Article

Intelligent communication in Wireless Sensor Network

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Abstract: Wireless Sensor Networks (WSN) is designed to collect information across a large number of limited battery sensor nodes. Therefore, it is important to minimize the energy consumption of each node, which leads to the extension of the network life. Our goal is to design an intelligent WSN that collects as much information as possible to process it intelligently. To achieve this goal, an agent has been migrated to each node in order to process the information and to cooperate with these neighboring nodes while Mobile Agents (MA) can be used to reduce information between nodes and send those to the base station (Sink).
This work proposes to use communication architecture for wireless sensor networks based on the Multi Agent System (MAS) to ensure optimal information collection. The collaboration of these agents generates a simple message that summarizes the important information in order to transmit it by a mobile agent. To reduce the size of the MA, the nodes of the network have been grouped into sector. As for each MA, we have established an optimal itinerary, consuming a minimum amount of energy with the data aggregation efficiency in a minimum time.

Successive simulations in large scale wireless sensor networks through the SINALGO simulator show the performance of our proposal, in terms of energy consumption and package delivery rate.

Keywords: Wireless sensor network, agent cooperation, mobile agent, itinerary, multi agent system, communication.

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1. Introduction

Advances in wireless technologies and technologies in micro manufacturing and microprocessor integration have created a new generation of Wireless Sensor Network (WSN) for a wide range of applications.

A wireless sensor network consists of a set of nodes capable of collecting information from a monitored environment and transmitting it to a base station (Sink) via the wireless medium. WSNs are often characterized by dense, large scale deployment in resource constrained environments. The limits imposed are the limitation of processing capacity, storage and especially energy because they are usually powered by batteries. The constraint of the size of a sensor node forces designers to limit the size of its battery and therefore the amount of energy available. Replacing a battery is rarely possible, either for cost reasons or environmental constraints. This causes a problem related to the energy consumption during operation of the various nodes of the network.

The WSN have given rise to many research issues in order to improve network performance, including maximizing its lifespan. And as a result, unlike traditional networks that are concerned with ensuring a good quality of service, the WSN must give primary importance to energy conservation. It is therefore widely recognized that energy limitation is a key issue in the design of the WSN because of the strict constraints it imposes on the operation of the network. Experimental measurements have shown that, in general, data transmission is very expensive in terms of energy consumption, while data processing consumes much less [1]. The cost of the transmission energy of an information bit is approximately the same as that required for processing a thousand operations in a typical sensor node [2]. The lifespan of a sensor network can be extended by the application of different techniques of energy consumption. One of these techniques is the technique of partitioning the network into sectors, as in our previous work [3].

For the past ten years, Multi Agent Systems (MAS) have grown rapidly and are applied to a wide variety of fields such as, for example, the field of simulation and artificial life, robotics, and images processing. It is integrated in the WSN, because of their intelligence and adaptation to the field. Ant colonies, spiders, etc., are examples of MAS, which are applied to the WSN to process captured data, routing, detection of shorter itinerary, etc.

The integration of Mobile Agent (MA) into the WSN solves several problems that can harm the wireless sensor network. Indeed, it can be used to reduce the cost of communication significantly, in particular the elimination of redundancies, by moving the processed data by an agent introduced into each node instead of bringing them to the raw state at Sink by the knot itself.

In this work, we will realize a system capable of simulating a network of wireless sensors in an environment, in order to minimize the energy dissipation. The multi agent system principle of operation is used for the intelligent processing of the data captured by the nodes, in terms of reduction of redundancy, evaluation of their importance, elimination of non useful information, and cooperation between the sensor nodes neighbors. The main purpose of this technique is to group the data by a mobile agent and send them at a time to minimize transmission, instead of each node sending data through intermediate nodes. It also incorporates the principle of multi agent system operation for the intelligent processing of the data captured by the nodes, in terms of reduction of redundancy, the evaluation of their importance, and the elimination of non useful information. A mobile agent activated by the Sink has been proposed and sent to the sector. This agent will circulate in the sector nodes in an itinerary schema specified, to gather the processed and captured data by the agents (node).

In other words, an agent has been integrated in each sensor node, such that each node of the network is seen as an autonomous agent having its own characteristics and behaviors towards the various events they receive. Mobile agent is used to reduce the cost of communication dramatically, in particular, the elimination of redundancies between source nodes, by moving information processed by an agent introduced into each node instead of bringing them to sink in the raw state. In addition, the source nodes cooperate with these neighbors to ensure the movement of the MA. So, these agents (introduced in the nodes) eliminate the redundant information that contains in the MA and the node by itself. Iteratively, the network was partitioned into sectors [3] where the source nodes in each sector are included in an itinerary. This technique makes it possible to find an optimal itinerary for an MA to collect data from several distributed sensor nodes. The source nodes within each sector can be obtained by choosing the angle in an adaptive itinerary. The main purpose of this technique is to group the data by a mobile agent and send them at a time to minimize transmission,

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instead of each node sending their data. To collect data in each area, we have created an itinerary algorithm, so that it allows the mobile agent to:

- Reduce the response time;
- Travel the itinerary from the furthest node to the well;
- Start aggregating data from the source node as much as possible until you reach Sink;
- Consumes less energy on the itinerary back to the sink;
- Avoid exhausting energy when visiting source nodes;
- Decrease the chances of being lost due to not enough energy from the source nodes;
- Use neighboring nodes to help source nodes that have less energy.

