PRECISION AGRICULTURE: AN ENERGY EFFICIENT COMMUNICATION PROTOCOL FOR WSN

Capstone Design

By
Ghita Hossaini-Hilali

Supervised by
Dr. Kevin Smith

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PRECISION AGRICULTURE: AN ENERGY EFFICIENT COMMUNICATION PROTOCOL FOR WSN

Capstone Report

Student Statement:

A statement affirming that “The designer has applied ethics to the design process and in the selection of the final proposed design. And that, the designer has held the safety of the public to be paramount and has addressed this in the presented design wherever may be applicable.”

_______________________________
Ghita Hossaini-Hilali

Approved by the Supervisor(s)

_______________________________
Dr. Kevin Smith
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Last but not least, I dedicate this work to my parents who are my driving force and the reason that I take up challenges every day. They are the people that sacrificed everything in order to provide the best education for me.
Abstract

Precision agriculture has been the subject of various research throughout the past years. Considering the growing population and the scarcity of natural resources, many researches have recommended environmental monitoring in order to define the precise need for soil regarding irrigation, fertilization, and pesticide application. Agricultural monitoring can be conducted through the establishment of a wireless sensor network that collects data trough sensor nodes implemented in the soil. The sensor nodes communicate wirelessly to transmit data sensed to the base station. The main limitation of these sensor nodes is that they run on batteries therefore they have limited lifetime. One proposed solution to minimize the energy consumption in data communication between the sensor nodes and the base station is the introduction of Leach protocol. Leach is a low energy adaptive clustering hierarchy that minimizes communication between sensor nodes and thus increases the lifetime of the wireless sensor network. This project presents a deep background research on the topics mentioned above and it conducts a simulation of the Leach protocol for a wireless sensor network in order to evaluate its effects on the battery lifetime of sensor nodes.
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List of Abbreviations

PA: Precision Agriculture
PI: Precision Irrigation
WSN: Wireless Sensor Networks
IoT: Internet of Things
CH: Cluster Head
CN: Cluster Node
LEACH: Low Energy Adaptive Clustering Hierarchy
WWANS: Wireless Wide Area Networks
WLANS: Wireless Local Area Networks
WMANS: Wireless Metropolitan Area Networks
WPANS: Wireless Personal Area Networks
IT: Information Technology
TDMA: Time Division Multiple Access
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Introduction

Moroccan agriculture has witnessed, during the past years, a great development, whether on the level of the cultivated land or the modernization and mechanization of the sector, the diversification of the agricultural product, the high cost-effectiveness of the sector or the increase in the number of farmers practicing agriculture.

Today, the agricultural sector is among the most important pillars of the Moroccan economy, and its contribution is considered a balance in the gross domestic product, and the rate of growth in Morocco is closely related to the rate of agricultural production. Indeed, the agricultural sector has largely improved in order to maintain its position as the largest contributor to Morocco’s GDP. Almost 14% of Morocco’s GDP which is equivalent to 74 billion Moroccan Dirhams contributes to the Gross Domestic Product of the Country [1]. Moreover, the agricultural sector employs more than 40% of the total employment in Morocco [2]. Agriculture is therefore a key sector for Morocco.

During the past few years, Morocco was able to achieve its self-sufficiency in some food products, within the framework of the green scheme, which His Majesty King Mohammed VI supervised in its launch in April of 2008 and wagered on developing agricultural chains, improving livestock breeding, and intensifying the use of mechanization, and focus on water economy [3]. Moroccan agriculture has also achieved high levels of production, in the production of citrus, grains, sugar and oils. Livestock (sheep, cows, goats, camels, and poultry) are among the most important elements of the agricultural sector in Morocco.

The water issue is a very important one for the development of agriculture in Morocco, and is linked to the network of dams of all kinds spread over the entire Moroccan territory, which Morocco has achieved, since the 1960s, great experience in building and
constructing dams, and significant gains for the agriculture sector [4]. However, Moroccan agriculture still depends on rainwater a lot and most cultivable lands depend on rainwater because of the lack of water resources throughout the year in the hotter parts of our country.

Hence, Morocco has limited natural resources to be used in agriculture, more precisely water that has become scarcer due to climate changes. It is then important to use them efficiently in such a way that nothing is wasted. The first step in managing these resources well, through precision agriculture, is to gather data about the cultivable lands. My capstone will focus on how we can effectively collect data from cultivable lands and especially on how the data can be communicated effectively in order to use this information to better manage our natural resources through precision agriculture and increase the lifetime of the embedded system set for this purpose.
I- Precision Agriculture:

Precision agriculture (PA) is a new global concept in the field of agriculture. It involves the exact and precise application of water, fertilizer and pesticide to meet the specific needs of each plant and each meter square of soil. Commonly, the accepted definition of precision agriculture is the sustainable management of agricultural resources which requires the application of the latter to the crop at the right time, the right amount, in the right place and in the right way [5].

