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Planification d'itinéraires basée sur l'algorithme GRASP dans les réseaux de capteurs sans fil.

BY:

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Acknowledgments

In the Name of Allah, the Most Merciful, the Most Compassionate all praise be to Allah, the Lord of the worlds, and prayers and peace be upon Mohamed His servant and messenger. First and foremost, I must acknowledge my limitless thanks to Allah, the Ever-Magnificent; the Ever-Thankful, for His helps and bless. I am totally sure that this work would have never become truth, without His guidance

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ملخص

تتكون شبكات الاستشعار اللاسلكية (WSNs) من عدد كبير من الأجهزة الصغيرة ، الموزعة مكانيًا ، والمستقلة ، تسمى عقد الاستشعار. وقد تم تجهيز الأخيرة بقدرات استشعار وحساب واتصالات لاسلكية ولديها موارد محدودة للغاية. لقد تم استخدام شبكات الاستشعار اللاسلكية على نطاق واسع في العديد من التطبيقات مثل المجالات العسكرية وتطبيقات الاستشعار عن الحركة والحلول الزراعية ومناطق الكوارث الطبيعية ... إلخ.

مصدر الطاقة الوحيد لعقد المستشعر هو البطارية. من الصعب جدًا إعادة شحن هذه البطارية أو استبدالها. لذا فإن استهلاك الطاقة هو موضوع مهم للغاية هو شبكات الاستشعار اللاسلكية.

في هذه المذكرة نحاول تقليل استهلاك الطاقة لعقد الاستشعار. نختار بروتوكول يسمى SPIN ونحاول تحسينه، بروتوكول SPIN له مزايا وعيوب. نقترح بروتوكولًا جديدًا يسمى GR-SPIN يدعم مزايا بروتوكول SPIN ويعالج عيوبه، لكن GR-SPIN تحافظ على الهيكل الأساسي لـ SPIN

يستخدم بروتوكول GR-SPIN خوارزمية GRASP (إجراء البحث التكيفي العشوائي الجشع) لتحديد المسار من العقد المصدر إلى Sink والعكس ، خوارزمية GRASP بسيطة وتحتاج إلى طاقة منخفضة جدًا أثناء الحوسبة. يقلل بروتوكول GR-SPIN من استهلاك الطاقة لعقد المصدر وبالتالي يزيد من عمر الشبكة.

الكلمات الرئيسية: شبكات الاستشعار اللاسلكية ، Sink ، SPIN ، خوارزمية GRASP، GR-SPIN ، استهلاك الطاقة ، اكتشاف الطريق .

Abstract

Wireless Sensors Networks (WSNs) consist of a large number of tiny, spatially distributed, and autonomous devices, called sensor nodes. The latter are equipped with sensing, computation, and wireless communications capabilities, and have very limited resources. Wireless sensor networks have been widely used in various applications such as military scenarios, sensing motion applications, agriculture solutions and natural disaster areas….

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 try to reduce the energy consumption of the sensor nodes. We choose protocol called spin and we try optimizie it, spin protocol has advantages and drawbacks. We propose new protocol called GR-SPIN Supports the advantages of the spin protocol and treat its drawbacks, but GR-SPIN Maintains its basic structure.

GR-SPIN protocol uses GRASP (Greedy randomized adaptive search procedure) algorithm to determine the route from the source nodes to the sink and vice versa, GRASP algorithm is simple and needs very low energy while computing. GR-SPIN protocol reduces energy consumption of the source nodes thereby maximize the network lifetime.

Keywords: Wireless Sensor Networks, Sink,SPIN, GRASP algorithm, GR-SPIN,energy consumption, route discovery,

Résumé

Les réseaux de capteurs sans fil (RCSF) se composent d'un grand nombre de dispositifs minuscules, répartis dans l'espace et autonomes, appelés nœuds de capteurs. Ces derniers sont équipés de capacités de détection, de calcul et de communications sans fil et disposent de ressources très limitées. Les réseaux de capteurs sans fil ont été largement utilisés dans diverses applications telles que les scénarios militaires, les applications de détection de mouvement, les solutions agricoles et les zones de catastrophe naturelle… etc.

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 le RCSF.

Dans ce mémoire, nous essayons de réduire la consommation d'énergie des nœuds de capteurs. Nous choisissons le protocole appelé spin et nous essayons de l'optimiser, le protocole de spin a des avantages et des inconvénients. Nous proposons un nouveau protocole appelé GR-SPIN qui prend en charge les avantages du protocole de spin et nous traitons ses inconvénients, en conservent sa structure de base.

Le protocole GR-SPIN utilise l'algorithme GRASP (procédure de recherche adaptative aléatoire Greedy) pour déterminer l'itinéraire entre les nœuds source et le puits et vice-versa, l'algorithme GRASP est simple et nécessite une énergie très faible lors du calcul. Le protocole GR-SPIN réduit la consommation d'énergie des nœuds sources, maximisant ainsi la durée de vie du réseau.

Mots-clés : réseaux de capteurs sans fil, puis, SPIN, Algorithme GRASP, GR-SPIN, consommation d'‘énergie, planification d'itinéraires.

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List of Abbreviations

WSN	wireless sensor network
ADV	advertise
RQS	request
msg	message
GRASP	Greedy Randomized Adaptive Search Procedure
SPIN	Sensor Protocols for Information via Negotiation
MAC	Media Access Control

General introduction

Today, wireless sensor networks are widely used in the whole world especially in the commercial and industrial areas such as for e.g. environmental monitoring, habitat monitoring, healthcare, process monitoring and surveillance.

Wireless Sensor Network (WSN) is a network contains hundreds or thousands of these sensor nodes. These sensors havethe ability to communicate either among each other or directly to the sink.each sensor node comprises sensing, processing, transmission, mobilizer, position finding system, and power units (some of these components are optional like the mobilizer)

The only energy source of the sensor node is the battery and the most cases it can not be Replaced or recharged. So, the energy consumption become very important issue in WSN and the question is how we can reduce the energy consumption of the sensor nodes to maximize the network lifetime. The Researchers in this field have suggested several thecniques to solve this problem, these techniques Includes Sensing energy, Communication energy and Processing energy but the most effective of them is techniques of Communication energy because the highest unit in the sensor node consumes the energy is the Communication unit.

The responsible to determine the route between the nodes to communicate is the routing protocol.So ,the optimazing of routing protocol Leads to Reducing energy consumption in an effective way.

In this thesis, we propose new protocol named GR-SPIN, it is the result of optimizing SPIN protocol. We choose SPIN protocol to optimize because it is designed Especially for WSN and it uses negotiation technical. The basic SPIN Protocol still has Problems such as Blind Forward Problem, Data Inaccessible Issue, Collision and Flooding. We propose solutions for these problems in GR-SPIN protocol and that is represented in reducing activity of sensor nodes as much as possible, decreasing the number of messages by making the transmission just between the source nodes and the sink and vice versa.also, making the most processing through the network in the Sink.The GR-SPIN uses GRASP algorithm is the route discovery process.

The structure of this thesis is as following:

The chaptre 1 presents a generality of wireless sensor network (WSN) and the sensor node including definition, architecture characteristics…etc. It also talks about the routing protocols in WSN and its classification according to the network Structure.

The chaptre 2 explains the power consumption of a sensor node with the rating the units in terms of energy consumption and an energy consumption model.this chapter represents energy efficient techniques in details.

The chapter 3 introduces the GR-SPIN Protocol and its the working mechanism with its steps and global, details description and general architecture illustrates how GR-SPIN work.

chapter 4 presents the tools of simulations , network model and the results of simulations to evaluate the performance of the GR-SPIN protocol compared of basic SPIN protocol.

Chapter 01

Wireless Sensor Network (WSN)

Chapter 1

Wireless Sensor Network (WSN)

1- Introduction:

Ad hoc network is defined as a self-configuring network without infrastructure that made of devices, and Wireless Sensor Networks (WSN) is an subset of ad hoc network in which the ”devices” are sensor nodes that are wirelessly interconnected. WSN is a new technology for collecting data with autonomous task oriented sensors.

Recently, this technology became more popular in today’s word for many reasons such as it can used in very harsh and poor environment where wired network can’t be deployed, also WSN save a lot of wiring cost and it can used in various application for all these reasons and more WSN is Widespread. And it is expected to continue expanding in the coming years, especially with the researches that you want to develop and make it easier to use.

2- Sensor node :

Is a tiny device that detects and measures amount of physical parameters, or event (such as temperature, pressure and vibration…etc.) in the physical word, and then translate them into signals that can be measured and analyzed [1].

XBee Sensor	WSN430 Sensor	MicaZ Sensor

Figure 01: Exemples of sensor node

2.1 The architecture of a sensor node:

Sensor node composed of four basic components as shown in figure 02 : a sensing unit, a processing unit, a communication unit, and a power unit. It can also has additional application-dependent components such as a location finding system, mobilize [2].

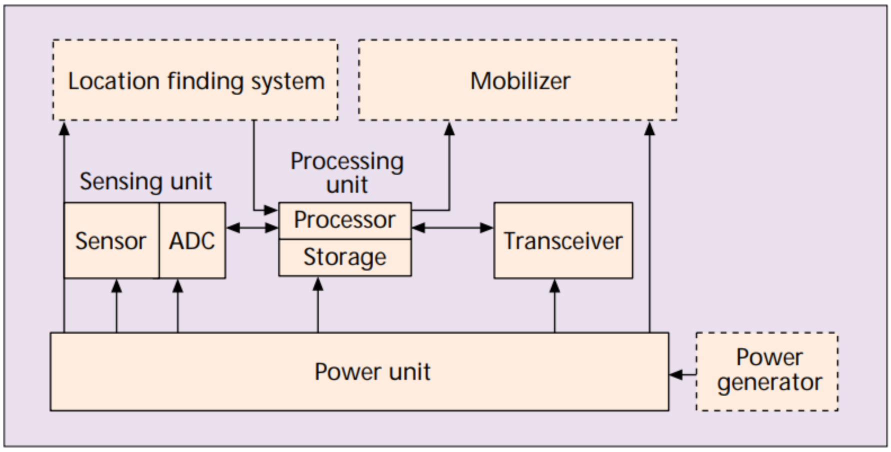


Figure 02: The components of a sensor node

- **A sensing unit**: is composed of two subunits sensor and analog-to-digital converters (ADC).the sensor produces the analog signals, and the ADC converts them to digital signals and send them to the processing unit [3].
- **A processing unit**: is the most important core of the sensor node, the Captured datais processed and stored in the memory [2][3].

- **A communication unit (transceiver unit)**:it is mainly used to transmit and receive the data to and from the other nodes within the network[2].
- **A power unit:**it is used to provide energy to all the components of the node, and it is neither rechargeable nor interchangeable, therefore it is very limited [4]

2.2 Sensor functions:

The sensors have threeprincipalfunctions:

- Sensing data
- Processing the sensed data
- Communicating with the other sensors within the network

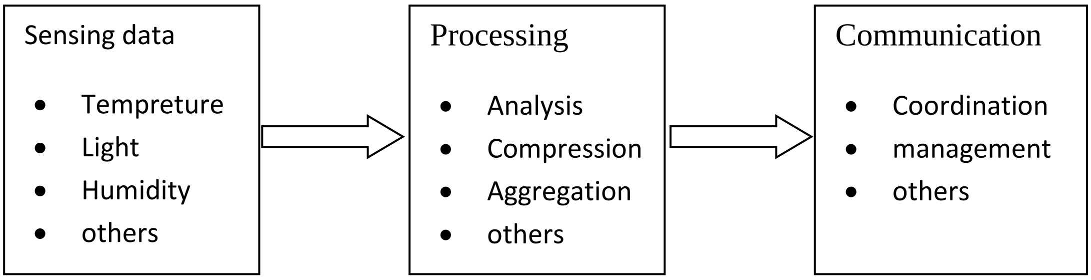


Figure 03: Functionality of a sensor node

2.3 Sensors type:

There are different types of nodes such as[5]:

- **Ordinary sensor node:**capable of executing data gathering, data processing and communicating with additional associated nodes in the network.
- **Sink node:**it is special node, it has higher resources than the other nodes, it receive all data from the nodes and can communicate with an external network (eg. internet)
- **Cluster head:** It is a high bandwidth sensing node used to perform data fusion and data aggregation functions in WSN
- **Actor node:**It is a high end node used to perform and construct a decision depending upon the application requirement
- **Relay node:** It is a midway node used to communicate with the adjacent node. It is used to enhance the network reliability

3- Wireless Sensor Network:

A WSN can be defined as infrastructure-less wireless network that is composed of a large number of sensor nodes which deployed in zone called sensing zone to gather information form it such as temperature, light, vibration…ect, the sensor nodes pass their data through the network to a main location or sink where it can be observed and analyzed[5][6].

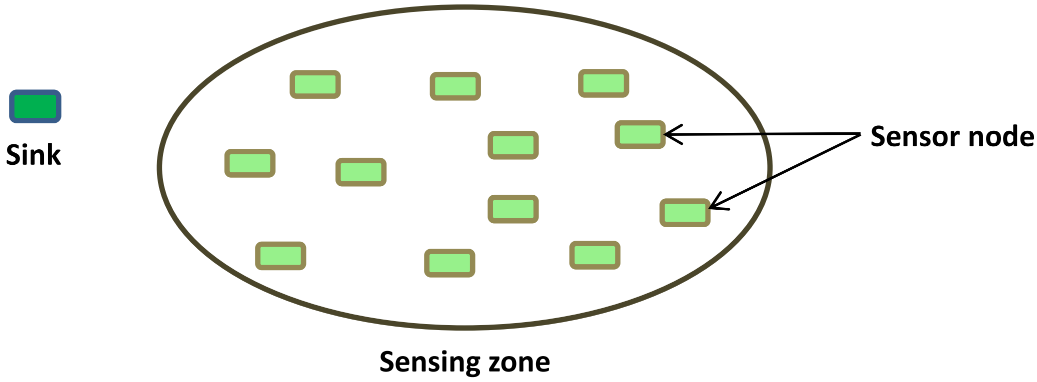


Figure 04: a General Wireless Sensor*Network*

3.1 Application of wireless sensor network:

There are various applications of wireless sensor network such as:

A. Military application: WSN be likely an integral part of military command, control, communications, computing, intelligence, battlefield surveillance, reconnaissance and targeting system.[5]

Figure 05: a Wireless Sensor Network in military applications

B. Health applications: Some of the health applications for sensor networks are supporting interfaces for the disabled, integrated patient monitoring, diagnostics, and drug administration in hospitals, tele-monitoring of human physiological data, and tracking & monitoring doctors or patients inside ahospital [1].