The rest of the article is organized as follows: section 2 provides an overview of the literature in which algorithms for a number of studies have been performed regarding routing in the WSN, in the first place, the classification of proposed routing solutions, then the solutions proposed in the integration of mobile agents in the directed diffusion protocol, and we present the statement of the problem. In section 3, we present the description of our communication strategy. Mobile agent packet structure for itinerary planning and the data collection cooperation are described in Sections 4 and 5, respectively. Next, section 6 sets out the purpose of our application, which is to establish a system to simulate the communication between a set of sensors and a base station. Then, Section 7 shows the evaluation of our proposal through simulation, while Section 8 analyzes the results of our approaches compared to other approaches, according to several criteria. Finally, Section 9 summarizes and concludes this article.

2. Related Work

In wireless sensor networks, the main issue concerns energy consumption. Indeed, since it is not possible to recharge the energy of the sensor nodes, they must remain operational as long as possible, so it is necessary to save the maximum energy consumed by these nodes. One of the characteristics of sensor networks is the ability to reduce the amount of data flowing through the network, in order to conserve energy, by merging data through particular nodes in the network. This process is called data aggregation. Aggregation not only requires the transmission of data but also imposes constraints on the architecture of the network. The basic idea of this architecture is to combine data from different source nodes by eliminating existing redundancies and also minimizing the number of transmissions possible to save the amount of energy consumed. In what follows we present some work in this subject.

The most energy efficient proposals are based on the traditional Client/Server (C/S) model, to manage multi-sensor data fusion in the WSN. Several works [4-11] have been realized to optimize the architecture of this model. In this architecture, when a sensor node detects information from the environment, it sends it as raw data through the other nodes to sink for processing. The transmission of raw information does not eliminate unnecessary or redundant information, which requires costly construction in terms of energy.

A number of research papers have proposed Compression/Decompression (C/D) of data algorithms to reduce the ability of information transmitted by sensors. The authors of [5,6] proposed a data correlation algorithm that compresses the data in a WSN. In this proposal, only one node is elected to send raw data to sink and the others only sent encoded data. After having the Sink received the data, he decodes it through the correlations between the compressed and uncompressed data. However, it is quite difficult to find a non-complex coding algorithm appropriate for sensor node where we should not consume a lot of energy in processing.

In [7], the authors proposed a Data Fusion (DF) of a maximum number of sensors. When a node sends its data to Sink, the intermediate nodes merge their data with the ones of the first node. So, this information is merged into one message instead of many, which saves energy. However, the intermediate nodes do not always have important information to send, nor do they eliminate the unimportant or redundant information. In addition, the authors neglected to study the importance of the scalability of this type of networks.

Additionally, researchers [9] have proved that cluster is a fundamental technique in the WSN. Their goal is to minimize the processing of aggregation of the data needed at the sensor node and move the load to the Sink. The clustering algorithm uses a hierarchical classification, and the nodes organize into groups and elect a cluster node as a leader. The latter collects the aggregated information from the sensors of his group and transmits them to the Sink. In this itinerary, a significant reduction in energy consumption is realized. Unfortunately, the authors did not address the problem of the complexity and amount of energy consumption required to build such clustered sensor networks.

In addition to [8,9], the authors of [12-15] also proposed a structured strategy (Tree and Cluster) based on data aggregation for the WSN. However, according to [16,17], structured approaches are not practical for dynamic scenarios, due to excessive communication costs and the centralization of the management of the structure WSN.

The authors of [8] proposed an ant colony algorithm for data aggregation in the WSN. Each ant will explore all possible itineraries from the source node to Sink. The data aggregation tree is constructed by the accumulated pheromone. But, the construction of this appropriate tree depends largely on the deployment of nodes, which is usually random which consumes a significant amount of energy. However, the Euclidean distance calculated from a Sink source node may not be applicable in the WSN because the communication range of a node is limited.

A Multi Agent System is a group of agents able to interact and cooperate to achieve a specific goal. Different properties are defined as autonomy, proactivity, flexibility, adaptability, ability to collaborate and coordinate tasks, etc.

The researchers proposed to use multi agent system solutions on the adaptation of distributed and complex wireless sensor networks. The researchers [18-24] have realized the community of artificial intelligence with intelligent sensors by the use of this system. Intelligent sensor node operates as stand-alone agents that develop a network of intelligent sensors. In our previous work [3,18,24], we proposed an approach of a communication using MAS in a WSN plan. So, with this solution we solved the density problem, by partitioning the network into clusters. We have yet, extend this work into another work [25], a scheme has been proposed to aggregate a maximum of information. In this work, we integrated in each sensor node an agent, in order to process the information and each node can cooperate with its neighbors.

