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THE USE OF WIRELESS SENSOR NETWORKS IN AFRICAN AGRICULTURE

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ABSTRACT

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The aim of this Master's thesis was to survey some of the works initiated in the use of Wireless Sensor Networks in African agriculture and to advocate the use of this technology on the continent by exposing its different applications like automated irrigation, soil moisture measurement and temperature detection. Examples of researches, seminars, theses and some development projects were studied to support the use of WSN technology in Africa. Seven different works discussing the use of technology in Africa were surveyed by analysing their purposes, main applications, successes and their real operations.

A farmer WSN tool kit was found a friendly device which can operate as a hand set WSN tool which can help farmers to interact with the network to retrieve valuable agricultural information. All the works surveyed suggested that by enabling the use of this technology applications in African agriculture will add remarkable changes in productions and change the traditional farming habits. Although this thesis surveyed different works, still it was more theoretical. If practical prototype examples had been tested, the results would have shown different methods to follow.

Keywords:
Wireless sensor networks, precision farming, internet of things, agriculture, irrigation, farming WSN kits, food security.

PREFACE

This work has been carried out at Oulu University of Applied Sciences in 2014-2015. The idea of this thesis was a result of discussion with my lecturer Dr. Kari Laitinen about my real life experiences during my previous work within different non humanitarian organizations in Africa. The challenges and what the technological advancement can contribute to the solutions. The thesis is a survey result of extensive reading and sourcing of useful information from different data collections of different ideas from different sources, analyzed then discussed with the supervisor to filter the useful information to have a compiled

The thesis interested me because it advocated solutions to some of the challenges I have faced during my previous work and encourage the use of some food aids into a practical technological tools as Wireless Sensor Network.

I would like to thank my supervisor Dr. Kari Laitinen for initiating the thesis idea, guiding and supporting me over during the study and thesis period. I'd like to thank my other lecturers for guidance during lectures and fellow graduate students for discussion, ideas, and feedback which have been absolutely invaluable.

Also I thank all other university facilitators and advisers for the great support.

With special thank, I would like to dedicate this thesis to my family for the great support, encouragement and realization of the importance of this degree.

Oulu, Finland, May 2015

Mustafa Ibrahim Ali

TABLE OF CONTENTS

ABBREVIATIONS

ADC (Analog to Digital Converter,

CPU (Central processing Unit,

FIFO (First in First Out),

GIS (geographic information systems),

IEEE (The Institute of Electrical and Electronics Engineers),

IoT (Internet of Things),

PC (Personal Computer),

RS232 (serial communication transmission of data),

RTCC (the real time clock and calendar),

USN (Ubiquitous Sensor Network),

WiFi (modern WLANs),

WSN (Wireless Sensor Network),

FIGURES

1 INTRODUCTION

The purpose of this thesis is to advocate the use of WSN (Wireless Sensor Network) in agriculture for Africa by promoting its expansion as an advance technology which is been applied in different applications today showing a promising future projection.

1.1 Prelude

Agriculture has formed the bulk of the global human economic activities and mean of survival to sustain life for centuries. As population increases, it will be more difficult to handle variations in production within shrinking farming fields to keep the food balance.

Having an ideal farming will help to save the wasted environment, lower the cost, minimize the use of resources and produce high yields.

Today technology is considered as a key tool to overcome many challenges and ease the way how people live. Technological advancements have played a big role in agriculture development especially for the farming machineries and food processing industries.

WSN has been recognized as an energy efficient technology, offers mobility, flexibility of uses in different applications, and is becoming dominant in precision agriculture.

This technology helps in land utility management planning through a systematic evaluation by sectoring the area according to its soil quality. Usually the farming sector needs more fertile land, while the dry and less fertility one can be left for animal grazing and settlement planning.

WSN also can be used for different applications in agriculture to support locating the ground water level, irrigation management, real time monitoring of weather situation, soil temperature and soil moisture.

The use of this technology can help also in crops logistical management through smooth distribution to the stores or marketing destinations through a remote information sharing.

The advantage of the WSN can play a big role in farmers' awareness by strengthening the agriculture Information.

Synthesizing the use of Wireless Sensor Network technology of the above valuable applications in African agriculture will be an added value to improve the traditional farming system which will enhance formers profitability, productivity, and efficiency.

There are many research and development projects related to the use of WSN in African agriculture.

The thesis discusses the application of this technology in agriculture, the gained benefits in Africa and the changes will be provided to the traditional farming system within the continent.

In chapter 2 Wireless Sensor Network has been introduced. Chapter 3 is a survey to different WSN agricultural applications researches and development projects been done in Africa.

Chapter 4 addresses the main applications of WSN in African applications. Chapter 5 advocate the different approaches of integrated WSN meant for African agriculture. Chapter 6 highlights the possible future direction of this thesis by

proposing aid funded institutional and industrial researches to advocate the use of WSN in African agriculture and Chapter 7 concludes this thesis.