Figure 06: a Wireless Sensor Network in Health applications

C. Agricultural sector: using a wireless network frees the farmer from the maintenance of wiring in a difficult environment. Irrigation automation enables more efficient water use and reduces waste [5].

Figure 07: a Wireless Sensor Network in Agricultural sector

D. Environmental Applications: In environmental applications, sensor networks are increasingly used to monitor nature. Some environmental applications of WSNs include tracking the movements of birds, small animals, insects and natural disasters(earthquake, volcano…)

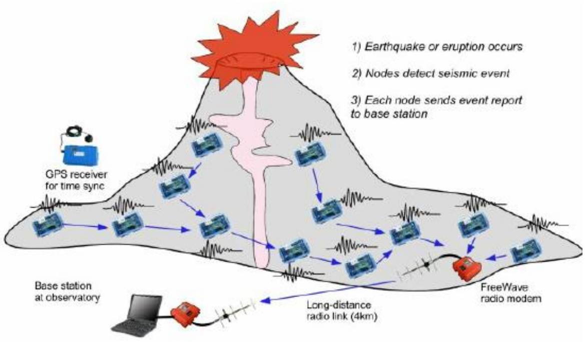


Figure 08: a WSN application for volcano monitoring [1]

E. Industrial Applications: a Wireless Sensor Network technology has demonstrated a great potential for industrial applications, specifically in monitoring data such as pressure, humidity, temperature, flow, level, viscosity, density and vibration. Measurements can be collected through sensing units and transferred wirelessly to a main system for operation and management. Adopting WSNs for process monitoring provides great advantages over traditional wired system [1].

Figure 09: a WSN application for Industrial Applications

3.2 The architectures of WSN:

There are different kinds of WNS's architectures, as following [8]:

3.2.1 Direct Communication Architecture:

Each sensor nodes communicate to the sink directly. Thus, this architecture is not appropriate for wide WSN's application, because it is not scalable.

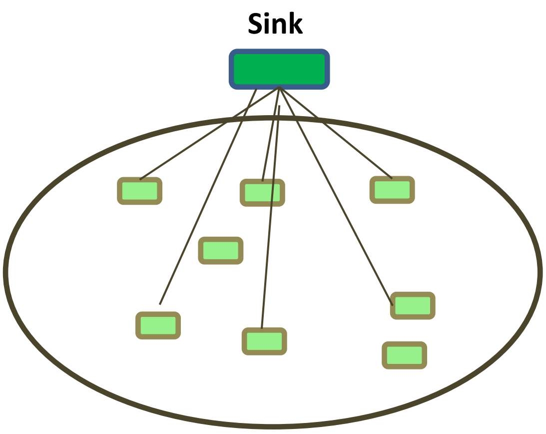


Figure 10: Direct Communication Architecture

3.2.2 Multi-hop and Peer-to-Peer Architecture:

This architecture in not scalable, because sensor nodes which place nearby to the sink, they are using for packets routing between other nodes and the sink, usually; therefore, if the WSN be widespread, traffic of such nodes will increase; consequently, their energy will be waste, consumed and finished; so they go out of the WSN, in fast;

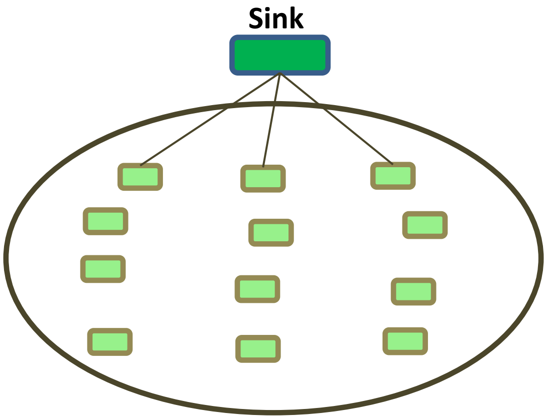


Figure 11: Multi-hop and Peer-to-Peer Architecture

3-2-3 Multi-hop Based on Clustering Architecture:

- Sensor nodes make a clustering structure;
- Choosing a cluster-head for any cluster; each cluster-head can communicate to the sink, directly; thus, each clusters' nodes send their gathered data to the corresponding clusterhead;
- Problem: the weakness of this architecture is most communication operations are doing by cluster-heads; thus, their energy will be consumed, decreased and wasted, sooner than other nodes (if the cluster-heads be had weakcapabilities or on homogenous WSNs);

• Solution: changing the role of cluster-head between corresponding cluster nodes, dynamically; or using from strong and heterogeneous cluster-heads;

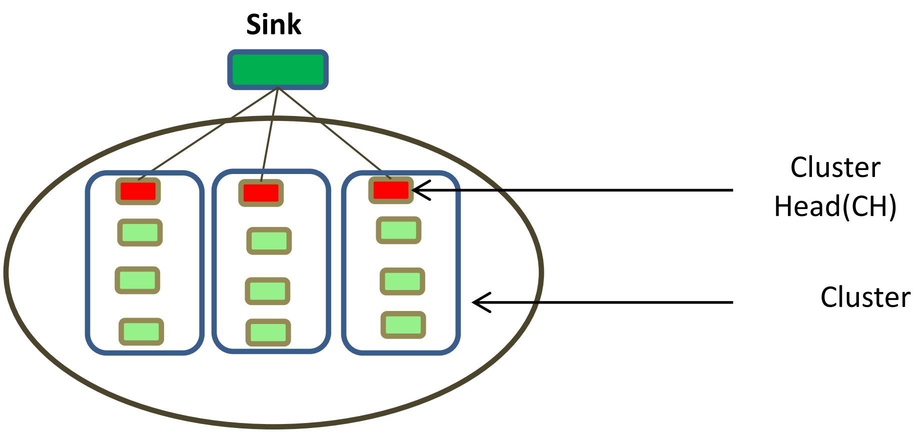


Figure 12: Multi-hop Based on *Clustering* Architecture

3.2.4 Multi-hop, Clustering and Dynamic Cluster-Heads Architecture

This architecture solves the weakness of previous architecture by dynamically change the role of cluster-head among corresponding cluster's nodes.

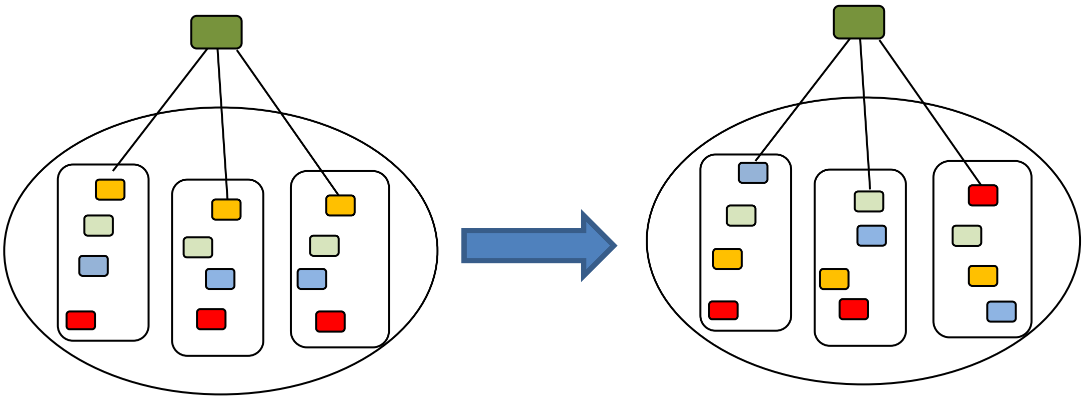


Figure 13: Multi-hop, Clustering and Dynamic Cluster-Heads Architecture

3.3 Characteristics of WSN:

A WSNhas several characteristics, we mention the following ones:

- Hardware limitations of sensor nodes:the sensor nodes have very limited memory, processing and power.
- Network lifetime limited: the sensor nodes powered by batteries but expected to operate for a long period, and it is infeasible and costly to replace once and mostly we can not access to nodes have been deployed to replace them. Then the network lifetime in short [9].
- Infrastructure-less: Network setups can be carried out without fixed infrastructure.
- Scalability: It might accommodate new devices at any time
- Security: weak secure, because hackers can enter the access network and obtain all the information.
- Wireless communications and weak connections.
- Self-organization: the sensor nodes in the network must have the capability of organizing themselves as the sensor nodes are deployed in an unknown fashion in an unattended and hostile environment.
- Multi-hop communication: a large number of sensor nodes are deployed in WSN. So, the feasible way to communicate with the sink or base station is to take the help of an intermediate node [10].

4- Routing Protocols for WSN :

The routing protocol is a process to select suitable path for the data to travel from source to destination. The process encounters several difficulties while selecting the route, which depends upon, type of network, channel characteristics and the performance metrics [11].

4.1 Routing challenges and design issues:

There are some major design challenges in wireless sensor networks due to limited of resources such as energy, bandwidth and storage of processing. While designing new routing protocols, the following essentials should be fulfilled by a network engineer [11][12][13]:

- **Energy efficiency:**

Wireless sensor networks are mostly battery powered. Energy shortage is a major issue in these sensor networks especially in aggressive environments such as battlefield etc. Energy presents a main challenge for designers while designing sensor networks. So, the routing protocol should be energy efficient.

- **Complexity:**

The complexity of a routing protocol may affect the performance of the entire wireless network. The reason behind is that we have inadequate hardware competences and we also face extreme energy limitations in wireless sensor networks.

- **Scalability:**

As sensors are becoming cheaper day by day, hundreds or even thousands of sensors can be installed in wireless sensor network easily. So, the routing protocol must support scalability of network. If further nodes are to be added in the network any time then routing protocol should not interrupt this.

- **Delay:**

Some applications require instant reaction or response without any substantial delay such as alarm monitoring. So, the routing protocol should offer minimum delay.

- **Robustness:**

Wireless sensor networks are deployed in very crucial and loss environments frequently. Occasionally, a sensor node might be expire or leaving the wireless sensor network. Thus, the routing protocol should be capable to accept all sorts of environments including severe and loss environments. The functionality of the routing protocol should be fine also.

➢ **Security:**

Security is one of the major challenges in WSNs. Most of the attacks that are performed on WSN are insertion of false information by compromised nodes within the networks. Development of security schemes for WSN also faces challenges related to constrained environment.

➢ **Fault Tolerance:**

Some sensor nodes may fail or be blocked due to lack of power, physical damage, or environmental interference. The failure of sensor nodes should not affect the overall task of the sensor network. If many nodes fail, routing protocols must accommodate formation of new links and routes to the data collection base stations.

4.2 Classification of Routing Protocols:

There are many ways to classify the routing protocols. Almost all of the routing protocols can be classified as Flat Routing, hierarchical Routing and Location based Routing according to the network strurcture.[12][13]

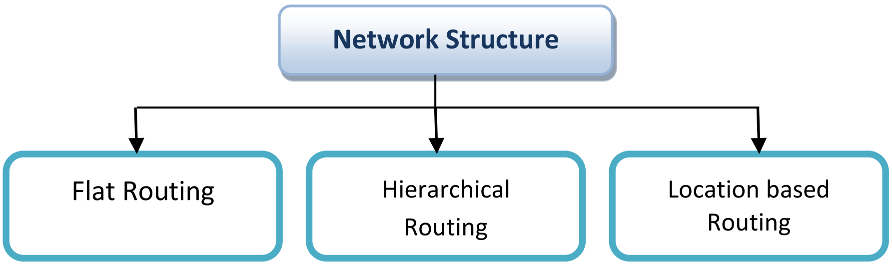


Figure 14: Classification of WSN Routing Protocols based on the network structure[12]

4.2.1Flat Routing :

In flat networks, each node typically plays the same role and sensor nodes collaborate together to perform the sensing task. In this type of network it is not possible to assign a global identifier to each node due to large number of nodes. Therefore, base station send queries to different part of the field and waits for the data from sensors in selected parts of the field. There are many protocols under this structure such as:

- Sensor Protocols for Information via Negotiation (SPIN)
- Directed Diffusion

- Rumor routing:
- Minimum Cost Forwarding Algorithm (MCFA)
- Gradient-Based Routing (GBR)

4.2.2 Hierarchical Routing :

Hierarchical routing works in two layers, first layer is used to choose cluster heads and the other layer is used for routing. To make the WSN more energy efficient, clusters are created and special tasks (data aggregation, fusion) are assigned to them. It increases the overall system scalability, lifetime, and energy efficiency. Examples of protocols in the following:

- Threshold sensitive energy efficient sensor network (TEEN)
- Adaptive threshold sensitive energy efficient sensor network (APTEEN)
- Low energy adaptive clustering hierarchy (LEACH)
- The power-efficient gathering in sensor information systems (PEGASIS)

4.2.3 Location based Routing :

In most cases location information is needed in order to calculate the distance between two particular nodes, so that energy consumption can be estimated. Generally two techniques are used to find location, one is to find the coordinate of the neighboring node and other is to use GPS (Global Positioning System). Examples of protocols in the following:

- Geographical and energy aware routing (GEAR)
- SPAN
- SPEED

5- Conclusion:

In this chapter, we introduced the basic concept of the WSNs technology and the overview on sensor node like the components of sensor node and the task of each one; we saw also the popular application of WSNs and explained the routing protocols and their classification according to network structure.