The authors of [4,10,11,13-15] proposed mobile agent technology in the WSN for data collection. In these proposals, the MA is defined as a message that contains an application code, a list of source nodes predefined by the Sink, and an empty field to put the collected data. It is able to move between all the source nodes of the network by moving the captured data in a single message instead of each node itself bringing this raw information to Sink. The use of MAs allows for more efficient data aggregation over C/S. In these proposals, the MA visits the source nodes of the network, and gradually fuses the sensory data, before returning to the Sink. The disadvantage of this

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type of solution is the difficulty of creating the list of source nodes and defining the start time of the data collection. Another limitation is the definition of the regions to be treated by the MA. But, as a solution to optimize the MA itinerary in data fusion, the authors [16] proposed two heuristic itinerary algorithms. The Local Closest First (LCF) algorithm, the mobile agent starts its itinerary from one node and searches for the next destination with the shortest distance to its location. The Global Closest First (GCF) algorithm, the mobile agent starts their itinerary from a node and selects the next destination with the closest to the center of the surveillance zone.

Due to the limited bandwidth and the density of wireless sensor network, the use of a single mobile agent, can lead to a very inefficient design. In addition, the use of a single MA that successively visits all the source nodes of a large scale network may have the following drawbacks:

- Can actually lead to a very long response time, with many of the source nodes to visit;
- The sensor nodes in the MA itinerary exhaust the energy quickly than other nodes;
- During the visit of the source nodes, the size of MA increases continuously;
- MA transmission will consume more energy in its return itinerary to the sink;
- The increasing amount of data accumulated by the MA during his migration task increases his chances of being lost due to the noise in the wireless medium.

Authors [17,18] have proposed the use of multiple mobile agents for data fusion, which also involves extending network lifetime. On the other hand, when mobile agents are used for data merging tasks, the choice of moving itinerary for MAs is essential. While it is crucial to find an optimal itinerary for each mobile agent to visit al the indicated source node.

Chen et al. [19] proposed the Location based Multi agents Itinerary Planning (CL-MIP) algorithm; the main idea is to consider the Multi agent Itinerary Planning (MIP) solution as an iterative version of the solution Single agent Itinerary Planning (SIP). Another algorithm, Genetic Algorithm based Multi agents Itinerary Planning (GA-MIP) is proposed in [20]. GA-MIP first proposes a new two level MA coding method to solve the MIP problem. The GA-MIP algorithm considers the MIP problem as a single problem instead of using several steps adopted by the previous algorithms. The proposal in [21] considers models of MIP problems as a Totally Connected Graph (TCG). In the TCG, the vertices are the sensor node of the network, and the weight of an edge is derived from the estimates of the jump between the two edge nodes of the edge. The authors indicate that all source nodes in a particular sub-tree should be considered as a group. In addition, they have a balancing factor, while calculating the weights in the TCG, to form a minimum Balanced Spanning Tree (BST).

Mpitziopoulos et al. [22] proposed the Near-Optimal Itinerary Design (NOID) algorithm to solve the problem of calculating a near-optimal itinerary for an MA. The NOID algorithm was designed on the basis of rapidly adapting to network change conditions, the MA itinerary should only include source nodes with sufficient energy availability, and the number of AMs should depend on number and physical location of source nodes to visit.

Gavalas et al. [23] presented the Second Near-Optimal Itinerary Design algorithm (SNOID) to determine the number of MAs that should be used and the itinerary of these MAs should follow. The main idea behind SNOID is to partition the area around the Sink into concentric areas and start building the MA roads with the direction of the interior near Sink. All source nodes within the first zone are connected directly to the Sink, and these nodes are the starting points of the MA itinerary.

After having analyzed the solutions presented above, we can also deduce that there is still a lot of work in terms of energy efficiency by paying attention to the report of delivery of packets and the density of the network. In addition, the solution had to be independent of network deployment.

3. The communication strategy

Our strategy ensures better data collection management in a WSN, taking into consideration the energy of each sensor node to improve network performance. Due to the fact that a lot of the detected information could be redundant or not important, an optimization for the data collection could be a good technique to save the energy of the sensor node and extend the network lifetime.

In this work, we propose an intelligent strategy that collects information and processes intelligently. According to [1] to send a quantity of information in a single message is less than sending the same amount in several short messages. So, because of the density of the network, and the highest energy consumption at the communication level, instead of each node sending its data to Sink, the network has been broken down into sector.

Our strategy is as follows: An agent is introduced in each node of the network, which processes the information at the local level and judges their importance in order to eliminate any unnecessary or redundant information and to make the cooperation between neighboring nodes. In addition, the source nodes cooperate with their neighbors in order to transmit information.

First, we grouped the sensor nodes into sectors, in addition, we proposed a mobile agent at the level of each sector, in order to concatenate the information processed by the source nodes, to send them in a single message by a well defined strategy.