Precision agriculture is defined to be the modern way of farm management that includes the implementation of digital technologies in order to monitor and optimize agricultural production. Precision agriculture is in need of data collected from the fields that enable the farmers to make a decision accordingly, decisions related to irrigation, fertilization and pesticide application. Instead of treating the integrity of the agricultural field with the same amount of resources or the “blanket” treatment of soil, precision agriculture takes into account the different soil parameters in order to provide the crop with the exact amounts of resources that are crucial to their optimized development, quantity, and quality-wise. This newly adopted technic for farm management touches upon harvesting strategies also [5]. Therefore, helping to manage the variability in the resources and increasing the efficiency of crop productivity as well as reducing energy costs on agricultural input operations. In other words, precision agriculture means bringing water and other resources to meet as close as possible to the needs of soil and plants [6]. It differs from traditional methods by the fact that only a fraction of the soil is watered with a low flow rate, that it requires only low pressures and therefore relatively light equipment. Several techniques have been developed in this, among which we can cite drip by means of drippers and microdispersion by means of diffusers and, more marginally, the use of porous pipes. In order to minimize water
consumption, irrigation scheduling can be considered. This consists in determining the quantity of water, fertilizer and pesticide to be supplied, for how long and at what hours of the day [5]. Several of these parameters are attributed by factors related to map conditions (temperature, humidity, pH), soil properties (infiltration rate, slope) and type of crop, as well as the growth phase of the plant [6].

The program may then vary from day to day depending on the conditions stated. For large operations, it is possible to plan more sophisticated tenant programming that takes all of these parameters into account with a qualified professional. The decision-based technics of precision agriculture ensure the optimization of agricultural products such as crop yield but at the same time, it achieves a strategic use of agricultural resources including water, energy, fertilizers, and pesticides. With the increasing rates of both hunger and environmental impact of human activities, precision agriculture is the perfect fit to help reduce their generating factors. Indeed, precision agriculture reduces costs and environmental impact as well as an increase and improvement in food production [7]. Another main benefit of precision agriculture is the reduction in pesticide resistance development as well as the limitation of underground water pollution caused by pesticides [5].

1- Agronomic Impact

The more the population increases, the more the quantity needed to feed the planet is growing. Since the 1960s, farmers use intensive irrigation to meet this increased demand. Irrigation currently represents 70% of the total world consumption of freshwater. In arid areas, irrigation absorbs up to 90% of available water resources [8]. By 2050, the global population is expected to reach 9.8 billion [9]. Therefore, we will have to increase our global food production by 100% in order to cover all the forecasted needs according to the
department of economics and social affairs of the United Nations [10]. PA is believed to have an important impact in order to help achieve the yield production expected by 2050. The main goal of PA is to increase the input/output efficiency of agricultural fields, including the choice of strains and varieties in relationship with the edaphic or phytosanitary context.

2- Environmental Impact:

In developing countries leakage accounts for up to 50% of the loss of drinking water. Intensive irrigation is also accompanied by losses that can go up to 40% of pumping water [11]. Family members living in arid regions of Africa have 10 to 40 liters of water per person per day for drinking, cooking and washing, while residents of cities in Europe or North America consume 300 to 600 liters per day per person [12]. According to statistics, agriculture is held liable for 10% of the global greenhouse gas emission [12]. PA can have substantial impacts on the reduction of the ecological footprint caused by agricultural activity and its harmful impact on the lives of the world’s population. Moreover, by gathering soil data and applying agricultural inputs accordingly, PA reduces risks of pesticide resistance development and underground water pollution caused by the application of enormous quantities of fertilizers and pesticides that gets filtered from the soil to reach underground waters [13]. The main purpose of precision agriculture is to apply an optimal amount of irrigation throughout the fields.

3- Economic Impact:

The most obvious impact that would succeed the implementation of precision farming is cost saving. First of all, precision agriculture helps manage resources more efficiently by mapping out the needs of the lands and using only the amount of resources needed, hence limiting purchases of water and fertilizers [14]. Therefore, farmers can better manage their
expenses and have better margins. Figure (1) shows cost saving in absolute terms per acre when using precision farming [15]. Another economic impact is the fact that through precision agriculture, farmers can increase their production by better use of the land. Experimental studies by King have shown an increase in wheat yield under precision irrigation applications. Yields have been reported to be better in two consecutive years [16].