In the next chapter, we will discuss the energy consumption issue, energy consumption modal and the minimization techniques.

Chapter 02

Energy consumption of a sensor node

Chapter 2

Energy consumption of a sensor node

1- Introduction :

The use of wireless sensor networks is increasing day by day and at the same time it faces the problem of energy constraints. As each node depends on energy for its activities, In WSNs the only source of life for the nodes is the battery. It is undesirable to replace the batteries that are depleted or drained of energy; therefore the life time of the node depends on the life time of the battery.

In fact, the failure of one node can interrupt the entire system or application; as a resultthe energy consumption has become a major issue in wireless sensor networks.

2- Network lifetime definition:

The most challenging concern in WSN design is how to save the sensor nodes energy while maintaining the desirable network behaviour. Any WSN can only fulfill its mission as long as it is considered alive, but not after that. As a consequence, the goal of any energy efficient technique is to maximize network lifetime.

Network lifetime which is defined as the time until the first sensor's energy runs out is an important performance metric in WSNs[14]

3- The power consumption of a sensor node:

The energy consumption of a sensor node is typically distributed amongst communication, Computing and Sensing units as show in Figure 14.[15][16]

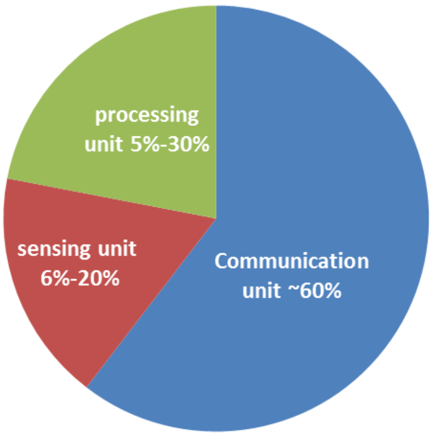


Figure 15: Energy consumption in sensing, processing, and communication [1]

3-1 Power consumption of the sensing unit:

The power consumed in the sensing unit in the least one,the sensing subsystem consists mainly of the sensors and an analog to digital conversion (ADC). The power consumed in the sensing subsystem is used in sensor sampling, which includes the wake-up and stabilization time associated with the sensor and the data acquisition time.

3-2 Power consumption of the Computing unit:

The power consumed in the Computing unit is a little bigger than sensing consumption; it is divided into two parts: 1) the switching energy which is determined by the supply voltage and the total switched capacity at the software level, 2) the leakage energy which corresponds to the energy consumed when the computing unit does not have any processing .

3-3 Power consumption of the Communication unit:

This power in the biggest one, it dominates the power budget with about 60% of the total available energy, it is mostly used in the transmission and reception. The energy consumption of this unit strongly depends of the communication protocols.

4- An Energy Consumption Model:

The energy consumption by a sensor node $\mathbf{E_c}$ is defined as the following equation [17]:

$E_C = E_{s/sensing} + E_{s/processing} + E_{s/communication}$ **(1)** Where:

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

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

$\mathbf{E_{s/communication}}$: the energy consumption of communication unit, it equals the sum of two values: E_{TX}which is energy transmissionandE_{RX}which is energy reception

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

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

$\mathbf{E_{RX}(k) = E_{elec} * k}$ **(4)** where:

K:the packet size (bits)

d: the distance between the transmitter and receiver

$\mathbf{E_{elec}}$**:**energy to run the transmitter or receiver circuitry

$\mathbf{E_{amp}}$**:**Transmit Amplifier

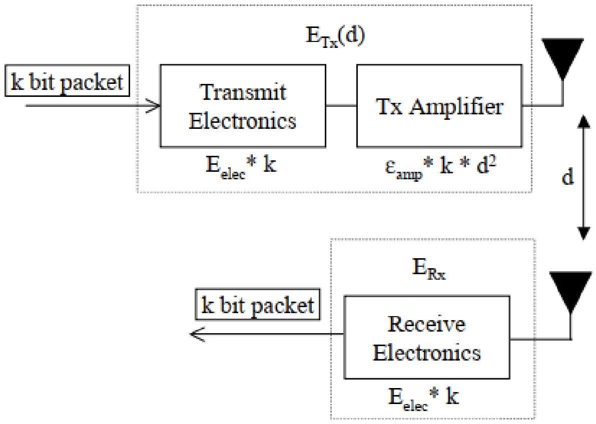


Figure 16: energy consumption model

According to this model, just the distance(d) between the transmitter and receiver and the packet size (k) are dominant factors in energy consumption.

5- Energy dissipation factors:

Energy consumption depends on several factors which are explained below:

5-1 Microcontroller Unit (MCU):

is responsible for control of the sensors and the execution of communication protocols and signal processing algorithms on the gathered sensor data. MCUs usually support various operating modes, including Active, Idle, and Sleep modes for power management purposes; each mode is characterized by a different amount of power consumption [18].

5-2 Radio:

The sensor node's radio is the component that consumed more energy than the other ones, it enables wireless communication with neighboring nodes and the outside world, and radios can operate in four distinct modes of operation [19]:

Transmit: Radio transmits a packet

Receive: The radio receives a packet

Idle: the radio is on, but it is not used (neither receiving nor transmitting), just listening.

Sleep: The radio is turned off

Naturally, the sleep mode is consumed the less energy, then must set them in this mode as long time as possible.

5-3 Medium access control:

The MAC layer provides access to the transmission support, transmission reliability, flow control, error detection and retransmission of packets, the nodes share the same transmission medium, and the MAC layer has so important tasks for coordination between nodes and minimization of energy consumption, therefore the principal causes of energy consumption in the MAC layer are:

5-3-1collision:

The sensor nodes generally have the same radio antenna and share the same transmission channel, there is probability of a collision to happened, consequently loss of information transmitted, Retransmission of lost packets can result in loss of energy.[20]

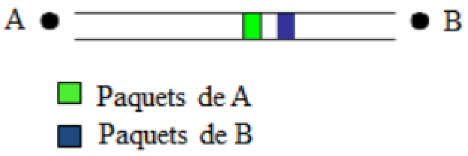


Figure 17:collision of transmission

5-3-2Overhearing:

The overhearing phenomenon occurs when a node receives packets which are not intended for it. Overhearing leads to additional energy loss.[20]

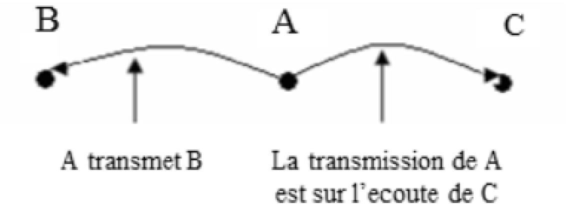


Figure 18: Overhearing of transmission

5-3-3 Overhead:

Many protocols of the MAC layer work by exchanging control messages to ensure different functionalities: signaling, connectivity, establishment of access plan and collision avoidance. All of these messages require additional energy [17].

5-3-4 Overemitting:

The phenomenon of overemitting occurs when a sensor node sends the data to a destination that is not ready to receive it. Indeed, the messages sent are considered useless and consume additional energy.[20]

5-3-5 idle listening:

Is one of the major sources of energy dissipation, It happens when a node is listening to an idle channel in order to receive possible traffic [20].

5-3-6 Packet size:

The size of the messages exchanged in the network has an effect on the energy consumption of the transmitting and receiving nodes. Indeed, increasing the size of the packets produces more energy, so large transmission power is required for large packets [21].

5-4 Data routing:

Sensor networks use multi-hop routing where the routing of packets from a given source to a destination is done through several intermediate nodes. The nodes of an adopted path consume energy either to transmit this data or to relay the data of the other nodes. a bad routing Increases energy consumption and negatively affects lifetime network.

6- Classification of Energy efficient techniques:

There are several classes of energy efficient techniques; we summarize them in the following schema (figure 17)

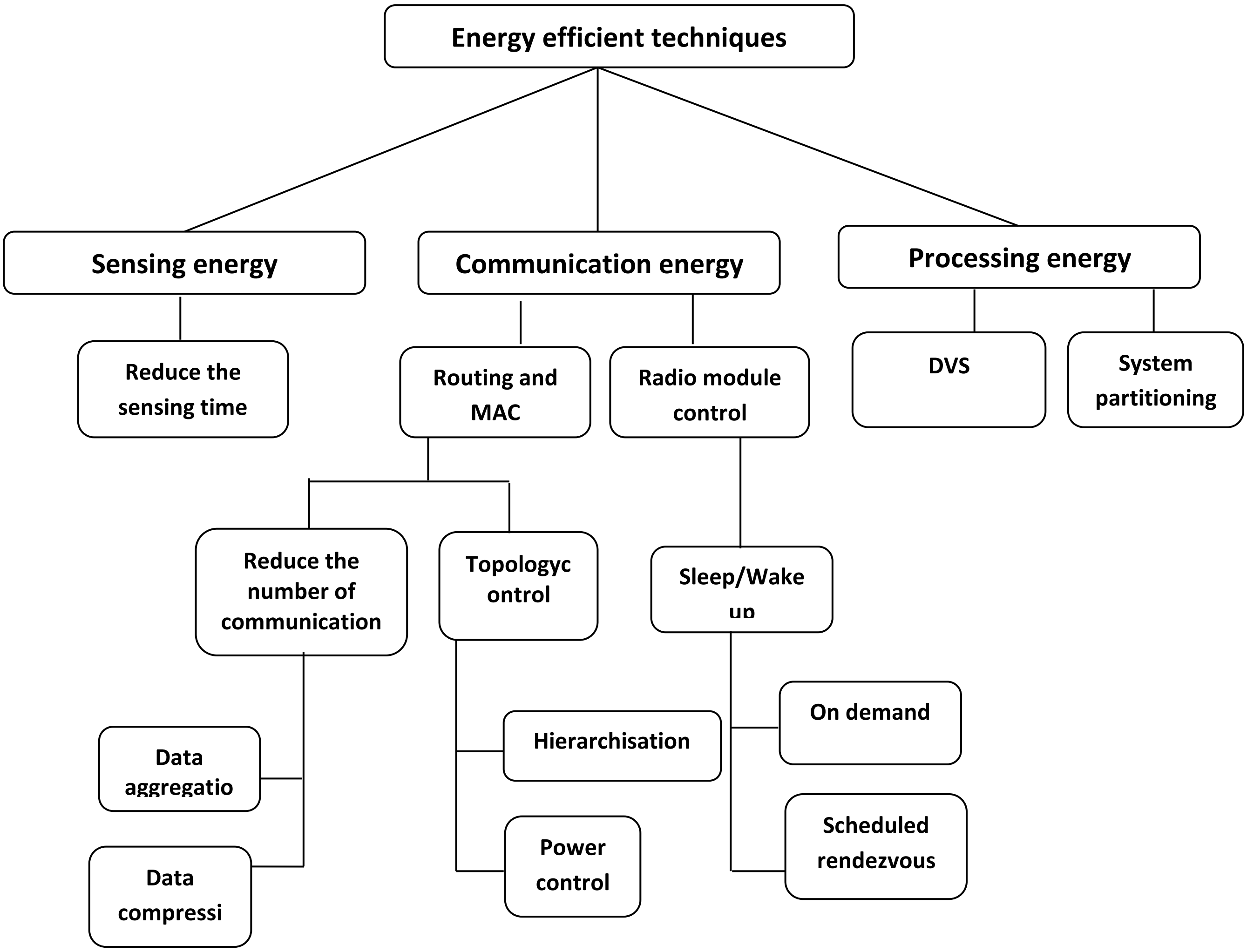


Figure 19: Classification of Energy efficient techniques

6-1 Sensing energy:

The only solution provided for minimizing energy consumption at the sensing is to reduce the sensing times.

6-2 Processing energy:

The processing energy can minimize by using tow techniques:

- **DVS approach (Dynamique Voltage Scaling) [22] :** consists of adaptively adjusting the supply voltage and the microprocessor frequency to reduce Processing power consumption with maintaining the performance.

- **The system partitioning approach:** consists in transferring a prohibitive calculation in processing time to a base station which has no energy constraints and has a large computation capacity [23].

6-3 Communication energy:

The minimization of communication energy consumption is summarized the following two aspects: Routing and MAC Protocols and Radio module control

6-3-1 Routing and MAC Protocols:

The routing and MAC protocols can minimize the energy consumption; these protocols arebased on reducing the number of communications or on controlling the network topology [24].

- **Reduce the number of communications:**

This technique base on the reduction of number of messages (transmission or reception) by using two operations:

- **Data aggregation:**

It is the operation that can form n received messages by a node, send just one message with summarized the information that is contained inthese n messages. This technique known also data fusion [25].

This technology reduce the number of messages in WSN.so, it very reduce the energy consumption.

- **Data compression:**

It reduces the number of bits to be transmitted and relayed by battery powered devices. Therefore, the network lifetime can be significantly extended [26]

- **Topology control:**

It focuses on reducing energy consumption by adjusting transmission power and grouping of sensor nodes (hierarchisation) [27].

- **Power control:**

Adjust the transmission power to a level just enough to reach the intended neighbouring receiving node, resulting in a lower energy consumption.[28]

- **hierarchisation:**

The nodes are organized in clusters and the cluster heads are responsible of data aggregation. Then cluster heads communicate directly with the sink.[29]

6-3-2 Radio module control:

The radio module control is an effective way to conserve energy. This aspect mainly includes the techniques "Sleep / Wake up" which are divided into two categories "on demand" and "scheduled rendezvous "[30][31]

- **On demand approach:**

It is the most intuitive approach to reduce power consumption. A sensor node should be awakened only when it receives a packet from neighbours. This technique uses multiple radios with low power and rate to inform the sleeping node about possible neighbours that are trying to communicate with.

