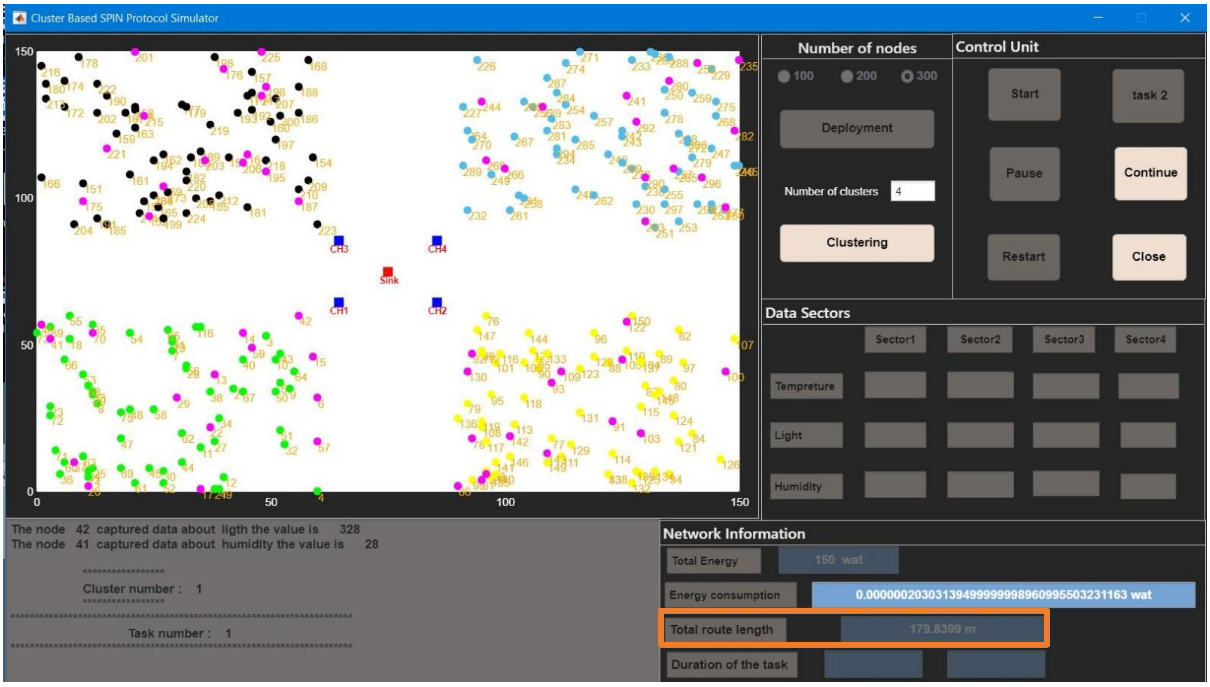


Figure 37: Route's total length

4.7.2. Energy consumption:

Here we can see the consumption of the whole operation of sending messages depends on the travelled distance in the route by the messages.

Figure 38: Energy consumption

4.7.3. Task's duration:

It is the presentation of the duration of the task or all the time to collect all data from the network during this task.

Figure 39: Task's duration

4.8. Results and discussion:

In this section we will present the results of route's length in 100 nodes and 200 nodes using 4 clusters as an example.

4.8.1. Route's length:

As we see bellow in the figure 40, and figure 41, that route's length in our protocol is way less than SPIN protocol all of that is due to the job of the cluster for reducing the number of messages and finding the most optimal route.