![Figure 1: Average Cost Saving from the Adoption of PA][15](image)

4- Limitations of Precision Agriculture:

PA has many advantages regarding the cost optimization and the reduction of resource consumption. Nevertheless, its initial installation cost is considered to be relatively high. However, we can now find fairly inexpensive equipment suitable for small areas. Moreover, the person in charge of the farm or the farmer himself must have received training for proper use [19]. In fact, farmers must be able to adapt to the digitalization changes the world is bringing and they should be able to keep up with the technology. Automation integral on large surfaces is complicated. The growers should be in fact able to fully
assimilate the data collected by monitoring the fields and decide accordingly and to be able to interpret the data. In order to implement PA in real life conditions, one will have to face a lot of obstacles. One of the main obstacles faced by PA is to incite farmers to adopt this new technology especially that farmer tend to be conservative. The strategy to be used in this regard must focus on the following two points. On the one hand, we must seek to raise awareness by disseminating the results of research on the subject. On the other hand, we must aim to provide training and technical support, in collaboration with agricultural associations. Once farmers agree to adopt smart agriculture methods, they need to be given accurate information about the daily irrigation needs for their crops and thus be adequately trained to interpret the output of the PA system. This is when the development of a computer or web application comes to give them this information at any time. In addition, for the Moroccan context, farms are located in remote areas where connectivity is very low or inexistent. Another barrier relates to areas with high soil salinity and poor water quality. These areas are currently excluded from the scope of the research, and the results will undoubtedly be less favorable, but the farmers who cultivate them also need help [20]. One possibility would be to use the information provided by a soil map and to enter the most recent data on the degree of salinity in each region into the web application. This could then be taken into account when calculating many factors required for PA.

II- Wireless Networks:

A wireless network, as its name clearly states, is a network in which a minimum of two ends are able to exchange information and communicate with one another without the mean of a wire. When using wireless networks, one has the possibility of staying connected while moving within a more or less important range of perimeter. Wireless networks make it very easy to
connect elements that are far apart. Moreover, these types of networks do not require an important settlement of infrastructure in order to be installed. on the contrary, wired networks need specific infrastructure in order to be implemented. That is the main reason why wireless networks have been developed more rapidly for the past few years [21].

1- Types of Wireless Networks:

a- WWANS (Wireless Wide Area Networks):

Extended in large areas, it may be a city or a country. The kind of technology that is based on this type of network is GSM, 3G or 4G. Therefore, WWANs are specific to mobile networks that enable connectivity throughout long distances covering a whole country. This kind of service is mainly serviced by mobile phone service providers [24].

b- WLANS (Wireless Local Area Networks):

Extends over a small area, maybe a school, a home, a university or a campus. This kind of network is used to connect two buildings for example. It uses radio waves to communicate or WIFI [24].

c- WMANS (Wireless Metropolitan Area Networks):

We can consider this type of network as a mid-network in terms of size between the WWANS and the WLANS, it doesn’t extend in more than 40 km. It can be considered as a network of many WLANS. The technology that enables communication in this type of network is ViMax or IEEE 802.16 [24].
d- WPANS (Wireless Personal Area Networks):

A more scalable type of network, it includes things that are meant for personal use and to convey information over short distances. This type of network relies heavily on IEEE 802.151 (Bluetooth) or 802.15.4 (Zigbee). The important specification of this network is that it is power efficient, inexpensive, manageable and does not require any infrastructure [24].

2- Comparison of Wireless Networks:

Table 1 bellow represents a summary of the different types of wireless networks, mentioning their coverage limits, the rate of their performance and the communication type of each wireless network. In addition to that, Table (1) shows the different application of each type of wireless sensor network.
Table 1: Comparison of Wireless Networks