- **scheduled rendezvous approach:**

Which ensures that all nodes wake up at the same time, According to a wake-up schedule, sensor nodes wake up and are still active for a short time interval to communicate with their neighbours and then, they go to sleep until the next rendezvous time? All sensors should be synchronized in order to wake up and work at the same time.

7- Related Work:

There are so many protocols can be used to minimize energy consumption. In our proposition, we chose SPIN protocol to optimize.

7-1 SPIN Protocol:

SPIN (Sensor Protocols for Information via Negotiation) that disseminates all the information at each node to every node in the network assuming that all nodes in the network are potential BSs. This enables a user to query any node and get the required information immediately. [34]

7-2 SPIN Messages:

SPIN nodes use three types of messages to communicate:[34]

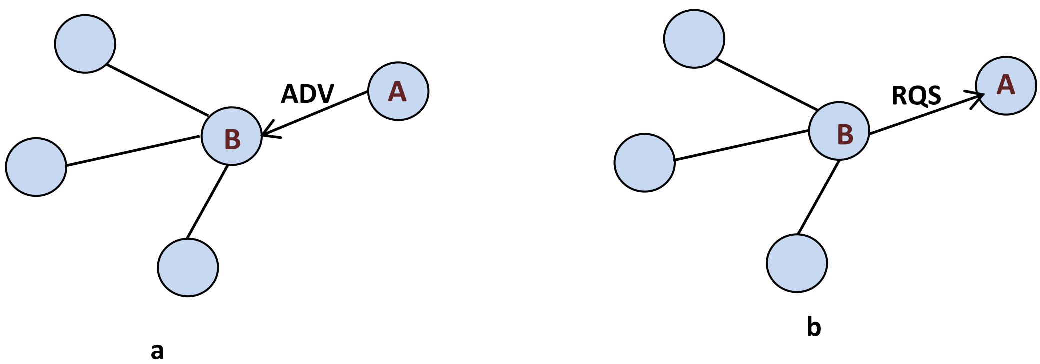
- **ADV:** new data advertisement. When a SPIN node has data to share, it can advertise this fact by transmitting an ADV message containing meta-data.
    - **Meta data:** Completely describe the data or the name of it. Meta-data size is very small as compared to the size of the DATA.
- **REQ:** request for data. A SPIN node sends an REQ message when it wishes to receive some actual data.
- **DATA:** data message. DATA message contain actual sensor data with a meta-data header.

Because ADV and REQ messages contain only meta-data, they are smaller and cheaper to send and receive than their corresponding DATA messages.

7-3 The Working Mechanism of SPIN:

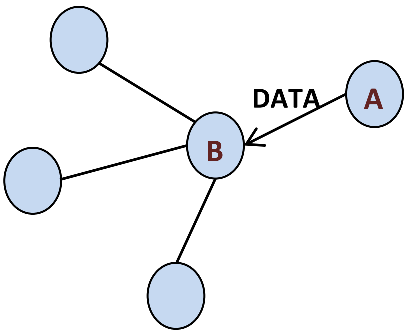
Communications in SPIN are done in three stages:

- When a node wants to send a data, it first sends an ADV message containing a description of the data.
- Any node received an ADV message consults its base of interest. If it is interested in this information, it sends a REQ message to the sender of ADV message.
- By receiving a REQ message, the sender transmits the data to the interested node.



(a): Node A has data and advertises it to node B.

(b): Node B responds by sending a request to node A.



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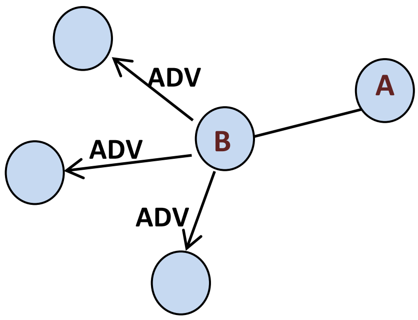

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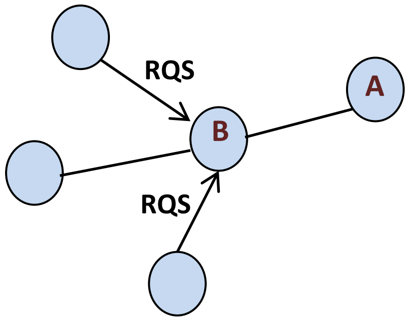
(c): Node A responds by sending a data to node B.

(d): Node B then sends out advertisements to its neighbors



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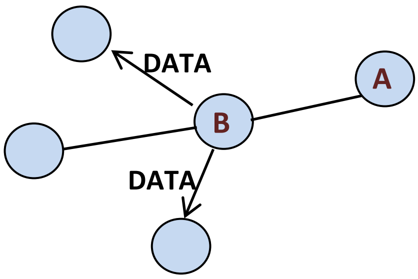

f

(e) and (f): this process is repeated until to access to all nodes.

7-4 advantages:

There are many advantages of the SPIN protocol, we mention the following [36][37]:

- Simplicity, each node only needs to know about its single hop network neighbours
- Minimizing the redundant data, negotiation mechanism almost halves the redundant data thereby reduce energy consumption of the nodes.
- It solves the implosion and overlap problem in the classic flooding protocol.

7-5 Drawbacks:

There are several drawbacks of the SPIN protocol, we mention the following:

- **Blind Forward Problem:** Source node will send the DATA packet to all the neighbor nodes that respond. Nodes who have received data will broadcast ADV message to all of its neighbors in a similar way, and send DATA packets to its neighbor nodes that respond. This process is repeated until the packets reach the destination. If the network has a new data to be sent, it must repeat the process. So this method could lead to a "blind forward" problem. It is not only a waste of energy, but doesn't take into account the balance of energy consumption of the network nodes.[37]

- **Data Inaccessible Issue :** In the SPIN protocol, if sensor nodes collect new data that need to be forwarded, it will directly broadcast ADV message to its neighbor nodes. In some cases, due to energy of itself, some nodes are reluctant to forward the new data; furthermore, a node's neighbour nodes are not interested in the source of the data or they already have the data. [37]

- **Collision:** In the SPIN protocol, the number of message for one data is big, if many nodes collect data in same time, the number of message will be huge and may causes Collision, and this can lead to the network unable to collect information, and make the WSN lose the meaning of application.

7-6 Studies :

There are several studies about SPIN Protocol. we mention the following ones in next table:

Title of the study	**Author**	**Proposed protocol**	**Description of the study**
SPIN-IT A Data Centric Routing Protocol for Image Retrieval inWireless 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

AModified SPIN for Wireless Sensor Network	ZeenatRehna, Sarbani Roy, NandiniMukherjee (2011)	Modified SPIN	Authors suggested that datamust 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 nodeand 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 Dissemination via Negotiation in Large scale Wireless Sensor Network	M. Tabibzadadeh, M. Sarram& M. Ghasemzadeh, (2009)	Cluster BasedSPIN (CBS).	The authors suggestedthat SPIN can be modified with the property of clustering for saving time and energy. It was named as Cluster 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 V. 1 Stadies about SPIN Protocol

8- Conclusion:

Energy consumption in sensor networks is still a persistent problem, In order to solve this problem. Researchers have been on working on solving this problem by using different techniques.

In this chapter, we saw where does the energy of a sensor node go and the energy consumption model. Also, we summarized the different energy efficient techniques in WSN. Also, we explained in details the SPIN Protocol.

The focus in the next chapter will be on our proposition to optimized SPIN Protocol according to GRASP algorithm (Greedy Randomized Adaptive Search Procedure) to select the best path from the source to the destination.

Chapter 3

Proposed protocol (GR-SPIN)

Chapter 3

Proposed protocol (GR-SPIN)

1- Introduction :

We saw in the previous chapter Energy dissipation factors, Classification of Energy efficient techniques. Also, we took overview about the SPIN Protocol and the studies that optimize this protocol. In this chapter we explain in detail our proposition to optimize SPIN Protocol with using GRASP Algorithm and we named GR-SPIN Protocol.

The objective of GR-SPIN is to minimize the energy consumption of all the nodes within the network and this leads to maximize the network lifetime.Also, to overcome the existed problem in the basic SPIN Protocol such as Blind Forward Problem, Data Inaccessible Issue, Collision and Flood. Features of GR-SPIN found solution of these problems, we reduced Activity of sensor nodes as much as possible, also we decrease the number of messages and we succeed to make the majority the processing in the Sink. All of these features enable the sensor nodes consume too little energy compared to the basic SPIN and therefore the maximization of the network lifetime.

2- The global description of GR-SPIN:

Initialization:

The partitionning of network area: We divided the network area horizontally and vertically into four equal regions.

The structure of GR-SPIN is shown in Figure 1, which includes the following three steps:

Step 01: Data advertising

In this step,the source nodes sense the data from the sensing zone.Then, discover the rote to the sink and send adv message to the sink.

Step 02: Data requesting

In the sink, after receiving the list of the adv messages. The Sink will treat them and decide who to send them rqs messages to ask the data. Of course before sending, the sink discovers the rote to the concerned source node.

Step 03: Data transmission

In this step, any source node receives rqs massage from the sink will send the data to it.

All of these steps are repeated in each region and in each task. We means with the task in the process to collect all data from the all regions

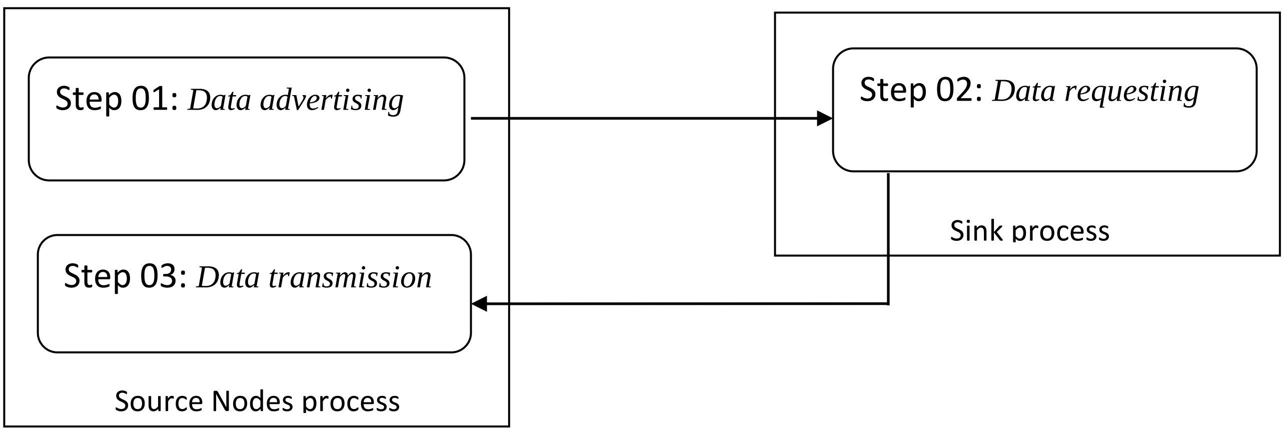

Figure 20: General Process of GR-SPIN

3- Detailed description of GR-SPIN:

In this section, we present the above three steps of the proposed strategy in more detail.

3-1 Step 01: Data advertising

Accomplish of this step is in the sources nodes, the following figure21 explains this step clearly.

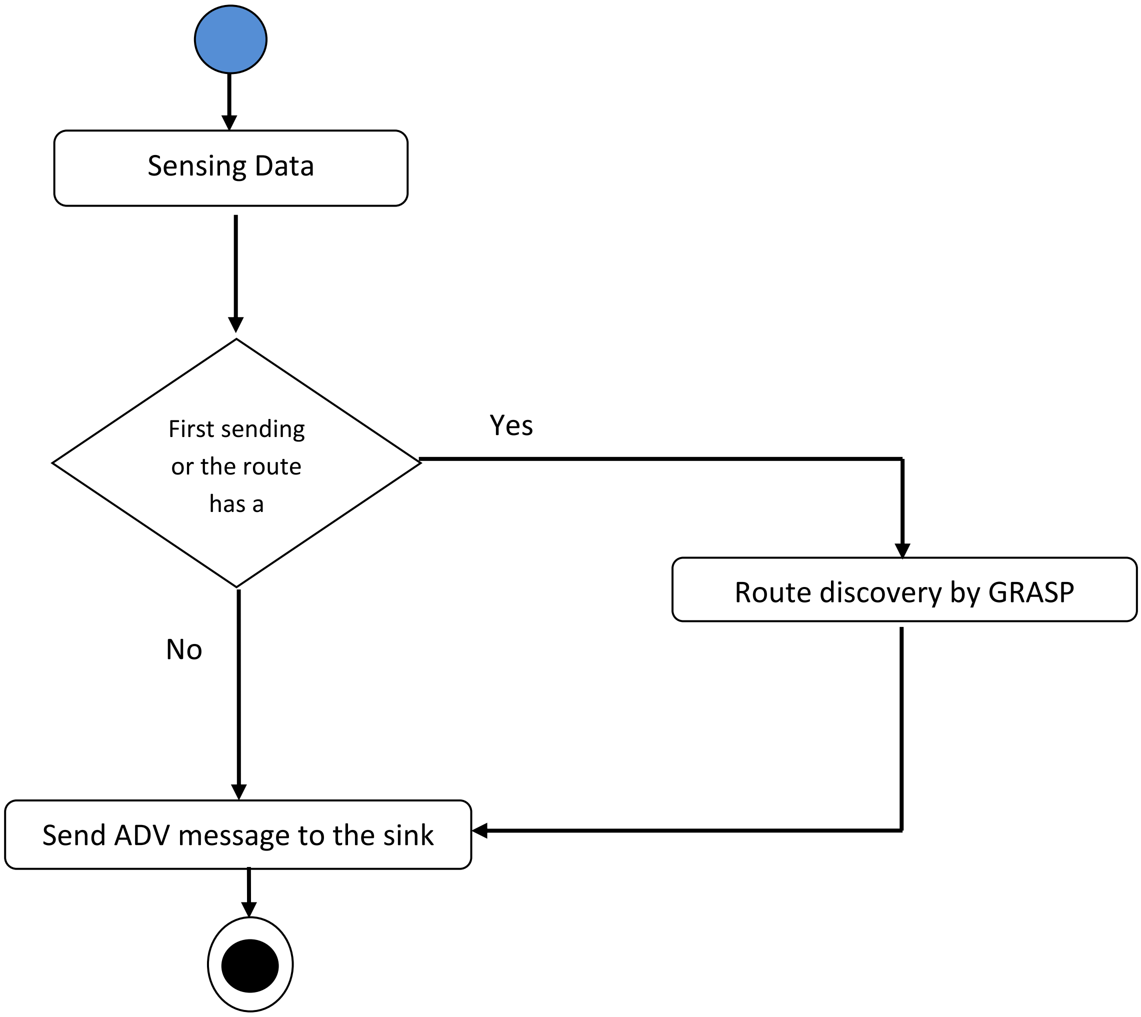

Figure 21: General process of Data advertising step

3-1-1Sensing data:

In our proposition we have three types of data Temperature, Humidity, Light. Their values are as following: Temperature from -40°C to 123.8°C, Humidity from 0 to100% RH, Light from 320 nm to 730 nm. Source node chose one data and its value randomly.