After the Sink designates the source nodes, it sends each sector an MA, to aggregate the data, with a list of well defined source nodes. The list of source nodes is sorted according to an itinerary algorithm, so that the MA circulates between these nodes. For a neighboring node to cooperate with its source node, it must be based on two possible behaviors. The first behavior is that a node cooperates with other nodes of the network, as much as possible in order to save the transmission of information. Indeed, the reduction of cooperation can lead to the loss of certain appropriate information. The node consumes some energy in its cooperation, but it reduces the probability of losing important information. The second behavior is that a node agrees to cooperate with the network nodes that are in the itinerary to the Sink. Indeed, the node consumes some energy in its cooperation, but it guarantees the transmission of the packets. During the itinerary of a mobile agent, if the energy of the next source node is not sufficient enough to transmit the mobile agent, this sensor node transmits this information to an intermediate node between itself and the next source node of the list.

Our sector approach based on multi agent system is divided into three phases: the first phase is to determine the source nodes satisfying the interest according to the direct diffusion, the second phase is to plan the network into sectors, and the third phase is to determine the itinerary of the mobile agent in each sector to collect the data.

3.1. Detecting source nodes

Once, the Sink receives a new task requested by an application, first, Sink broadcasts interest packets to detect the source nodes that perform the task, according to the Direct diffusion routing protocol. So, it generates a message (interest), and then sends it to all its neighboring nodes in a single hop. These neighbors send this message to their neighbors and so on. The purpose of spreading this message is to discover all the source nodes that perform the task, and also it will allow us to know and identify all the nodes of our sensor network.

3.2. Partition the network into sector

As in our previous work [25], once, the Sink receives the identifiers of the source nodes, after a definite delay, the Sink partitions the network in sectors, with the starting point is the base station, as shown in figure 1.

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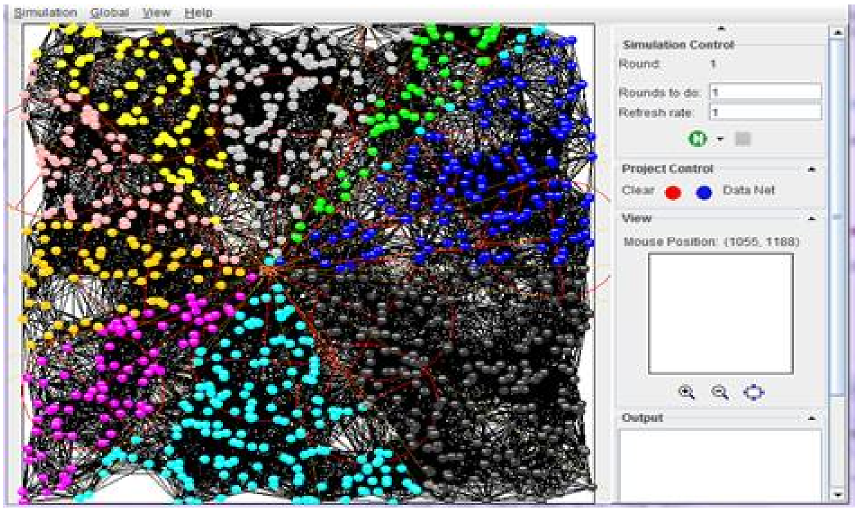

Figure 1: partitioning the network into sectors

3.3. Plan the MA itinerary

At this stage, mobile agents activated by the Sink have been proposed. The latter will send these agents, so that they circulate between the nodes of its sectors. These mobile agents aggregates data processed and captured by the source nodes to return to Sink with the collected information. To plot the MA itinerary, we have created an algorithm, which allows finding an optimal itinerary, in order to manipulate the list of nodes in a coherent itinerary.

Our algorithm allows a mobile agent to move from a source node further to a source node closer to Sink, to avoid overloading the MA. The latter determines the list of source nodes they will be visited according to the distance between the source node and Sink. So that the first source node of the list is the one furthest from the sector and the same for the other source nodes.

4. Mobile Agent

4.1. Mobile Agent Packet Structure

After Sink uses direct diffusion to designate the source nodes, it sends each sector a mobile agent. The latter is a packet of data circulating in the sector, it is used to collect the data captured by the source nodes. The information contained in a mobile agent packet is shown in figure 2.

Sec_ID	MA_Seq_N	Next_Src_ID	Src_List	Int_List
Data_Cooperation				

Figure 2: MA Packet Structure.

Both attributes are used to identify a mobile agent packet(sec_ID and MA_Seq_N). Whenever Sink sends a new MA packet, it increments the MA_Seq_N. The Src_List list specifies the source nodes of the sector, which will be visited by the mobile agent. This list will be filled in by Sink. Next_Src_ID specifically determines the succession of source node identifiers that must be visited by the MA. If Next_Src_ID is equal to Sink, it means that it is the last node visited by the mobile agent. The Int_List list specifies the intermediate nodes (the help nodes) between the source nodes. Data_Cooperation contains the information that is processed by the source nodes of the itinerary (useful and non-redundant information). It is from the 2nd source node of the itinerary that the MA begins to process the redundancy of information collected at the node and so on.