<table>
<thead>
<tr>
<th>Type</th>
<th>Coverage</th>
<th>Performance</th>
<th>Standards</th>
<th>Applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wireless PAN</td>
<td>Within reach of a person</td>
<td>Moderate</td>
<td>Wireless PAN Within reach of a person Moderate Bluetooth, IEEE 802.15, and IrDa Cable replacement for peripherals</td>
<td>Cable replacement for peripherals</td>
</tr>
<tr>
<td>Wireless LAN</td>
<td>Within a building or campus</td>
<td>High</td>
<td>IEEE 802.11, Wi-Fi, and HiperLAN</td>
<td>Mobile extension of wired networks</td>
</tr>
<tr>
<td>Wireless MAN</td>
<td>Within a city</td>
<td>High</td>
<td>Proprietary, IEEE 802.16, and WIMAX</td>
<td>Fixed wireless between homes and businesses and the Internet</td>
</tr>
<tr>
<td>Wireless WAN</td>
<td>Worldwide</td>
<td>Low</td>
<td>CDPD and Cellular 2G, 2.5G, and 3G</td>
<td>Mobile access to the Internet from outdoor areas</td>
</tr>
</tbody>
</table>

### III- Wireless Sensor Network:

Wireless Sensor Networks (WSN) have more notoriety in today’s world as they have been the subject of many studies in the past years. This new technology is used to sense data and gather many physical criteria that enable the monitoring of various parameters that are considered crucial [25]. Recent technological advances confirm the presence of IT and
electronics at the heart of the real world. More and more objects are thus being equipped with processors and mobile communications, allowing them to process information but also to transmit data. The world is nowadays directed to the automation of all aspects of life. Wireless sensor networks enter in this context and they can be applied to many areas including military, health, agriculture, and logistics [26].

This wireless technique of monitoring data consists of a set of small devices, or sensors, which have particularly limited resources, but which allow them to acquire data, considered crucial to process it and to communicate. A wireless sensor network consists of a net of sensor nodes that are equipped with micro-sensors capable of collecting and transmitting environmental data independently [25,26]. The position of these nodes is not necessarily determined. They can be randomly dispersed in a geographical area, referred to as the “sensor field” corresponding to the terrain of interest for the phenomenon captured.

Wireless sensor networks fall under the category of WPANS that uses IEEE 802.15.4. Which represents a set of spatially distributed sensors meant for measuring some physical parameters like temperature, pressure, sounds, chemical composition, etc. The first WSN was meant for military purposes, it was never perceived that it will be part of our daily life and other various applications. At that time, it was called Distribution Sensors Networks and then in 2001, it gained the attention of many scientists that were passionate about Wireless Sensor Networks. They then started coming up with algorithms and methods that would increase the efficiency of the Wireless Sensor Networks, including increasing the lifespan of the sensors and improving the lives of their batteries [26].
1- Applications of WSN:

a- Military applications:

Sensor networks were originally developed through the military sector as their first applications were mostly military grade. Their use is very popular when it comes to the military sector because of the many characteristics that they have such as rapid deployment, reduced cost, self-organization, and the fault tolerance of the sensor. For instance, a network of sensors can be deployed on an access sector, such as a border or a no man’s land, and will thus allow the monitoring of all human movement or allow the analysis of the terrain before sending human troops, such as analyzing for radiation, biochemicals. Tests using WSN have already been carried out by the United States Army in the Californian desert [28].

b- Security applications:

The structures of planes, ships, cars, metros could be followed in real time by networks of sensors, as well as the networks of circulation or distribution of energy. Structural alterations of a building, a road, a wharf, a railway, a bridge or a hydroelectric dam (following an earthquake or aging) could be detected by sensors previously integrated into walls or concrete, without power supply or wired connections. Some sensors that only activate periodically can work for years, or even decades [29]. A network of motion sensors can form a distributed alarm device which will be used to detect intrusions over a large area. Disconnecting the device would no longer be so simple, since there is no critical point. Monitoring of roads or railways to prevent accidents with animals (roadkill) or humans or between several vehicles is one of the applications envisaged for sensor networks.
According to their promoters, these sensor networks could reduce certain flaws in security devices and security mechanisms, while reducing their cost. Others also fear security or totalitarian abuses if the use of these networks is not subject to serious ethical guarantees [29].

c- Environmental applications:

Thermosensors can be dispersed from planes, balloons, ships and signal possible environmental problems in the well field (fire, pollution, epidemics, meteorological hazards), making it possible to improve knowledge of the environment and the effectiveness of the means of control [29]. Sensors could be sown with the seeds by farmers to detect plant water stress or the nutrient level of soil water, to optimize the supply of water and nutrients or drainage and irrigation. On industrial sites, nuclear power stations or in oil tankers, sensors can be deployed in a network to detect leaks of toxic products (gas, chemicals, radioactive elements, oil) and alert users and emergency services more quickly, to allow an effective intervention. A large quantity of micro-sensors could be deployed in the forest or in certain protected areas to collect information on the state of natural habitats and on the behavior of fauna, flora and sinking. The University of Pisa (Italy) has thus produced networks of sensors for monitoring natural parks (fires, animals). Sensors swallowed by animals or positioned under their skin are already sometimes used. It thus becomes possible to observe the biodiversity, without disturbing, of animal species vulnerable to disturbance or complex to study in their natural environment, and to propose more effective solutions for the conservation of fauna [30]. The possible consequences of the mass dispersion of micro-sensors in the environment have raised several concerns. Indeed, these are most often provided with a micro-battery containing harmful metals. Nevertheless, the deployment of a million sensors of 1 cubic millimeter each represents only a total volume of one liter. Even if this whole volume were made up of batteries, it would not have a disastrous impact on the environment [30].
d- Medical and Veterinary applications:

The monitoring of the vital functions of a living organism could in the future be facilitated by micro-sensors swallowed or implanted under the skin. Multi-sensor capsules or micro-cameras which can be swallowed already exist, which can, without recourse to surgery, transmit images of the interior of a human body with an autonomy of 24 hours. A recent study presents sensors working in the human body, which could treat certain diseases. One project is to create an artificial retina composed of 100 micro-sensors to correct vision [31].

2- WSN in the Context of Precision Agriculture:

In our special context, our aim is to deploy the technology adopted by wireless sensor networks and use it for environmental monitoring specific to precision agriculture. The main idea is to establish a WSN that is going to be able to monitor agricultural parameters including soil pH, Humidity and temperature. The WSN needs indeed to have an effective communication protocol that is energy-efficient [32]. WSN work on a very simple principle, sensor nodes are deployed in the field within the sensing region or the sensor field, these sensor nodes have the ability to communicate with each other and to transmit data to a gateway or a sink node that is responsible for communication of real-time data to the user through various means including the internet. The user can then access the data and decide accordingly how to manage his/her field for an optimal crop yield [34]. Figure (2) shows the data collection process in a wireless sensor network and the communication technics used to transmit data from the sensor node to the sink node and from the sink node to the end user.
3- Sensor node:

It is considered to be a unit directly in contact with the field. It is responsible for sensing data and transmitting it to the system. Figure (3) shows the main elements of each sensor node.

![Figure 2: Wireless Sensor Network [35]](image)

*a- Power Source:*

The sensors are in constant need of power source because it is a hardware that is busy all the time, gathering the information. After deploying sensors in various unreachable terrains, it becomes difficult and costly to replace the batteries. More adapted sensors are able to renew their energy from solar sources, temperature differences or vibration [37].

![Figure 3: Composition of a Sensor Node [36]](image)
b- Transceiver:
The wireless sensors combine the functionalities of both transmitter and receiver into a single device. Each wireless sensor node has a radio transceiver with an internal or external antenna [37].

c- Sensor:
A sensor is a hardware device that is used to capture data from the external environment. Parameters such as temperature, pressure or chemical composition [37].

d- Controller:
The controller processes data and controls the functionality of other components in the sensor node. The most common one is the Micro-Controller [37].

e- External Memory:
From an energy perspective, the most relevant kinds of memory are the on-chip memory of a micro-controller and flash memory-off-chip RAM is rarely, if ever used. A memory is present in the Micro-Controller and can be taken off at any time [37].
4- Example of a WSN System:

Table (2) represents an example of a commercialized wireless sensor network adapted for precision agriculture. This project was based on the eKo wireless sensor network initial specifications.

| eKo Wireless Sensor Node | Number of Ports: up to 4 sensors  
Sensor Measurement Interval: 15 min |
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>eKo Base Station</td>
<td>Responsible for the connectivity between eKo sensor nodes and eKo Gateway</td>
</tr>
<tr>
<td>eKo Gateway</td>
<td>Enables data visualization software packages</td>
</tr>
<tr>
<td>eKo soil Moisture &amp; Temperature Sensor</td>
<td>Soil Moisture and Temperature sensor to determine the rate at which soil dries out.</td>
</tr>
<tr>
<td>eKo pH Sensor</td>
<td>pH Sensor to determine the level of pH of soil</td>
</tr>
</tbody>
</table>

Table 2: eKo Wireless Sensor Network

5- Limitations of WSN:

One of the main limitation found in WSN is the low capacities of the nodes; considering their small size sensor node tend to be equipped with low capacity
memories. Another major limitation of wireless sensor networks is that sensor nodes operate on batteries which pushes these nodes to have a limited lifespan [38]. The limited energy of the sensor nodes is probably the most disadvantageous characteristic, the greatest of the challenges in the field of sensor networks remains the study of protocols, which minimize the energy in order to maximize the duration network life. In other words, energy is undoubtedly the right resource to manage with the greatest care.