2 WIRELESS SENSOR NETWORK

2.1 Sensor and sensing

The academic and industrial advancement in semiconductor materials technologies has a big progress within the field of wireless sensing communication.

Sensing technique a process of gathering information about physical objects locations and environmental changes. The sensing process gathers information for analyzing and data recording which can be used for different purposes.

Human body has the best sensing apparatus which are represented in eyes, ears, tongue, nose and the skin where the body use them to see, hear, taste, smell and feel the touch.

Human utilized these body sensing characteristics to apply them as tools to detect events or changes in quantities and provides corresponding output to be analysed for daily life planning.

Theses sensing characteristics help human to interact with nature and perform a huge technological development by introducing sensor technology.

The device which performs a sensing task to convert energy from the physical world domain into electrical energy is called a sensor or a transducer.

2.2 Wireless Sensing Network Overview and Motivation

As the world becomes more wired, one of main advantages of wireless communication is mobility, where the user can access the network by roaming over air from different locations benefiting from the advantage of easier expandable network.

One of the most advanced wireless communication technologies today is the Wireless Sensor Networks (WSNs) of famous examples as ZigBee, Bluetooth and WiFi (modern WLANs) are based on IEEE (The Institute of Electrical and Electronics Engineers) 802.11 standards technologies.

There are self-configured networks, using radio signals, consisting of thousands spatially distributed autonomous tiny devices, equipped with sensors enabling them to sense and compute environmental behaver changes within the physical world.

Figure 1, shows an example of WSN for environment monitoring.

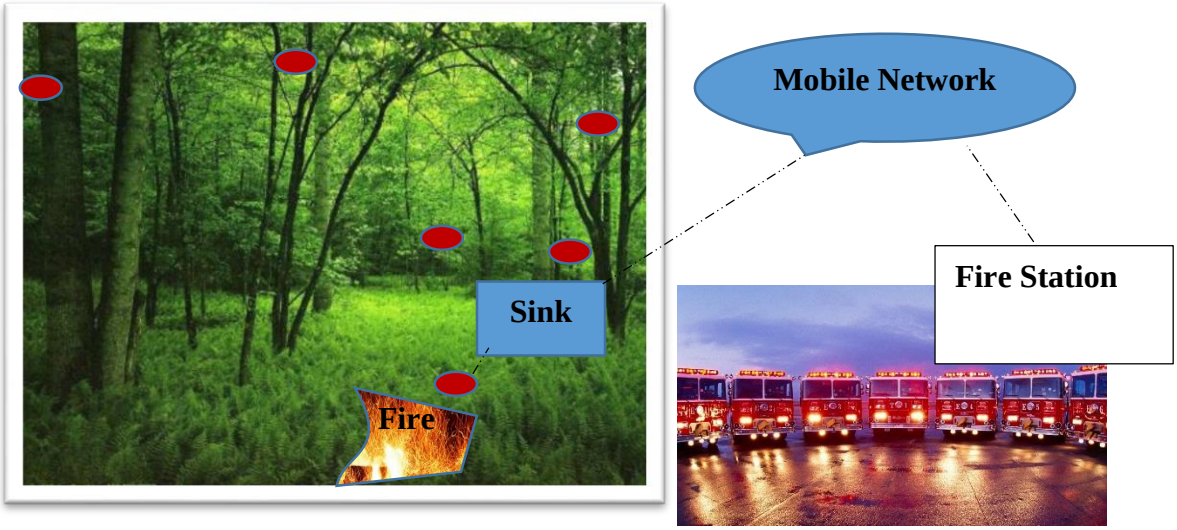

FIGURE 1 Environmental monitoring application example.

2.3 Sensor Main Node Components

There are two kinds of senor nodes used in WSNs, one is the node that deployed just to sense phenomenal changes within surrounding areas, while the other node is to act as an interface gateway for the a wider sensor networks system as shown in Figure 2 and Figure 3.