In basic SPIN, when source node sensed data, it broadcast adv messages and waiting for rqs messages and send the data to the sender of rqs message, this operation repeated until to the sink.This process affects energy in extremely negative way.

As we know any data sensed from the network must be sent to the sink, not matter to the other nodes. therefore,in the GR-SPIN any source node senses the data, it send it to the sink instead of broadcast, this process reduce the number of messages through the network and this leads to minimize the energy consumption and avoid collision and flooding.

In the process of the route discovery we take into account the balance of energy consumption of the network nodes to guarantee the maximize the network lifetime as much as possible.

3-1-2 route discovery:

Of course we need the route discovery process when the transmission indirect.

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

This task is responsible for determining the order of nodes (including source nodes) to be followed by the nodes from a source node to the sink or vice versa, according to the heuristic GRASP (Greedy randomized adaptive search procedure) algorithm.

We choose this algorithm because of its performance in terms of reduced computing time compared to other metaheuristics and clearly, for the quality of the final result.

GRASP (Greedy Randomized Adaptive Search Procedure) is a heuristic used for solving problems of combined optimization in which a new solution is found in each iteration through a randomized greedy procedure, This operation takes place in two phases:

The first phase: Construction of a solution which tries to build a circuit according to the semi-greedy algorithm.

The second phase: Local search which attempts to improve the route built in the first strategy by a local search. The final route will be the best solution obtain

The next figure explains general process of GRAP Algorithm.

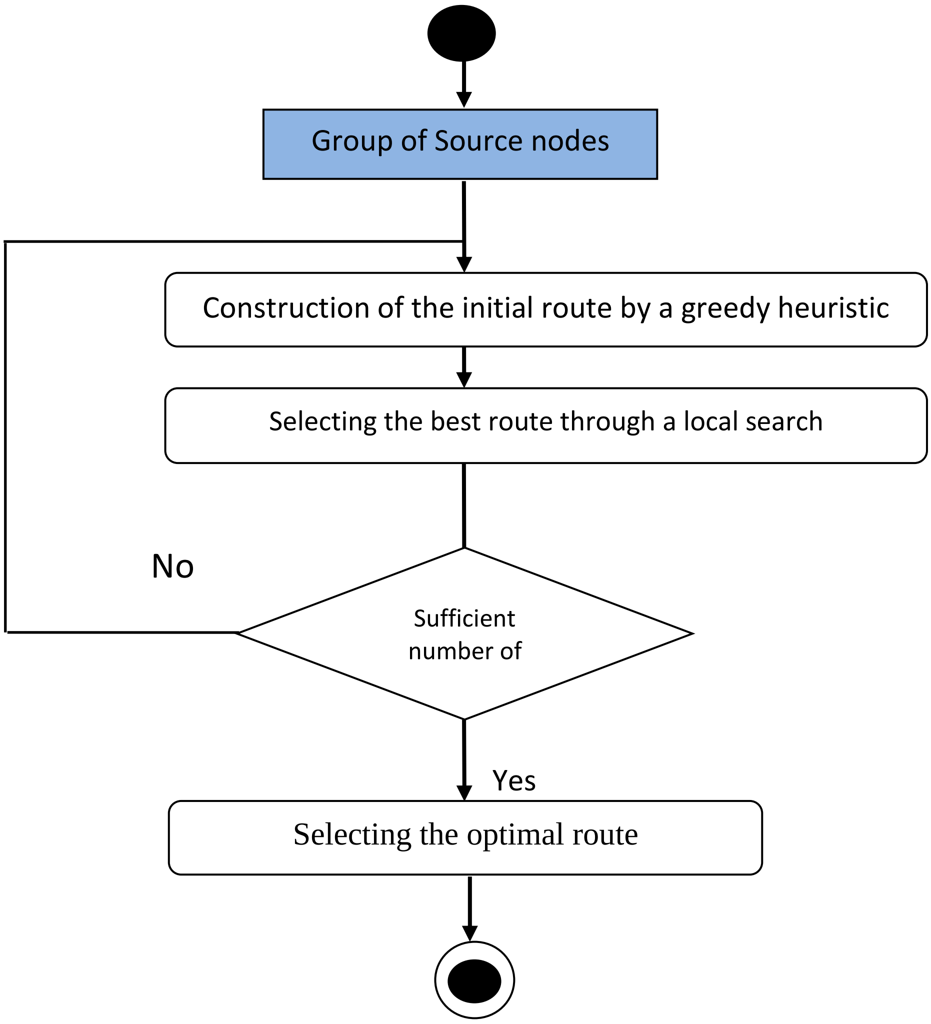

Figure 22: General process of Grasp [37]

A- Construction phase:

During the construction step, a circuit is iteratively produced; where each iteration adds an arc in the current partial solution.To determine which arc to add, we use a list of the best candidates obtained.(RCL: Restricted Candidate List) with a greedy function and we take a random arc from this list. After that, the RCL list is dynamically updated. This stage of construction continues until a complete solution is obtained.

The construction of the RCL is governed by a parameter α ϵ [0, 1]. The parameter αis used to control the randomness of the algorithm, if a is equal to one then the construction phase is totally random and if a is equal to zero, then the construction phase is totally greedy [38]

For our problem (minimization problem), RCL is constructed as follows.

$$RCL \leftarrow \{\in C \mid c(e) \leq cMin + \alpha\,(cMax - cMin)\}$$

Where:

C: list of all the possible arcs

e: the arc included.

$cMin$, $cMax$: the minimum and maximum incremental cost of 'C'.

c (e): the incremental cost of the arc 'e'.

The pseudo code for the build step is given below:

B- Local search phase:

Procedure GreedyRandomizedConstruction(α)
Solution ←ϕ
C ← E
Incremental cost assessment c(e) $e \in C$
whileC ≠ϕ
CMin←min$\{c(e), e \in C\}$
CMax←max$\{c(e), e \in C\}$
RCL ←$\{e \in c \mid c(e) \leq cMin + \alpha(cMax - cMin)\}$
Random selection of s from RCL
Solution ← Solution U {s}
update C
Revaluation of the incremental cost for $e \in C$
end
Return Solution

The route built by the previous step is not necessarily optimal. Due to this, GRASP performs a local search on the route obtained in the previous step in order to improve it, Local search is performed iteratively; it will replace the current solution with a better solution in the neighbourhood using the "First-improving" strategy, where the initial route is replaced by the first best neighbor found. The algorithm stops when no better solution is found.

The pseudo code for the local search step is given below:

Procedure RechercheLocal (Solution)
while(Solution not optimal)
Rechercher S′ while f(S ′) ≤ f (Solution)
Solution ← S′
end
Return Solution
end

After this step we will have a locally optimal solution that we will compare with the solutions obtained in each iteration, where each iteration is independent of the others, and takes place in the same way. The final solution will be the best solution obtained.

3-1- 3 send adv msg:

After the previous step, a source node knows the route to the sink. So, it sends adv msg to the sink.If the transmission direct (sink is in the transmission range of a source node) a source node send adv msg direct to the sink

3-2 Step02: Data requesting

The accomplish of this step is in the Sink, the following figure 23 explains this step clearly.

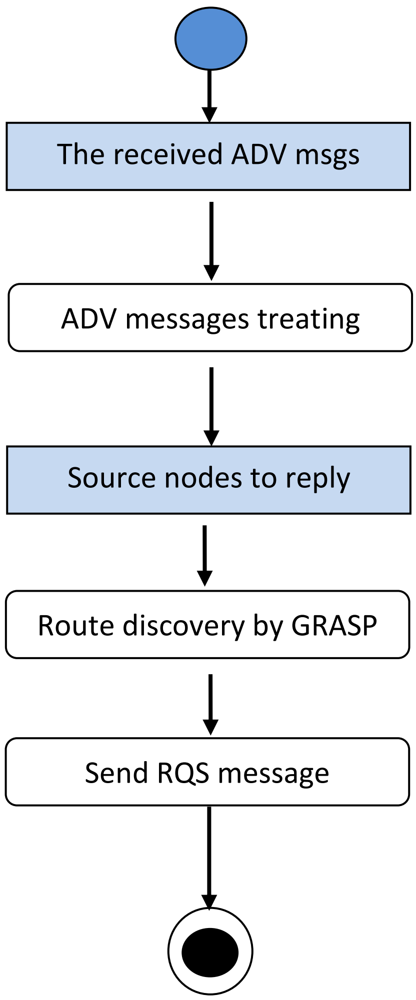

Figure 23: General process of Data requesting stage

3-2-1RQS msg treating:

After receiving the all adv message from the source nodes for each region,the adv message contains 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 message.

This task is realized as following:

For each region, the sink classes the name of data with the source nodes which sent this type of data (e.g the name of data is:light,the source nodes that sent data about light are the node number 98,13and 62)and then we have two possibilities:

- **First possibility:** no one of the source nodes sent this type of data (e.g all the source nodes did not send data about light),in this possibility the sink does not send rqs message, it move to the other types of data.
- **Second possibility:** just one source node sent one type of data (e.g just the source node number 12 sent adv message about humidity) in this possibility the sink Checks if it needs this data or not , if it needs this data will send RQS message to the sender ADV message.
- **Third possibility :** more than one node send adv message about one type of data(e.g the source nodes number 70, 85 and 3 sent adv message about temperature) in this possibility. First, the sink Checks if it needs this data or not, if it needs this data; for the balance of energy consumption, the sink will choose how has the highest energy rate and will send rqs message to The Chosen One.

This operation repeated for all types of the data.

3-2-2 Send RQS message:

After determining the source nodes to reply, the sink realizes the operation route discovery and send RQS message to them. One of content of the RQS messages is the route that used by the sink to send this message.

3-3 Step03: Data transmission

The process of this step is in the Sources nodes, the following figure 24 explains this step clearly.

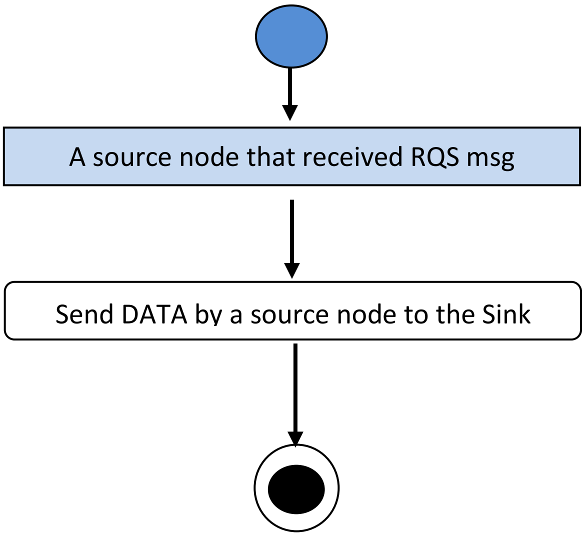

Figure24 : General process of Data transmission stage

Send DATA by a source node to the Sink:

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

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

The next architecture (figure 25) gives more details and explains our proposition clearly and simply