4.2. MA itinerary planning

To plot the mobile agent itinerary, we have created an algorithm, which makes it possible to find an optimal and efficient itinerary, in order to manipulate the list of source nodes in a coherent itinerary. Our algorithm allows a mobile agent to move from a sensor node further to a sensor node closer to Sink. So, the itinerary starts at the first sensor node with the longest distance, and ends with the nearest sensor nodes at Sink.

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In order for the mobile agent to avoid collecting redundant information between the source nodes, we calculate the size of the detected data accumulated by this MA using the method used by [21]. According to this method, a captured data sequence can be combined with a merge factor ϱ. Let Ni be the amount of accumulated data accumulated after the MA collects the Ni (Source Node i) result, and Ri the size of the locally processed sensed data that will be accumulated by the MA at the Ni. So we have: $N_1 = R_1$; $N_i = N_1 + \sum_{k=2}^{i} \varrho \, . \, R_k$ (i >=2)

Algorithm 01: Chaining source nodes at the Sink level

```
Begin
If  Sink receives source nodes identifications by DD then
Begin
// The Sink fills Src_List;
max = L[1] ;  // L: list contains the source nodes after applying the DD protocol
For   i = 2 to N Do
      If d(Sink , max) < d(Sink , L[i]) Then   // the farthest distance with the Sink
      max = L[i]
EndFor;
MA@ Src_List[1]:= max ; // max: the farthest distance with the Sink
MA@ Src _First = max;
L = L – {max};
For   i =1 to N Do
min = L[i];
For   j=2 To N Do
      If d(MA@Src_List[i] , min) > d(MA@Src_List[i]   , L[j]) Then
      min=L[j]
EndFor
MA@ Src_List[i+1]= min ;
L = L – {min};
N=N-1
EndFor
End ;
End.
```

Algorithm 02: Pass the MA between the source nodes;

```
Begin
While   MA arrives at a nodei but not Sink do
If   Nodei has new data then
                        If   MA is empty then
                        N=R1 ;              // Put the data to the MA package
                        Next_Src_ID = read the new destination from Src_List;
                        Pass the MA to Next_Src;
                        Else
                            If    Nodei data already exists in the MA Packet then
                            // Ignorer les données et passer au suivant ;
                            Next_Src_ID = read the new destination from Src_List;
                            Pass the MA to Next_Src;
                            Else
                            N=N+ ∑ ϱ . Ri ;    // Put the data to the MA package
Else
Next_Src_ID = read the new destination from Src_List;
Pass the MA to Next_Src;
End.
```

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5. Data Collection Cooperation

Figure 03 illustrates the cooperation of source nodes that do not have enough energy (to transmit the MA) with their neighbors during the data collection sessions. The source node C, which does not have enough energy, begins to seek cooperation near its neighbors of the itinerary when the previous source node B receives an MA as shown in step (1). The cooperation request is a short message, programmed for a single hop, and neighbors will be programmed not to replay this message. Thus, the node C waits during a fixed delay, if no neighboring node does have not enough energy; the sensor node considers that these neighboring nodes are not cooperating nodes. In this case, the message is programmed for two hops and so on until a cooperating node is obtained (source node or a simple neighbor node knowing that the priority of choice goes to the source node). So, the source node makes the decision to cooperate or not with a neighbor according to a specific energy threshold and which is in the itinerary of the list. After the appropriate decision is made, the source node C sends its processed information (useful and non-redundant) to the cooperating neighbor node C ''. Then, the previous source node B sends the MA to the cooperating neighbor node C '', as shown in step (2).

The other following source nodes in Src_List list of MA repeat the same previous steps until they reach Sink.