The next part of this project is going to monitor the introduction of an energy efficient communication protocol for wireless sensor networks which is Leach protocol.

IV- LEACH Protocol for WSN:

LEACH protocol stands for low energy adaptive clustering hierarchy protocol is classified to be a hierarchical routing protocol that aims to reduce energy consumption in the network. One of the main limitations in WSN is that the sensor node has limited life because they are powered by batteries. The main goal of this part of the report is to introduce a new solution regarding the communication protocol within the sensor nodes and between the sensor nodes and the sink node [41]. In the past years, much research has been directed towards minimizing energy consumption by investigating the routing protocol and communication system of wireless sensor networks. The technic consists of finding the most optimized algorithm embedded in the communication system of the network [42].

LEACH protocol is the perfect fit to minimize the number of communications between the sensor node and thus increase their life in order to increase the efficiency of the wireless sensor network. The principle of LEACH protocol is relatively simple, it does not allow all the nodes to communicate with the sink [43]. The protocol designs cluster heads that
become responsible for gathering data from normal sensor nodes and sending this data to the sink in order for it to be processed as shown in figure (4).

![Figure 4: Leach Protocol](image)

1- Characteristics of LEACH protocol:

- The routing protocol minimizes the consumption of energy of sensor nodes; therefore, this protocol enables the user to extend the lifetime of the network.
- The protocol is based on randomization when choosing the cluster heads. The process of attributing sensor nodes to cluster heads is also based on randomization.
- The protocol evens the energy consumption in the network.

2- How Does LEACH Work?

LEACH works on the principle of distributing energy dissipation among all the nodes in a wireless sensor network in a way to reduce the overall energy consumption in the network and therefore increase the lifetime of the wireless sensor network. The routing architecture of LEACH is based on, using specific nodes to communicate with the sink node. We choose to name these specific nodes responsible for communicating data from sensor nodes to the base station, the cluster heads. Cluster heads are selected based on randomization from all the sensor nodes, and they are not fixed as for each period or round another cluster head is selected to communicate data to the base station. If the cluster heads were to be fixed,
they would have been drained from their batteries very fast considering the heavy energy consumption applied to cluster heads as they have to support data from various sensor nodes and send it to the base station. We can consider the cluster heads as relays in order for the data to reach the base station from the sensor nodes with an optimal energy consumption within the network. After each round, cluster heads rotate again, and other cluster heads are elected for a maximal dissipation of energy in the network. Each sensor node decides which cluster it will be following and sending its data to, according to proximity. In order to minimize energy consumption and battery drainage of the sensor nodes [43].

The algorithm starts with the announcement of a new round by the sink node. As stated earlier, the cluster heads are selected based on randomization but, the user predefines a certain probability of a node to be a cluster head. This probability ranges from 5% to 15% approximatively [43]. The cluster head selection takes also into consideration if the node was already selected as cluster head before in previous rounds. The algorithms specific to LEACH protocol takes the decision of electing a sensor as a cluster head based on the following algorithm:

\[ t(n) = \begin{cases} 
\frac{p}{1 - p \cdot (r \mod \frac{1}{p})} & \text{if } n \in G \\
0 & \text{if } n \notin G 
\end{cases} \]

P: is the probability of a sensor node to be a cluster head.

r: is the number of rounds at the moment.

G: is the number of all the nodes which were not elected cluster-heads during the previous 1/P rounds.
After that, each node generates a random number between 0 and 1. If this number is less than $T(n)$ then this precise node is elected to be a cluster head for the current round. After selecting the cluster heads for that specific round, clusters are formed where cluster heads send a warning message to the sensor nodes declaring that they are now selected as cluster heads. After that, sensor nodes are attributed to a certain cluster head according to proximity as they choose the cluster head with the highest signal [43]. After the creation of clusters within the network, each cluster heads coordinate data transmissions within its group. It creates a scheduler time division multiple access plan and assigns each sensor node a time slot during which it can transmit its data, and each sensor node only transmits data when it has a new value sensed, in order to minimize interference between transmissions in the network and the number of signals sent from the sensor nodes to the cluster head.