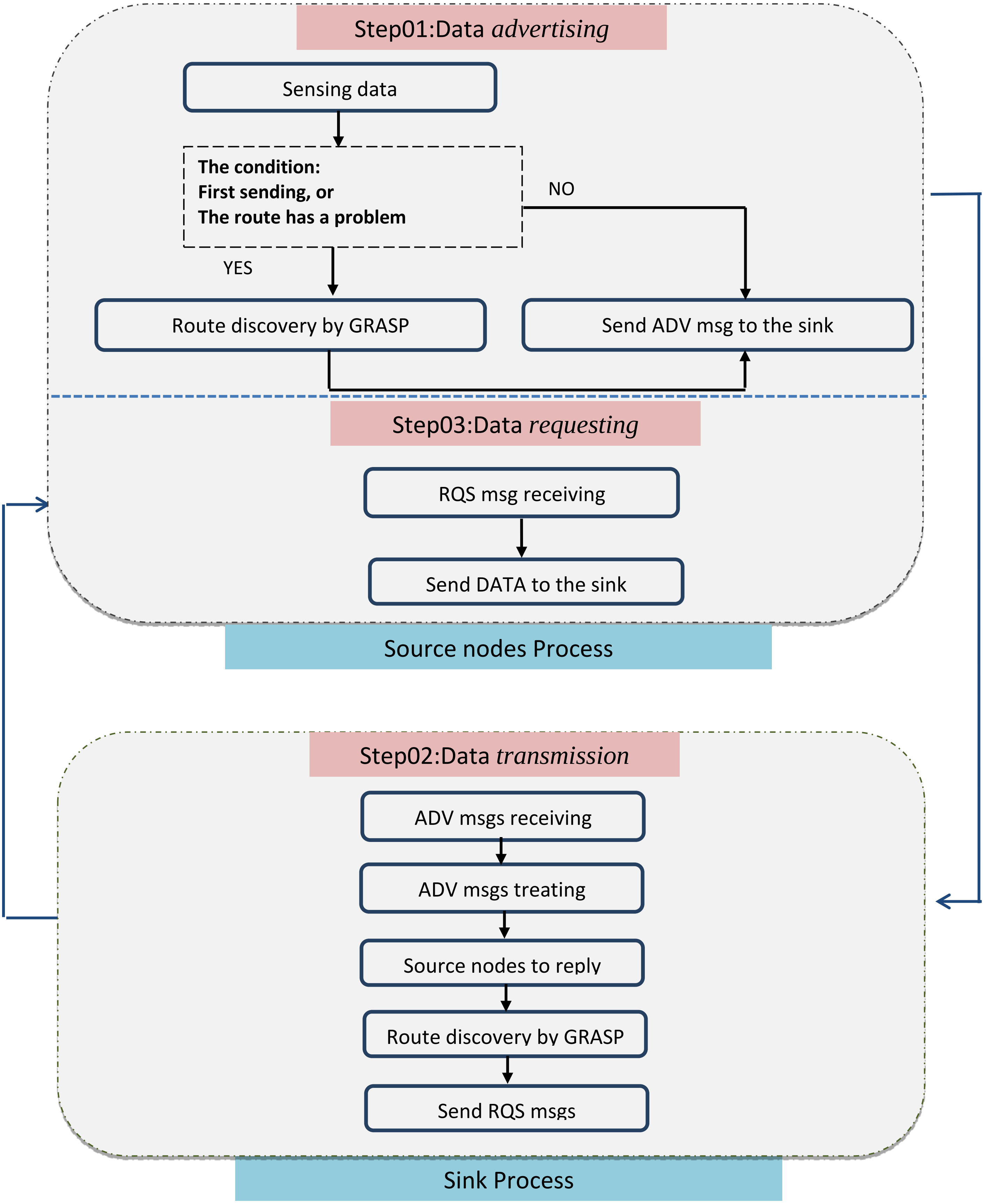

Figure25: Architecture general of our proposition

4- General operation:

The general process of GR-SPIN is described as following architecture:

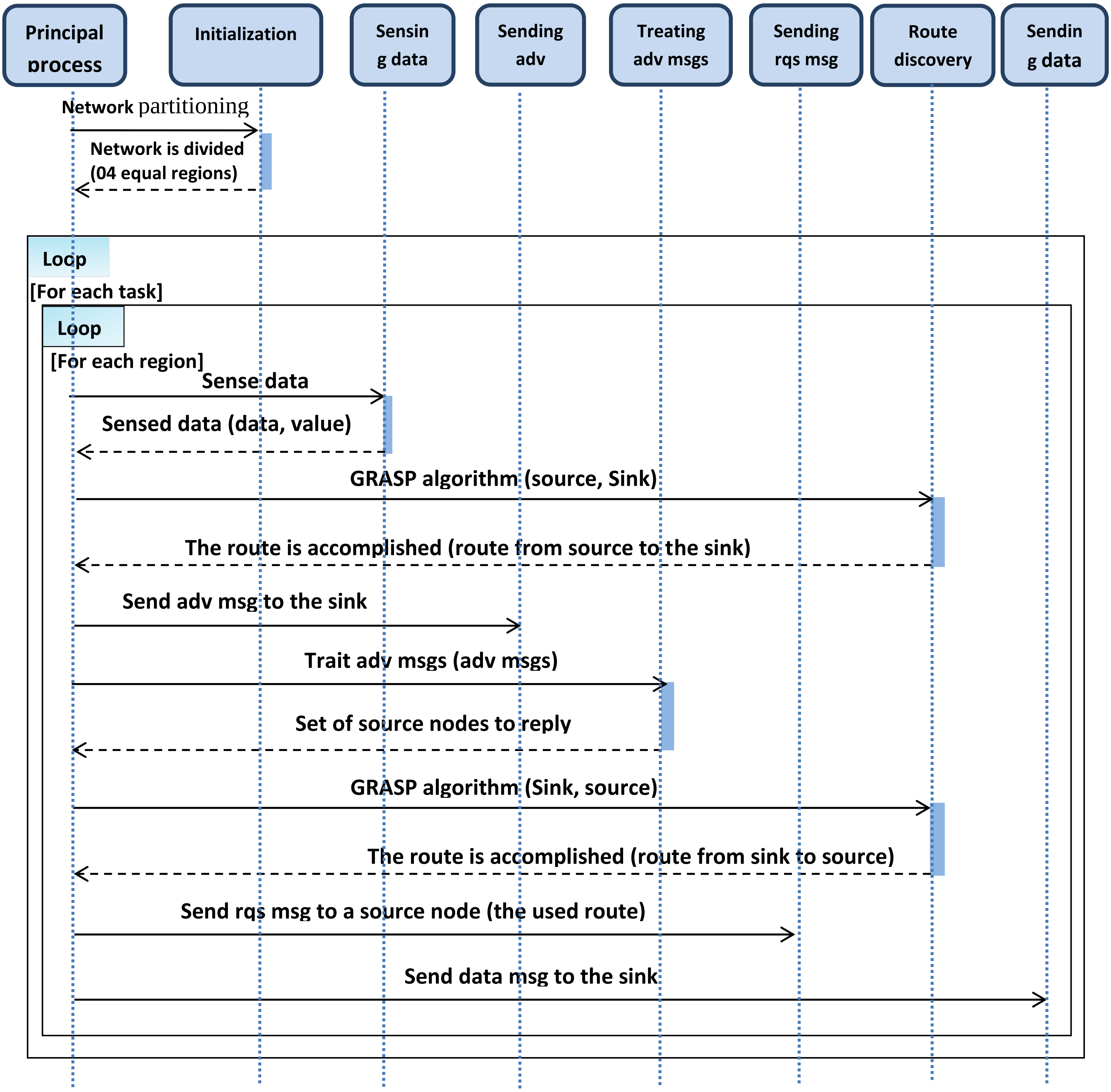

Figure 26: sequence diagram

- the Sink start the network partitioning, it divided the network vertically and horizontally into 4 equal regions.
- the source nodes sensed the data with its value.
- The source nodes that sensed data run the route discovery process to determine the route from itself to the Sink.
- After determine the route , they send avd message to the Sink.
- The sink received the adv messages and trait them to select the source nodes to reply by sending rqs message.
- The Sink runs the route discovery process to determine the route from itself to each selected source node.
- After determine the route , the Sink sends rqs message to each selected source node, this message contains the route that used by the Sink.
- Any source node receives rqs message it sends the data to the Sink by using the route that sent by the Sink.

All these operations are repeated in the 04 regions and they repeated for each task.

The task is the process to collect the data from the source nodes.

5- Conclusion:

In this chapter we introduced the GR-SPIN Protocol and we explain its The Working Mechanism, starting with global and details description and ending with general architecture illustrates how GR-SPIN work.

Our proposition contains several advantages compare of SPIN Protocol in energy conservation and this is reflected in the following,we reducedthe Activity of sensor nodes as much as possible,we moved the most processing in sink. We decreased the number of messages where the transmission became only between the sink and source nodes or vice versa with multi-hop transmission by using GRASP algorithm in the route discovery operation.GRASP algorithm are very simple, clear and needs atoo little energy to process. All these features can greatly reduce energy consumption of the source nodes; thereforewe achieve the maximization of network lifetime.

The next chapter will be devoted mainly to the implementation of GR-SPIN.

Chapter 4

Implementation and results

Chapter 4

Implementation and results

1- Introduction :

The previous chapter covered an analysis of the description and modeling of GR-GRASP Protocol and explained the advantages of GR-GRASP compared of basic SPIN protocol.
This chapter presents the simulation results obtained from the execution of the program that we have implemented, as well as its analysis and validation. Also, we present the tools and development platforms used to implement the various components of the system.

To find out the performance of GR-SPIN,we deployed the sensor nodes randomly in the sensing zone. Then, we used Grasp algorithm (Greedy randomized adaptive search procedure) in the route discovery process to identify the route froma source node to the sink and versa vise (from the sink to asource node). GRASP is a semi-stochastic algorithm of reduced complexity compared to other heuristic algorithms. We executed GRASP algorithm for many iterations to obtain optimal results.

2- Simulation tools:

For coding and simulating GR-SPIN Protocol, we used the next tools:

Software:

Programming language: matlab language due to its features such as ease of use, robustness, has various libraries can be used easily, develop application with graphics user interface. Also, it is very effective in simulation, optimization (solve problem) …etc.

Figure27: Matlab icon

Hardware:

we used an "Dell" laptop with the following characteristics :

Processor: Intel(R) Core(TM) i3 CPU M

RAM: 8.00 GB(7.80 GB usable)

System type: 64-bit Operating System, x64- based processor

3- Network Model:

The network dimension in 100m × 100 m, we divided it vertically and horizontally into 4 equal regions. Then, we deployed the sensor nodes randomly. The source nodes are 20% from the total number, we distributed it into 5% for each regions. The base station (Sink) is located in the centre of the area as shown in figure1. To verify the quality of GR-SPIN, we determined three cases, small scale with 100 nodes, medium scale with 200 nodes and large scale with 300 nodes.

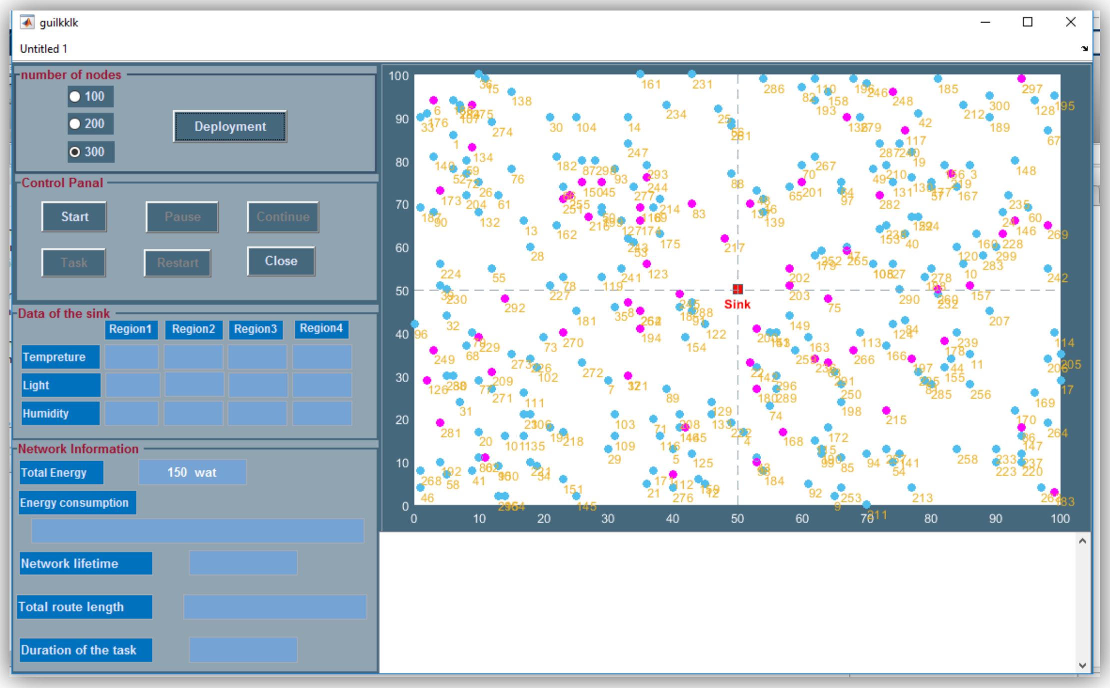

Figure28: Network visualization with 300 nodes

4- Sensor Model:

Simulation model of the sensor node that is implemented in our proposition is defined in IEEE 802.15.4 (standard ZigBee), it is called TelosB sensor.

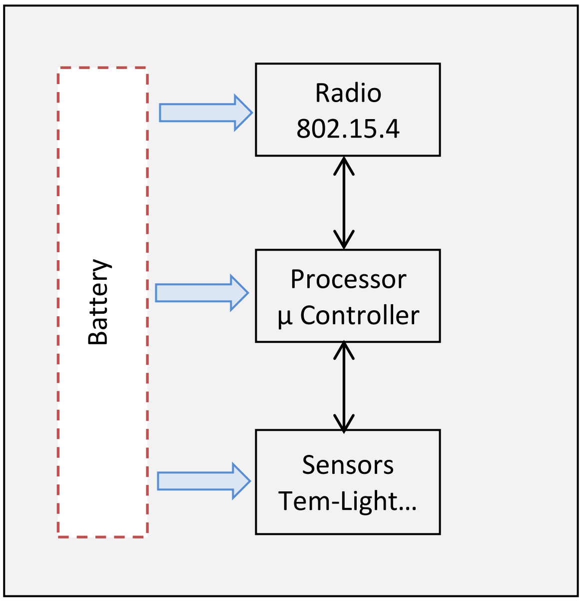

Figure 29: Block Diagram of TelosB sensor

The TELOSB mote is constitute of the components basic sensor, processor and radio devices. It can also has additional application-dependent components.