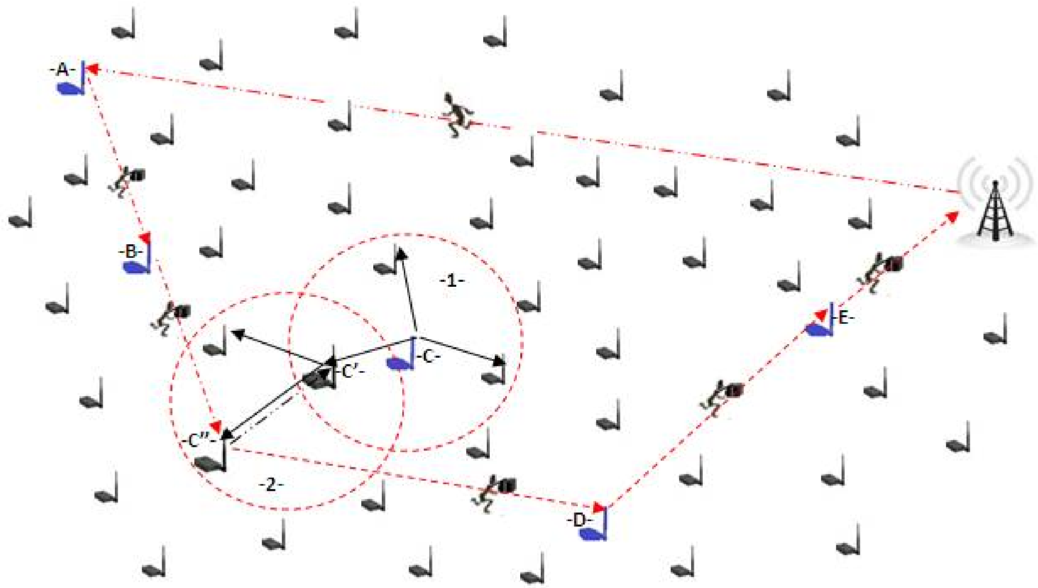

Figure 3: Data collection cooperation

Algorithm 03: pass the MA between the source nodes

Begin
Pass the MA to MA@First_Src ;
While MA arrives at source node **Do**
If MA@Next_Src_ID does not have enough energy **Then**
For i = 1 to node@Nbr_ neighbor **Do** // neighboring number of source nodes
Node diffuse ReqCoop
EndFor
If deadlines <= D **and** neighbor node cooperating responds **Then**
// the waiting time to send the MA to the next
If node receives ReqCoop **Then**
If E > S **Then** // if the energy remaining> at a predefined threshold
neighbor node cooperating responds
EndIf
EndIf
$N=N+\sum \varrho . Ri$; // Add data to the package

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Else
For i = 1 to node@Nbr_ neighbor **Do** // neighboring number of nodes neighbor
Node diffuse ReqCoop
If neighbor node = source node
N=N+ ∑ ϱ . Ri
EndIf
EndFor
EndIf
EndIf
Fill in the MA@Int_List // by the intermediate nodes between the two source nodes
MA@Next_Node = read the new destination from MA@Int_List ;
Pass the MA at MA@Next_Node ;
End.

The energy E represents only the remaining battery level, plus E of a node has more, it is advisable to participate in the cooperation.

6. Simulation setup

For our simulation platform, we chose to use the Sinalgo simulator: it is a simulator that allows creating, simulating and validating distributed algorithms [24]. We have established a system to simulate a communication between a set of sensors and a Sink form a WSN. It is based on the technique of partitioning the network into sectors and the use of multi agent system and mobile agents, which are considered as a mechanism to save the energy of a WSN. So, we will achieve an effective application in terms of energy consumption, the task duration and the packet drop ratio. In order to design our simulator, we have adopted the following assumptions:

- The sensor nodes have limited energy;
- Sink has an infinite supply of energy;
- Sink and sensor nodes are stationary;
- At the beginning, each sensor has an initial energy;
- After network activation, each node is an agent;
- The administrator chooses the number of nodes, the radius and the position of Sink;
- The number of sensors is limited;
- Node positions are known;
- The deployment is random;
- Two sensors do not occupy the same coordinates.

We performed our simulations on a 1000m x 1000m square with a random distribution of nodes for 1000 seconds. We limited the radio range and data rate of each node to 87 meters and 1Mbps, respectively, as suggested in [12]. Transmit and receive power parameters, which directly influence the radio range, have been chosen from the ranges defined in the sunspot system [17]. The local processing time is set at 40 ms. Table1 represents the simulation parameters:

Simulation parameter	**Values**
The size of the network	1000mx1000m
Node distribution	Random
Radio range	87m
Debit	1Mbps
Size of data captured per node	variable at 0.5Ko to 4Ko
Data captured interval	10 s
Simulation time	1000 s
Local processing time	40ms
Treatment Code Size	0.4Ko
Fusion Factor (ϱ)	01

Table 01 : Basic simulation parameters

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7. Evaluation of the proposal

Mobile agents and multi agent systems have been proposed to significantly reduce communication costs, which have a significant impact on the efficacy of the WSN. Several works have been done, as explained in section 2, prove that the use of multi agent systems in the WSN is more efficient. As in our previous work, we have demonstrated that the integration of stationary agents in sensors is more efficient, as well as the partitioning of a network into sectors by providing a Client/Server network or a clustered network. Still, several works have been done, prove that the use of mobile agents in the WSN is more efficient. Among these works in Section 2, Local Closest First (LCF) and Global Closest First (GCF) are simple approaches to itinerary planning for a single mobile agent. LCF looks for the next source node that has the shortest distance from the current node, while GCF looks for the next source node, which has the shortest distance from the base station.

Our article proposes to use an intelligent strategy based on multi agent systems and mobile agents for the aggregation of data in a WSN and processed them intelligently. The proposed strategy is called: Intelligent Itinerary based on a Wireless Sensor Network (IIWSN).