V- Matlab Simulation:

After defining the principle on which LEACH protocol is based, the next step is to the simulation using Matlab, especially the wireless communication toolbox within this software. Matlab is a well-known analysis and simulation software that has uncountable features and it can be applied to many different domains. The wireless communication toolbox facilitates the simulation of wireless communication networks such as wireless sensor networks embedded in agriculture.
1- Simulation Parameters:

In order to conduct the simulation, various parameters had to be imputed. Figure (5) shows the parameters that I have chosen for the Matlab simulation. The simulation was based on the eKo Wireless sensor network initial specifications mentioned earlier in this report.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>N = 100;</td>
<td>Number of nodes</td>
</tr>
<tr>
<td>W = 500;</td>
<td>Length of the network</td>
</tr>
<tr>
<td>L = 500;</td>
<td>Width of the network</td>
</tr>
<tr>
<td>p = 0.1;</td>
<td>Desired percentage of cluster heads</td>
</tr>
<tr>
<td>R = 50;</td>
<td>Radius of radio range for a node</td>
</tr>
<tr>
<td>num_rounds = 200;</td>
<td>Max Number of simulated rounds</td>
</tr>
<tr>
<td>Ei = 2;</td>
<td>Initial energy of each node</td>
</tr>
<tr>
<td>Etrans = 5.0000e-06;</td>
<td>Energy for transmitting one bit</td>
</tr>
<tr>
<td>Erec = 5.0000e-06;</td>
<td>Energy for receiving one bit</td>
</tr>
<tr>
<td>Eagg = 4.0000e-07;</td>
<td>Data aggregation energy</td>
</tr>
<tr>
<td>Efs = 1.0000e-9;</td>
<td>Energy of free space model amplifier</td>
</tr>
<tr>
<td>CHpl = 6400;</td>
<td>Packet size for cluster head per round (bits)</td>
</tr>
<tr>
<td>NonCHpl = 200;</td>
<td>Packet size for normal node per round (bits)</td>
</tr>
</tbody>
</table>

Figure 5: Simulation Parameters

2- Simulation Output:
As the simulation is run, we can witness the process of the election of cluster heads and the death of sensor nodes as they are drained from their batteries. The blue nodes represent the sink node or the base station. The black nodes represent the sensor nodes, the red nodes represent the cluster heads and the empty nodes represent the dead nodes. Figure (6) shows clearly that at the beginning of the simulation all nodes are alive whereas Figure (7) shows the sensor nodes at the end of the simulation.

Figure 7: Sensor nodes at the end of the Simulation

Figure 8: Total energy Dissipation Graph
In Figure (8), we can see that the total energy dissipated. We can notice that the total energy dissipated is 200 J because we have chosen to simulate 100 sensor nodes and each one with an initial energy of 2 J. The increasing slope is very high at first, then it starts deceasing. Because at the beginning of the simulation all nodes are alive and then they start dying because they became drained out of battery.

![Life time of sensor nodes](image)

**Figure 9: Graph of the Lifetime Sensor Nodes**

In Figure (9), the number of the nodes is first fixed to 100 because all the nodes are still working and then this number starts decreasing as the sensor nodes start dying. The number of sensor nodes does not reach zero because the simulation stops when the number of death sensor nodes reaches 95% of the network.
The throughput of the number of data files sent over time, measures the rate of success when sending the message from the cluster heads to the base station. Figure (10) shows that the throughput is increasing with time.

3- Comparative Study:

In order to clearly prove the efficiency of Leach protocol I conducted a comparative study of the lifetime of the nodes under leach protocol and under the most basic routing protocol in wireless sensor networks, the Directed Diffusion routing protocol for wireless sensor networks. The algorithm of the DD protocol is very basic. After the declaration of a new round, data is sent from one to another in order to reach the sink node following the shortest path between the sensor node and sink [44]. Figure (11) show the different step of the Directed Diffusion algorithm according to the shortest path.
Using Data of dying nodes under the Directed Diffusion communication protocol for wireless sensor networks and using my Matlab simulation to generate the same data for the case of the Leach protocol for wireless sensor network, I plotted the graph shown in Figure (12) that shows the first dying nodes for both protocols. The red graph represents DD and the blue one represents Leach. We can deduct that sensor nodes die much slower in leach than they do in DD.

From Figure (12), we can conclude that sensor nodes last 3 times longer in Leach than they do in DD. In addition, after 3 months of daily usage of the network, 91% of the sensor nodes are still alive using Leach protocol, whereas only 66% of the sensor nodes will be still
alive using DD. Moreover, after one year of daily usage of the network, 66% of the sensor nodes are still alive using Leach protocol, whereas only 37% of the sensor nodes will be still alive using DD.