Parameters of TelosB sensor	
Processor Performance	16-bit RISC
RAM	10K bytes
Frequency band	2400 MHz to 2483.5 MHz
Outdoor Range	75 m to 100 m
Indoor Range	20 m to 30 m
Sensors	Light –IR – Humidity-Temperature…etc.
Battery	2X AA batteries
User Interface	USB

Table V. 2: Parameters of TelosB sensor [1]

5- Simulation parameters:

The used parameters and their nominal values are presented in the below tables (V2, V3, V4). These tables include essential parameters for the network, the type of nodes and the GRASP algorithm.

Network Parameters	
size of the network	100m ×100m
deployment of the nodes	Random
range of radio transmission	20 m
size of packet	120 bits

Table V. 3 Network simulation parameter

Number of nodes			
Cases	**Total**	**Source nodes**	**sensor nodes**
Case1	100	20 (20%)	80
Case2	200	40 (20%)	160
Case3	300	60 (20%)	240

Table V. 4 The type of nodes

GRASP algorithm Parameters	
Number of iterations	300
Quality control parameter (α)	1

Table V. 5 GRASP algorithm Parameters

6- Performance metric:

In order to evaluate GR-SPIN Protocol, we define the following performance measures:

6-1 Total length of the route:

This is the sum ofall the routes are adopted when sending messages

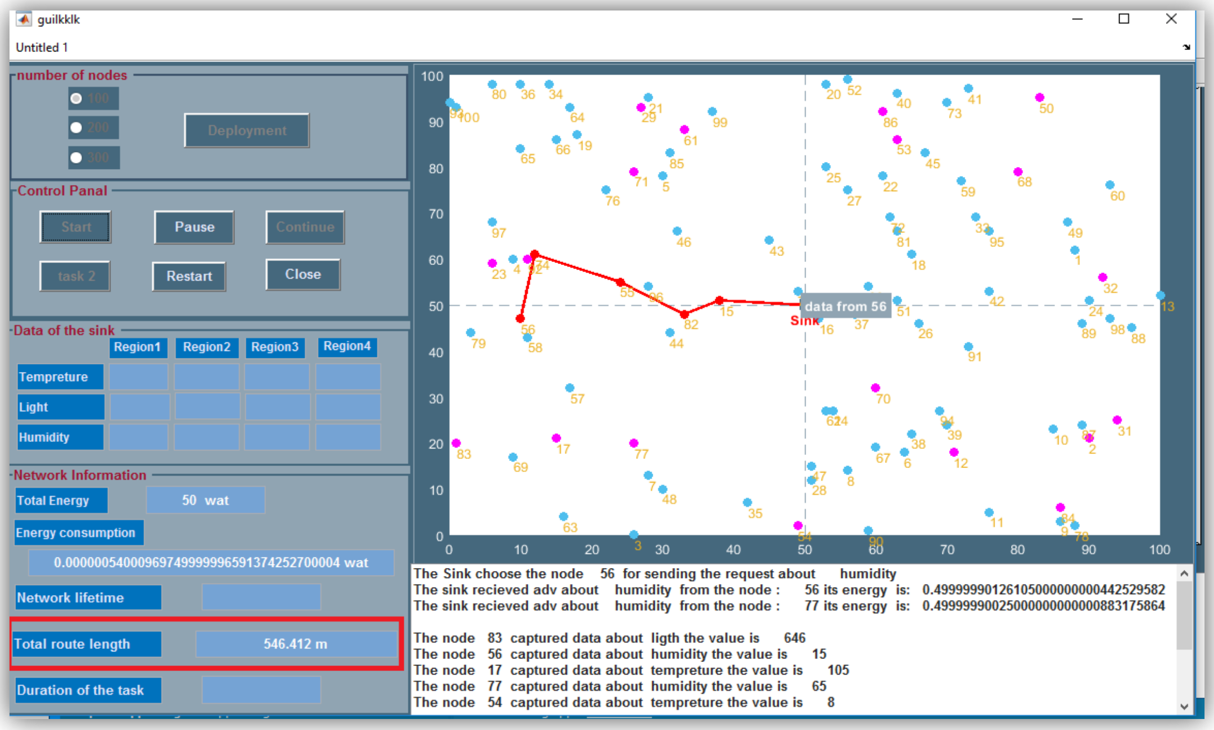

Figure 30 : Total length of the route

6-2 Network lifetime:

Time spent until one of the nodes became unable to work that means this node died

6-3 Energy consumption:

This measure is essential for extended network lifetimes. The aim is to minimize energy consumption and this depends on the routes used when sending message

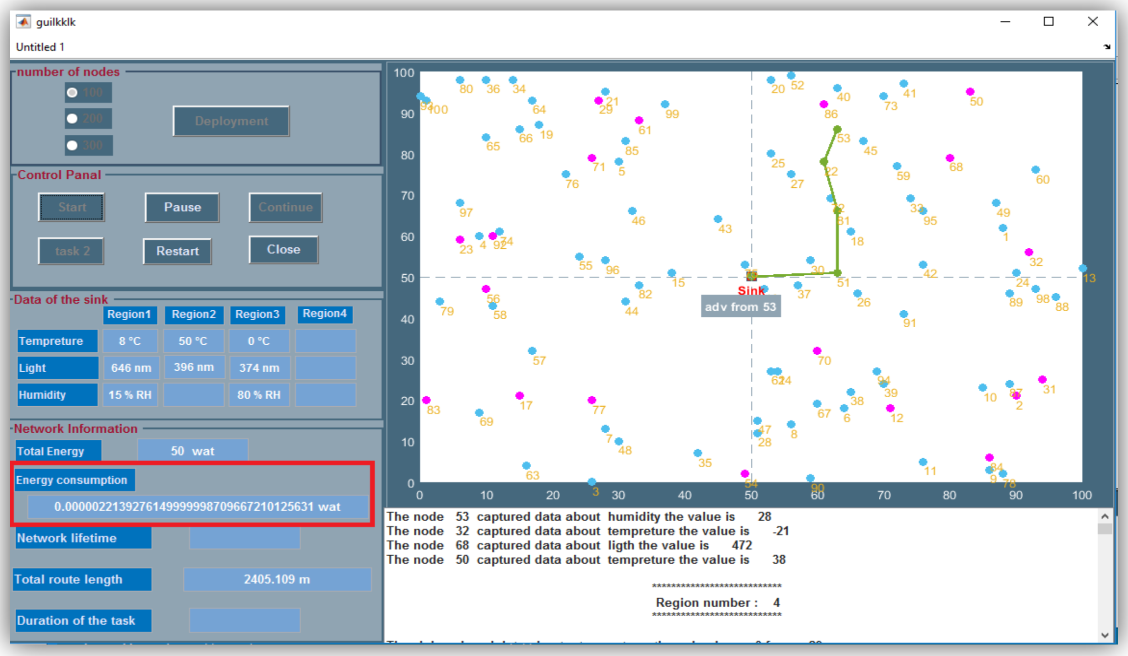

Figure 31 : Energy consumption

6-4 Duration of the task:

The duration of the task represents the time occupied to collect all the data from the network.

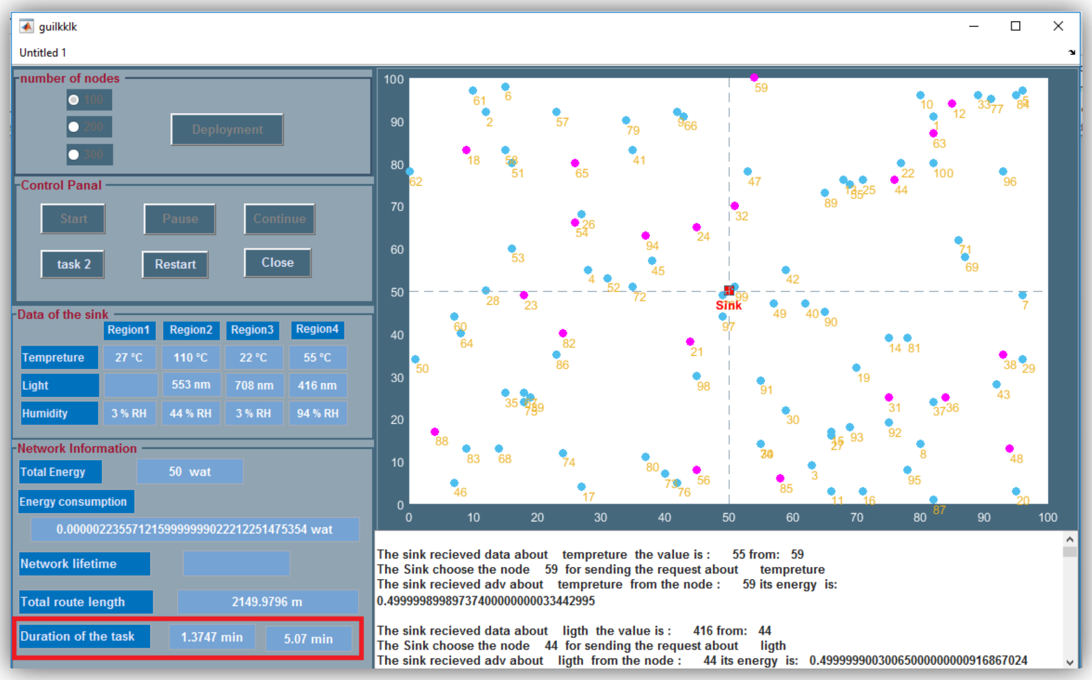

Figure 32: Duration of the task

7- Results and discussion:

7-1 length of the route:

As shown in figure 33 and figure 34, Total length of the route of GR-SPIN is much lower than ttal length of the route of SPIN, because in GR-SPIN protocol we realy reduced the number of messages,the transmission just between the source nodes and the sink. while SPIN the number of message is very huge because any source node detect data, it sends it to the nodes in network.

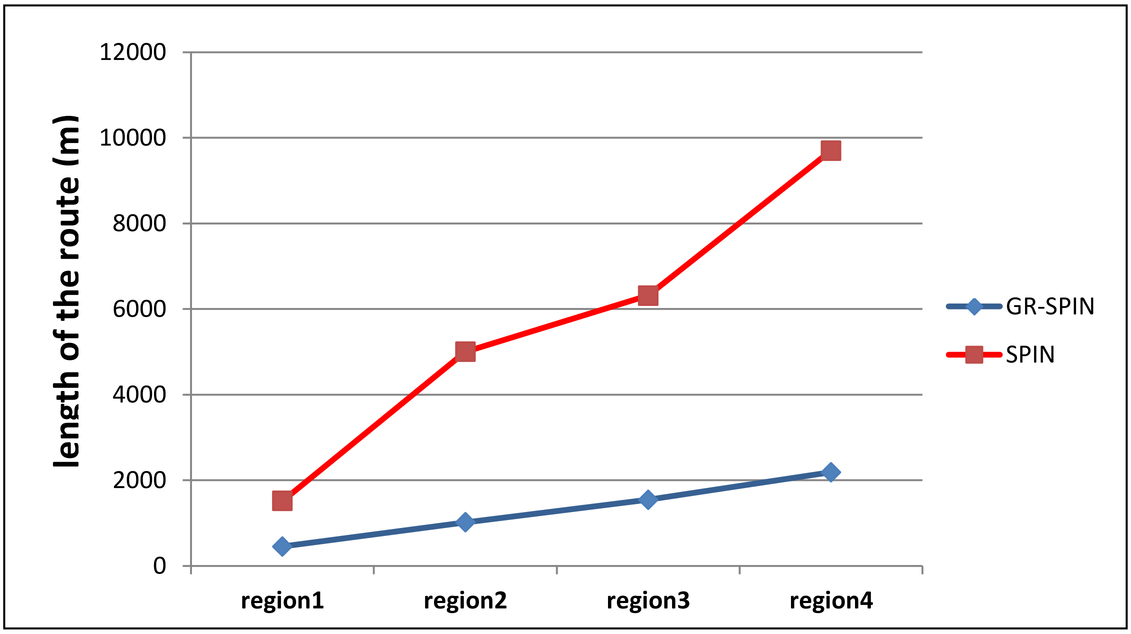

Figure 33: Total length of the route for GR-SPIN and SPIN (number of node is 100)

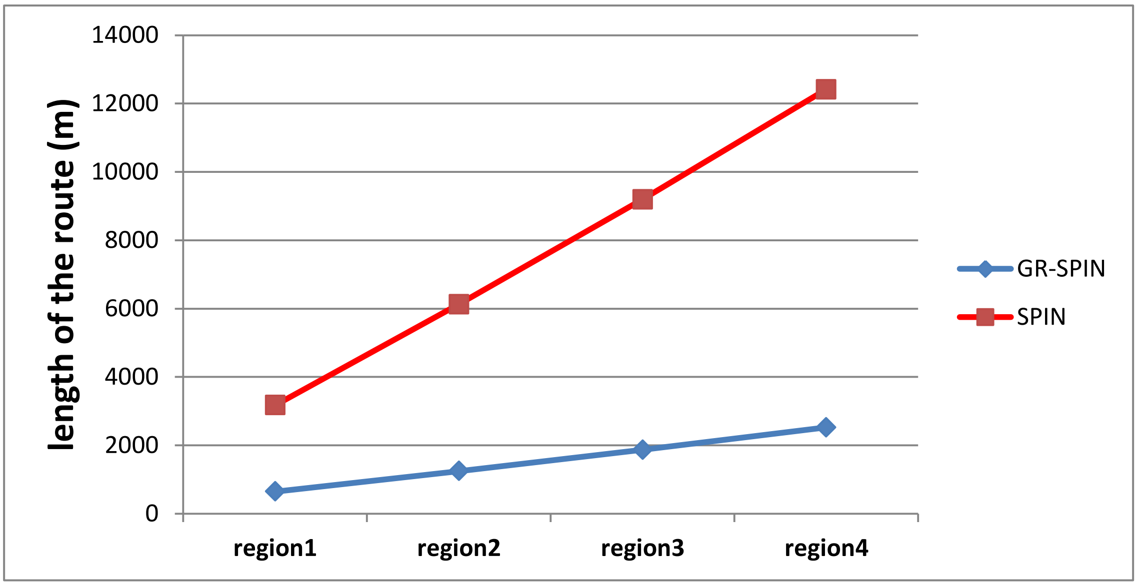

Figure 34: Total length of the route for GR-SPIN and SPIN (number of node is 200)

7-2 Energy consumption:

In the figure 35 and figure 36 illustrate that the GR-SPIN Protocol consume less energy than SPIN Protocol, this is due to GR-SPIN Protocol has less messages and source nodes has a letter processing, the most processing in sink.