8. Results and analysis

So, in order to demonstrate the performance of our approach IIWSN in the WSN, we compare it to the LCF and GCF approaches, according to two criteria. First, we examine the impact of the number of source nodes on the criterion of energy performance, this parameter is considered the most important criterion. Since energy consumption is the parameter that defines the life of the WSN, we set the number of source nodes from 05 to 60 in steps of 05, and obtain a set of results for each case. We have shown the results thus obtained in figure 04, which show the impact of the number of source nodes on the energy, to obtain sensory data of all the source nodes.

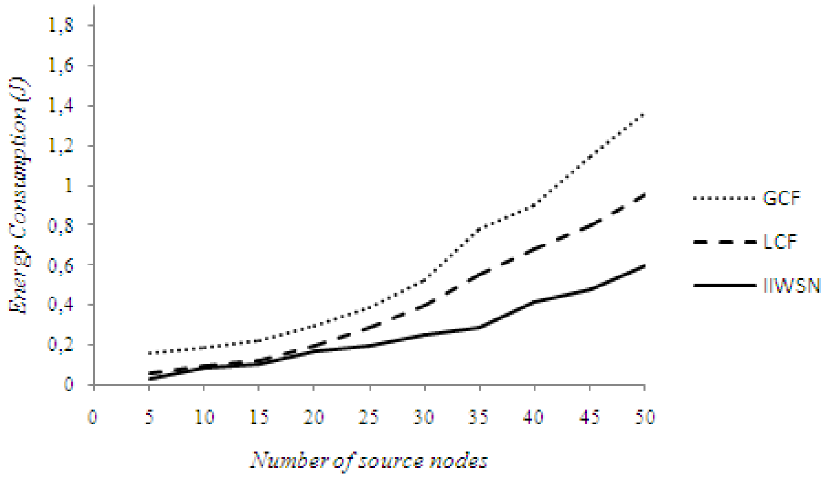

Figure 04 : Comparison of Energy Consumption

Figure 04 shows the comparison of the performances of the three approaches in terms of energy. First, and quite normal, when the number of source nodes is increased, more energy is needed to perform the tasks of each of the three approaches. We note that our IIWSN approach is always better than the GCF approach regardless of the number of source nodes, and better than the LCF approach from where we increased the number of source nodes. We can conclude that the difference between our approach and the other two approaches is becoming more and more important, and this difference increases continuously with the increase in the number of source nodes.

At first, there is not a difference between IIWSN and LCF, but there is a small difference between our and GCF. From 20 source nodes, our approach minimizes energy consumption by more than 3% at LCF and 12% at GCF. However, at 60 source nodes, the consumption of our approach minimizes energy consumption by more than 29.5% and 42% than LCF and GCF respectively. By comparison of the result, the solution of our IIWSN approach presents a better energy efficiency.

Moreover, and in another experiment, we show the comparison of the performances of the three approaches in criterion of duration of a task. For LCF and GCF approaches, the task duration is equivalent to the average end-to-end reporting delay, from the time when MA is dispatched by the sink to the time when the agent returns to the sink. However, the duration includes the processing time of the data at the source nodes to eliminate redundancies. So, since several mobile agents are working in parallel, and with several experiments, we calculated the duration of a task of a mobile agent to return to the Sink, So, the duration of a task is the average time of an agent mobile where his itinirairy starts from Sink until he returns to him. However, the duration includes the information processing time at the nodes, plus the co-operating time of the source nodes that do not have enough energy to transmit the MA with its neighbor nodes, and the longer the time of the mobile agent. The results obtained are shown in FIG.5.

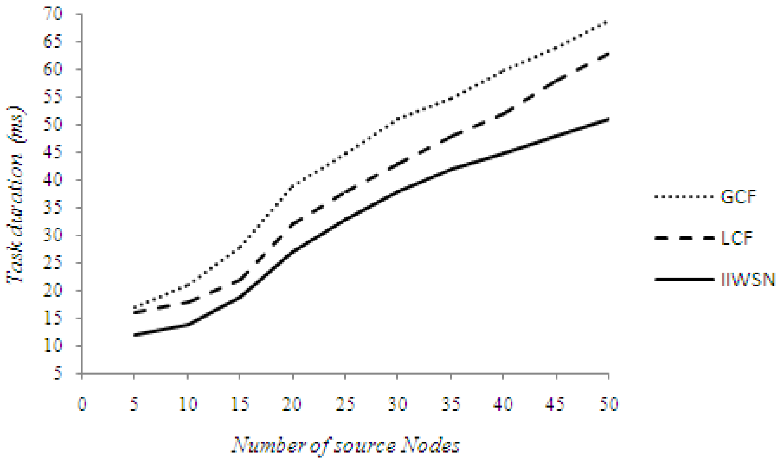

Figure 05 : Comparison of task duration

The figure above shows the comparison of the performance of the three approaches in terms of task duration. First of all, and quite normal, when the number of source nodes is increased, plus the time required for mobile agents to perform the tasks of each of the three approaches. By observing the results, we can see with more source nodes to visit, the size of an MA becomes more and more and many transmissions will be made. At first, almost both LCF and GCF approaches are similar, but from 10 source nodes, GCF consumes more time than LCF. Compared to energy performance, regardless of the number of source nodes, we note that our approach in terms of task duration is always lower than the LCF and GCF approaches. It may be further remarked that the difference between our proposition and the other two approaches becomes more and more important, and this difference increases continuously with the increase of the number of source nodes. In addition, we notice that maximum value between different values, is less than 10 ms. This means that accuracy could be influenced for applications that are very time sensitive and require less than 10ms. In addition, these differences could be easily explained because with more source nodes to visit, many of the itinerary checks will be done to move the mobile agents.