In addition, in Leach protocol the first elected cluster heads are the ones expected to die first and because Leach elects cluster heads based on randomization the dying nodes are dispersed in all the field. Therefore, the farmer will lose coverage of spots spread in the sensor field. Whereas in DD, the first dying nodes would be the ones closer to the sink node as they are experiencing a lot of pressure from other nodes to transmit data to the sink node because they are closer to it, and therefore they will lose their battery energy rapidly. If they are not replaced the famers loses coverage of an important area whereas in leach the farmer loses just spot coverage of the fields which can be consolidated with the sensor nodes closers to it. Therefore, Leach Protocol optimizes the energy dissipation in the sensor nodes.

VI- Steeple Analysis:

1- Social:

Precision agriculture is of great interest to Moroccan society. In fact, this technic incorporated in agriculture brings all kinds of benefits to farmers, the environment and society. This innovation will in fact generate great opportunities for the people working in agriculture that are generally issued from the lower class. In fact, precision agriculture helps increase crop yield of the lands and thus their profitability increase also. This will enable us to generate more profit in both big and small farms in Morocco. The project will also create more job opportunities as the innovation requires specially formed professionals. Moreover, the goal of precision agriculture is to optimize the available sources and decrease wastes transmitted to the underground waters, this technique will decrease the pollution by fertilizers
of this kind of waters. All in all, precision agriculture is beneficial to society as a whole in the long run.

2- Technological:

Precision agriculture enables the optimization of resources including water, fertilizers, and time. In fact, this technique provides exactly what the plant needs in terms of irrigation and nutrients. The plants are treated as individuals and not as a community. The suppression of the blanket treatment of plants enables the reduction in sourced consumptions. Finally, the project does not involve any polluting waste, on the contrary, it gets rid of any unwanted pollution.

3- Economical:

The project enables the effective utilization of resources and will enhance the crop yield by up to 25%. This will generate more income for farmers and growers and will decrease their expenses. The savings made thanks to this project can be directed to other pertinent needs of growers in order to find even more effective and adapted solutions to the optimization of resources.

4- Environmental:

On the one hand, the innovation optimizes water resources as the plants are irrigated precisely and are provided with exactly the amount they need at the exact time they need it. This enables the optimization of water resources as it is expected that their available quantity in the world will decrease. On the other hand, the innovation enables to detect the exact needs of the crops and thus send specific amounts of fertilizers needed by the plants. This technique enables the reduction of underground water pollution as we decrease the amount of excess
fertilizer that goes through the grounds until it is filtered to the underground waters and thus polluting it.

5- Political:

This project will have a moderate political impact. In fact, if the crop yield increases in Morocco we can increase our exported quantities of crops to foreign countries. This will create a competitive advantage in favor of Morocco that can enhance its political advantages for the country.

6- Legal:

It is clearly stated in the Moroccan constitution that each Moroccan has the right to use this kind of technology in agriculture. Drone usage as part of precision agriculture will need a special license to be used as personal drone usage is prohibited in the country.

7- Ethical:

This project follows to perfection the rules of ethics as it designed to decrease the pollution of underground waters and to decrease the consumption of both natural resources such as water and other agricultural resources.
**VII-Conclusion & Future Work:**

Precision agriculture is a key solution for the optimization of resource and the reduction of the agricultural cost. Moreover it increase effectively the crop yield of the farmers. This concept should be introduced more to Moroccan growers as this is the direction the world is moving towards.

Leach protocol is an energy-efficient routing technic that minimizes the connection between sensor nodes. In comparison with other basic routing technics that enable communication between nodes themselves. Many other improved protocols can be based on Leach protocol as it is considered to increase the lifetime of any wireless sensor network. This technic elongates the durability of the network and its efficiency for agricultural monitoring.

As for future work that can be conducted later on, a wireless sensor platform can be created in order to generate data that can, later on, be analyzed. Moreover, after automating the data collection process for agricultural monitoring, an interesting expansion of this project would be to automate the decision-management and application process in agriculture and farming in general, meaning to study the feasibility of an automated system that irrigate, fertilizers and applies pesticide whenever it is needed in the fields without human intervention. Moreover, leach protocol is not a final solution to the optimization of energy of the sensor nodes as it can be used as a base for other routing protocols in WSN that can be even more efficient. Hybrid communication protocols that include Leach can also be an option. Finally, other options can be investigated to optimize the lifetime of the batteries, the most basic solutions would be the introduction of solar panels or wind turbine.
REFERENCES