That means the network lifetime of GR-SPIN is Much bigger than lifetime of SPIN.

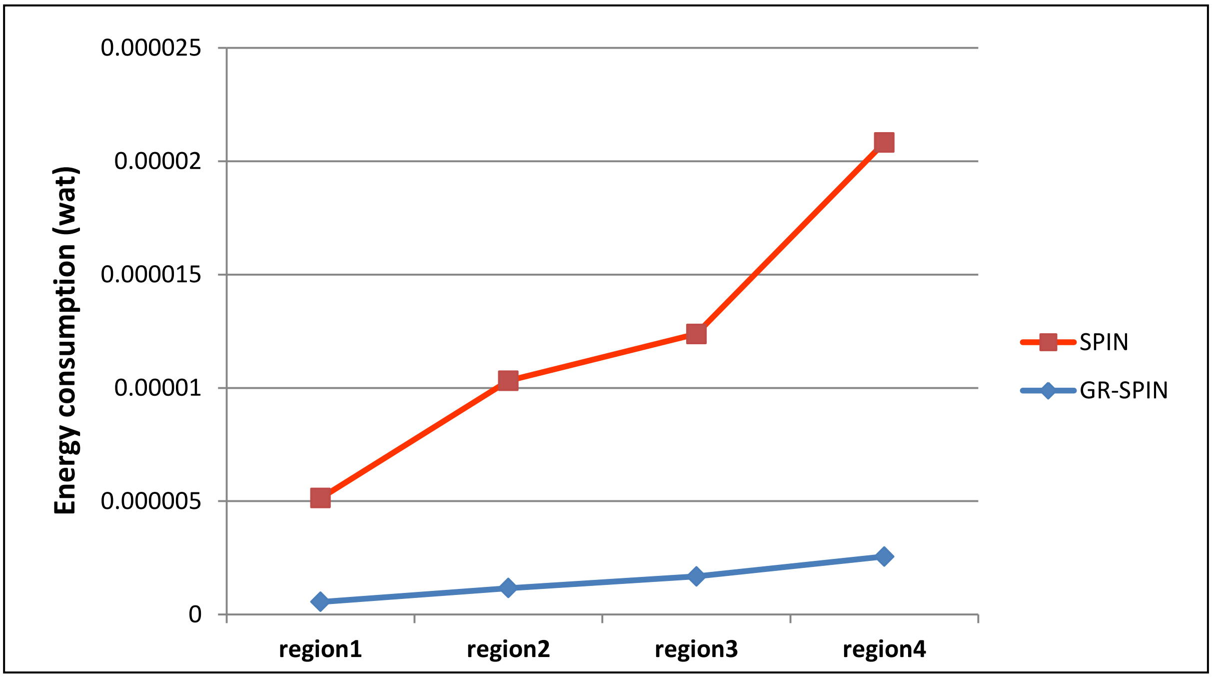

Figure 35: energy consumption for GR-SPIN and SPIN (number of node is 100)

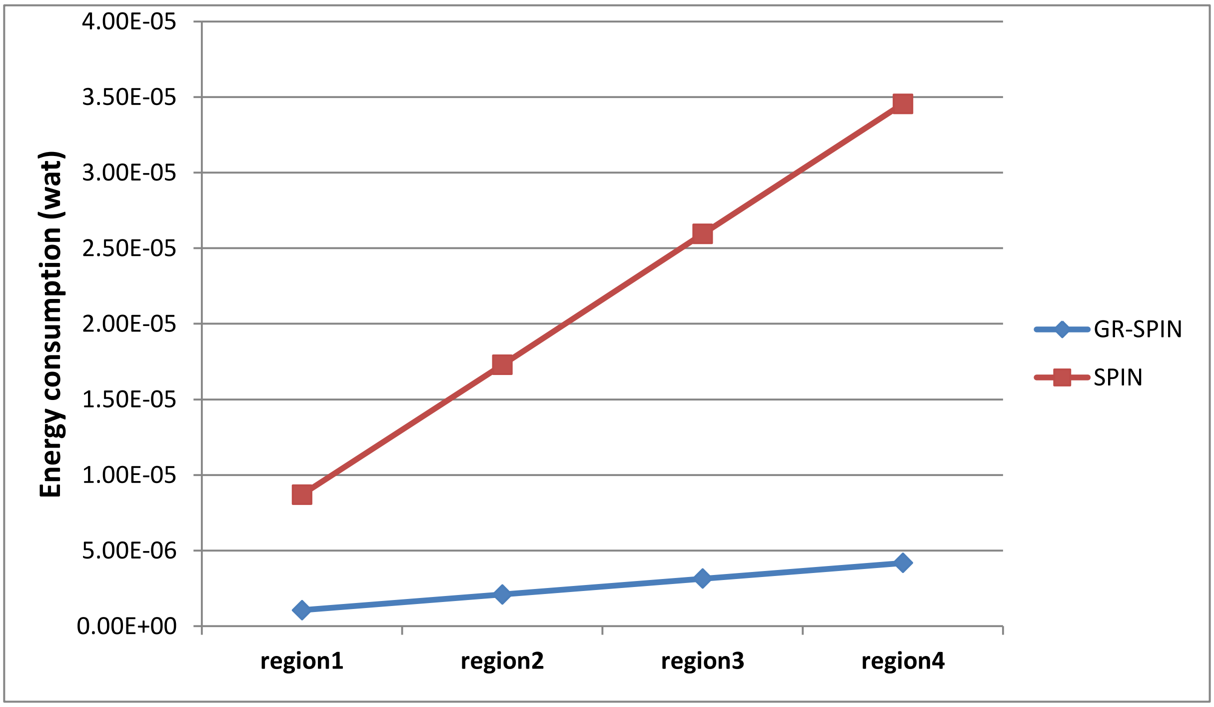

Figure 36: energy consumption for GR-SPIN and SPIN (number of node is 200)

7-3 Duration of the task:

Concerning duration of the task, the figure 37 and figure 38 Clarifies that GR-SPIN needs Less time than SPIN and this is logical due to the big difference is in the number of messages.

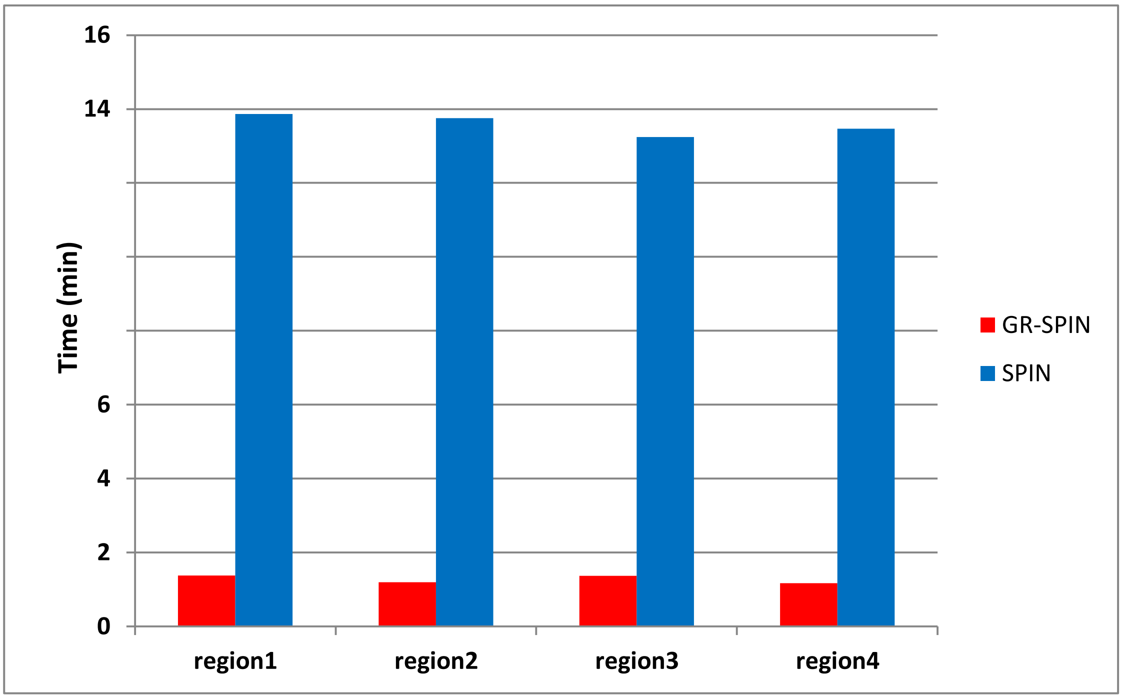

Figure 37: Total length of the route for GR-SPIN and SPIN (number of node is 100)

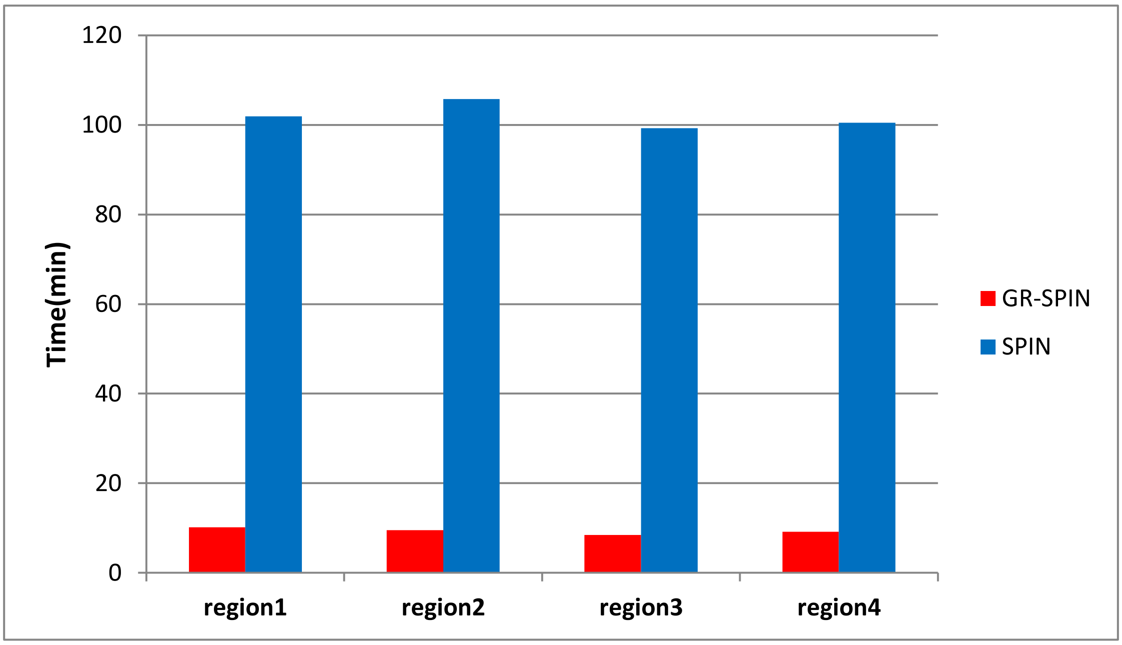

Figure 38: Total length of the route for GR-SPIN and SPIN (number of node is 200)

We notise in all the previous results when the number of nodes increases,the difference between the two protocols also increases, which confirms the preference of GR-SPIN over SPIN protocol

8- Conclusion:

In this chapter, we have seen simulation tools and parameters, network model. also in this chapter, we have presented the results obtained of comparing the tow protocols GR-SPIN and SPIN. The results showed that the total length of the route ,the energy consumption and the duration of the task decreased significantly in GR-SPIN compared to SPIN. That means GR-SPIN Succeed to maximize the network lifetime.

General Conclusion

In our thesis, we discussed the problem of energy consumption in wireless sensor networks.we proposed new protocol named GR-SPIN, this protocol is the result of optimizing the basic SPIN protocol(Sensor Protocols for Information via Negotiation), we maintained on the principal of the basic SPIN that is negotiation methodology and this is represented in any node detects data must negotiate with its neighbors before sending this data, On the other hand we changed in the number of messages, we reduced them as much as possible by making the transmission just between the source nodes and the sink instead of broadcasting , we decreased the processing of the source nodes.all these improvements to minimize energy consumption and maximize the network lifetime.

GR-SPIN Protocol has initialization and three steps as following :

Initialisataion : Happen in this is the partitioning of network area horizontally and vertically into four equal regions

step01 data adverting : it contains by sensing data by source ,route discovery process and sending adv message to the sink

step02 data requestion : after receiving adv messages by the sink,traits them to determine which nodes to replay and perform the route discovery process and send rqs message

step03 data transmission : any source node receive rqs message send the data to sink by using route that is used by the sink.

Concerning the route discovery process,we used heuristique GRASP (Greedy Randomized Adaptive Search Procedure) because its features such as simplicity, clearly and does not need much energy and computing time while processing.

The results of simulation Proved the preference of GR-SPIN compared by basic SPIN Concerning Energy cost, network lifetime, total route, duration.

GR-SPIN Protocol succeeds to improve SPIN Protocol in energy consumption according to the obtained results. In the future work we have many Improvements we try to do, they are:

- Add mobile feature to the nodes
- Expand the network area and increase the number of nodes
- Compare GR-SPIN with other protocols in WSN

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