In addition, and in another experiment, we have changed the size of the data captured at each source node from 0.5Ko to 04Ko. The results obtained are shown in figure 06 :

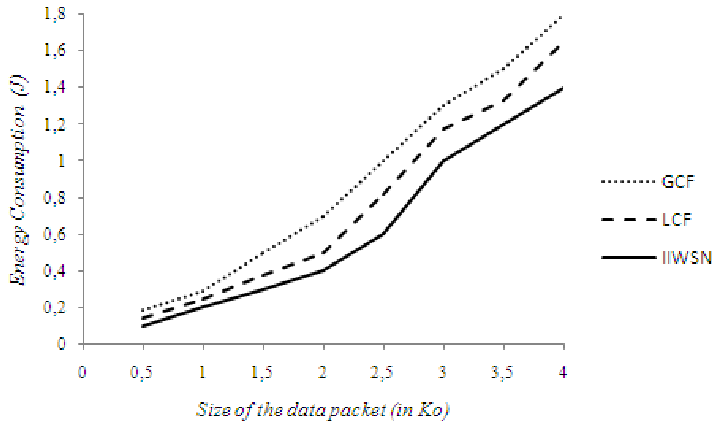

Figure 06 : Consommation d'énergie en fonction de size

The analysis in the previous figure highlights several interesting elements: first of all, and quite normal, the energy consumption increases with the increase of the size of the packets to perform the tasks of each of the three approaches. The first observation is that the energy consumption of our approach, is also always lower than that of the other approaches and this whatever the size of the packets. On the other hand, when packet size is a bit, the energy consumption of our approach is less important compared to other approaches. The other side, for medium size packets 2Ko, our approach is lower compared to the other approaches of 15% and 22% than that of LCF, and GCF respectively. We can still notice, from 2Ko the difference between our and the other two approaches becomes more and more important, and this difference increases continuously with the increase in the size of the packets. However, for large packets, our approach is advantageous, at 4Ko, IIWSN minimizes energy consumption, more than 23% and 29% to that of LCF, and GCF respectively. By comparison, the solution of our approach presents better energy efficiency.

9. Conclusion

In an environment where the sensor nodes are close to each other, and where there is considerable redundancy in the sensed data, the sensor nodes generate a large amount of transmissions over the wireless canal, causing not only a loss of the band wireless pass through but also the drawing of a lot of battery energy. Instead of traditional mode approaches like C/S and DF, where the sensor nodes send the raw detected data to Sink, we based ours on a paradigm of MAs and agents at each node to process the information (useful and non redundant information).

In this work, we have proposed a strategy that cleverly collects information and processes. As we demonstrated in our previous work, to send a quantity of information in a single message is less than sending them in several short messages. Thus, due to the highest network density and energy consumption at the communication level, instead of each node sending its data to Sink, the network has been broken down into a sector..

Our system consists of two types of agents, including stationary agents and mobile agents. Stationary agents consist of integrating an agent into each sensor node, so each agent processes locally sensed information from its corresponding sensor node and estimates its importance. The sensor nodes have been grouped into sectors, and an MA has been proposed at each sector to concatenate the information processed by the source nodes, to send them in a single message by a well defined strategy. This agent will circulate in the sector nodes in a specified itinerary, to collect the processed and captured data by the agents (node). Next, each source node cooperates with its neighboring nodes of the same sector to transmit the mobile agent according to a method based on several important parameters to decide the relevance of cooperation.

Our approach limits the communication of non useful information, and consequently decreases the amount of traffic and energy consumed. This means a gain in the amount of information and the overhead needed to send them. First, we have proved in previous work, by successive simulations

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that the division of a sector WSN presents better performances comparing to the approaches like C/S and DF, where we used the strategy of the agent.

In this work, we have proven through successive simulations that our approach shows better performance compared to LCF and GCF approaches, in terms of power consumption and packet delivery rate in the dense wireless sensor network. The reason for these results is that in our approach the MA guaranteed the collection of information in his itinerary. Because source nodes that do not have enough energy to cooperate with their neighbors to transmit the mobile agent in a more efficient and safer itineray. As future work, we try to minimize the loss of packets, either by partitioning the network in another way, or we add other parameters to the cooperation formula of the mobile agent with the sensor nodes.

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Intelligent Wireless Sensor Network Management Based on a Multi-Agent System

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