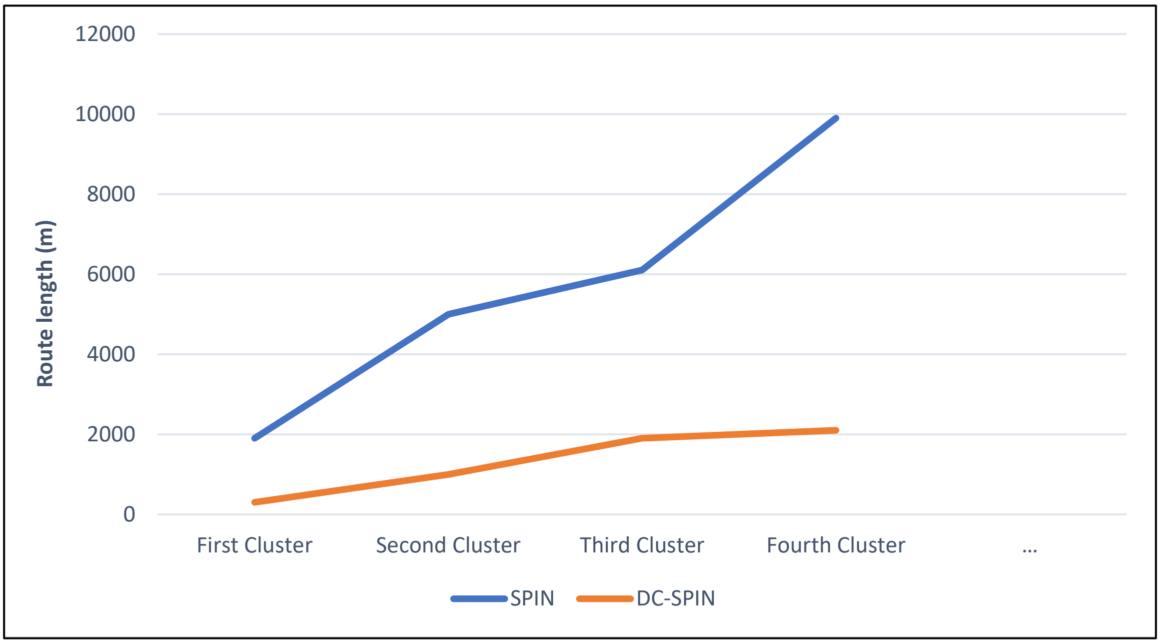


Figure 40: Route length of DC-SPIN and SPIN for 100 nodes

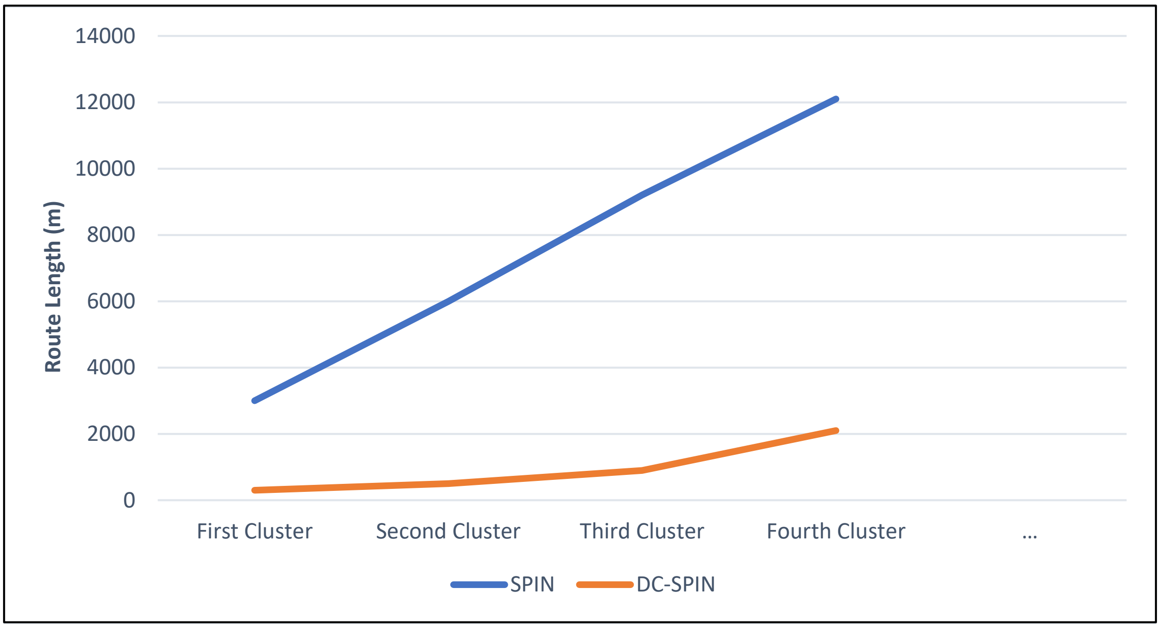


Figure 41: Route length of DC-SPIN and SPIN for 200 nodes

4.8.2. Energy consumption:

Since we got a way less route length by this protocol than SPIN protocol for sure we will get less energy consumption than SPIN. And that what the figure 42 and figure 43, present bellow:

Figure 42: Energy consumption of DC-SPIN and SPIN for 100 nodes

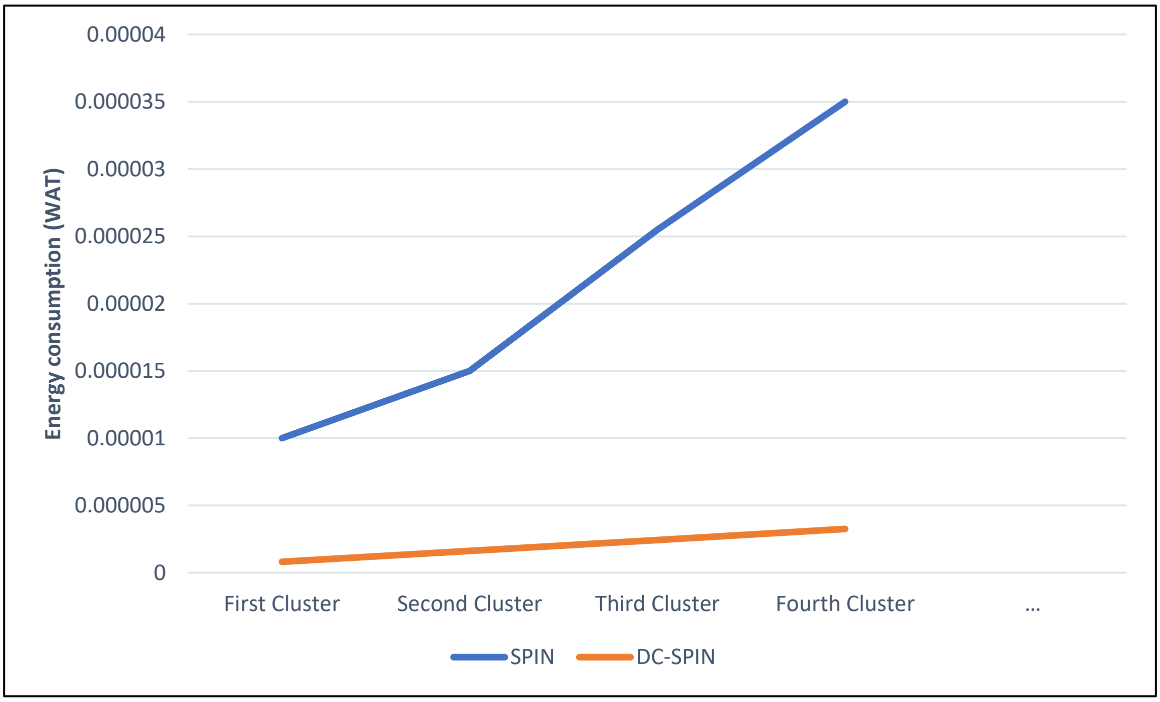


Figure 43: Energy consumption of DC-SPIN and SPIN for 200 nodes

4.8.3. Task's duration:

Due to the reducing of the number of messages and the length of the route, Task duration will be reduced also and that what we can see bellow in figure 44, figure 45:

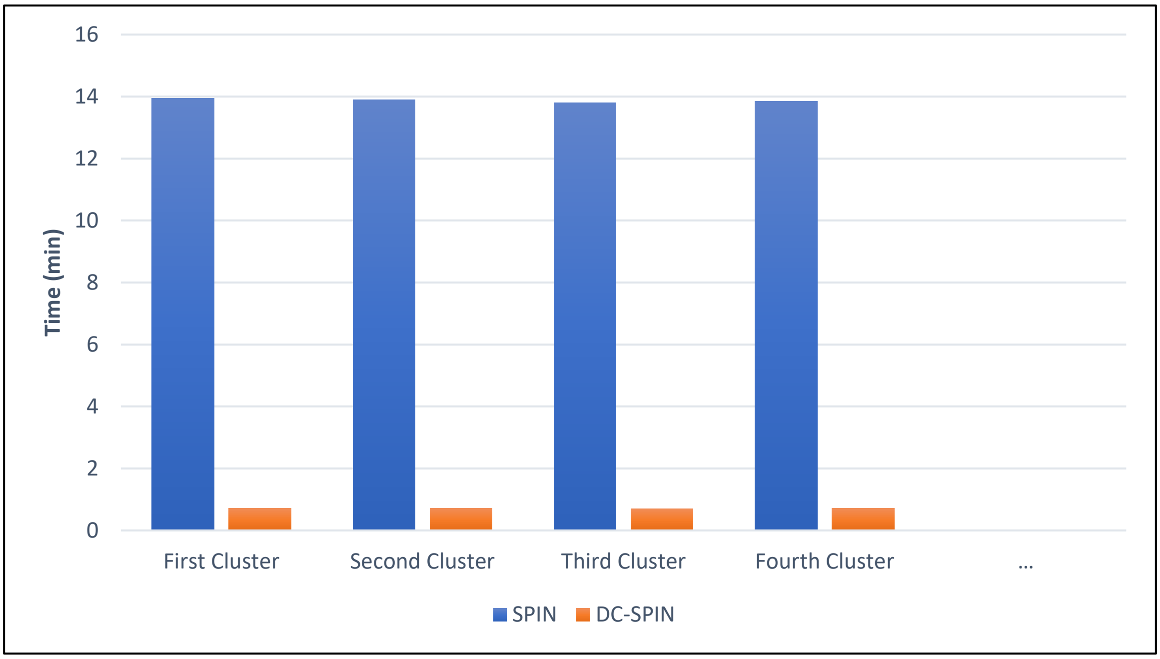


Figure 44: Task duration of DC-SPIN and SPIN for 100 nodes

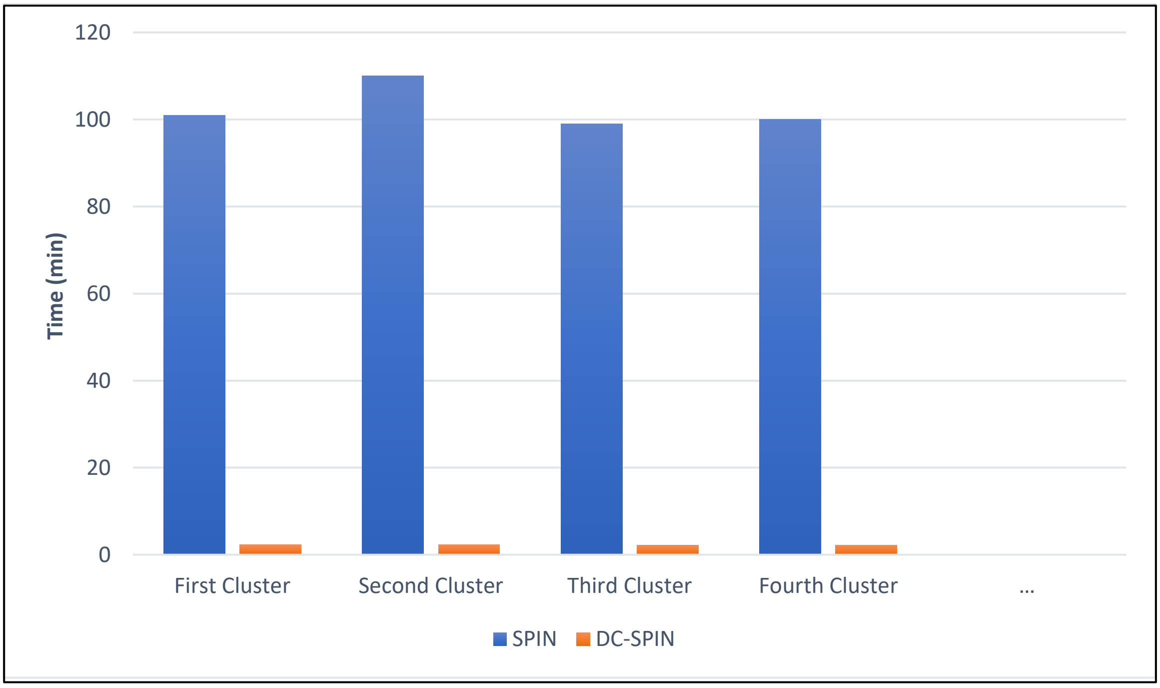


Figure 45: Task duration of DC-SPIN and SPIN for 200 nodes

4.9. Conclusion:

In this chapter, we've seen simulation tools and settings that used for the simulation, so as result of our simulation we found that our proposed protocol DC-SPIN much better than SPIN and we've seen that from obtaining results from simulation such as route's total length, energy consumption and task's duration. That means we achieved our goal which is maximizing network lifetime.

General Conclusion:

In this thesis, we saw what is WSN discussed it major problem which is energy consumption. To solve this problem, we proposed a new protocol that we named DC-SPIN based on SPIN protocol (Sensor Protocols for Information via Negotiation), we kept the main thing in this protocol which is the negotiation methodology and we made our research to reduce number of messages which will reduce many factors such as route length, energy consumption and task’s duration. And that operation has been done instead of broadcasting the ADV message and make a lot of routes possibilities to the sink just to maximize network lifetime.

DC-SPIN protocol has initialization and four steps:

- **Initialization:** this is the random deployment of the network centered by the sink.

- **Step 00: Partitioning:** this is the partitioning of the network that will be done by the sink to k clusters using K-means algorithm

- **Step 01: DATA advertising:** here the source will sense a data, then the cluster-head will find the best route from the source node to the sink passing by the CH.

- **Step 02: DATA Requesting:** here the sink check CHs first if there is a CH under 50% energy the sink will change it. After that, the sink will request the needed data after receiving the ADV messages and treat them and make the list of the nodes that will replay. Which will be sent after discovering the best way passing by the CHs.

- **Step 03: Data transmission:** any source node receive REQ message from the sink will send back DATA message to the sink using the same route discovered by the sink in DATA Requesting.

The results of the simulation proved that DC-SPIN much better than the basic SPIN by measuring energy consumption, route’s length and duration.

GENERAL CONCLUSION

DC-SPIN shows that he had a good succeed to improve the basic SPIN according to the results. In the future we may improve DC-SPIN by:

- Add the security to make the data more secured.
- Expand the network area and increase nodes number.
- Assign more work to the sink to reduce energy consumption more and more.

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