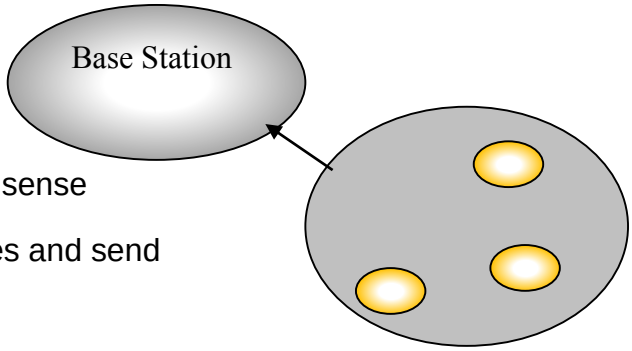

FIGURE 2 Node sense phenomenal changes and send

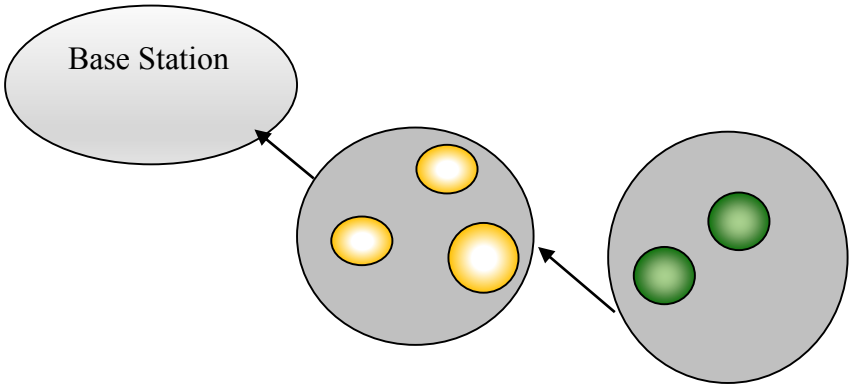

FIGURE 3 Node sense phenomenal changes and send through intermediate

Every WSNs node consist of five subsystems which are shown in Figure 4, and explained below:

a. Sensing Subsystem

It consist of tiny sensors, sense the changes of voltages, fed the changes of measured voltage to an ADC (Analog to Digital Converter) , the digital converted signal is send to the CPU (Central processing Unit) for further processing.

b. Processing Subsystem

It's the microcontroller of the node, having a central processing unit and an embedded Analog to Digital Converter (ADC) it's able to respond to different orders like reprogramming, reconfiguration.

c. External Memory Subsystem

The main types of memory contains (program, data and flash memories).

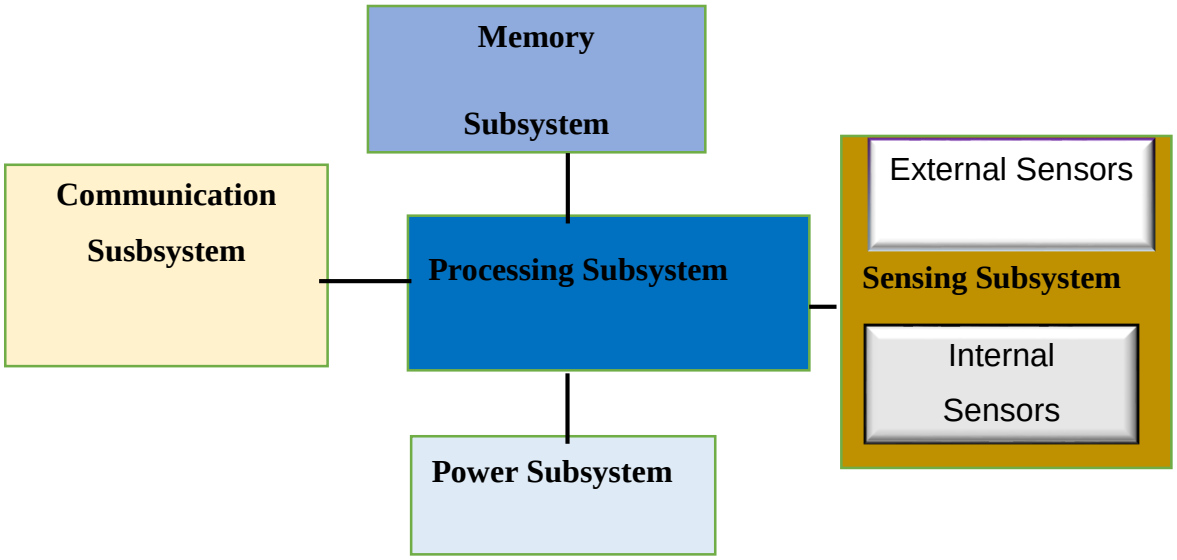

FIGURE 4 Sensor node subsystems

d. Communication Subsystem

It's a transceiver having a wireless antenna, responsible of transmitting the radio signals using the optical signals or infrared waves as a medium, operates in ISM (Industrial, Scientific and Medical purposes) band. It uses a free radio frequencies for communication in most countries, allocated in the international table of frequency allocation, contained in Article s5 of the radio regulations (volume 1). (Wireless Communication, Jean Paul Linnartz' Reference Website)

e. Power Subsystem

The energy supply source for wireless sensor node are batteries with a restriction in sizes, but some note are powered by solar energy systems or other forms of renewable energy sources.

2.4 Hardware of a Wireless Network Sensor Components

Main components of a wireless sensor network node are shown in Figure 5.

Subsystem in WSNs node consists of a hardware component as shown in Figure 5 which includes:

- Sensing hardware, detect events or changes in quantities and provides outputs to be measured, the results evaluated for analysis.
- Transceiver which transmits or recieves data on a wireless medium based on radio frequency communication requierd, working in an ideal power consumtion mode by having the posibility to sleep when no action is reqaured.
- Memory, used for programmes code and for in memory buffering.
- Microcontroller as the CPU which contains the memory or the storage capacity, has different tasks as control and communication with other components within the sensor to read and process the data.
- Battery, the source of energy to operate the unit.

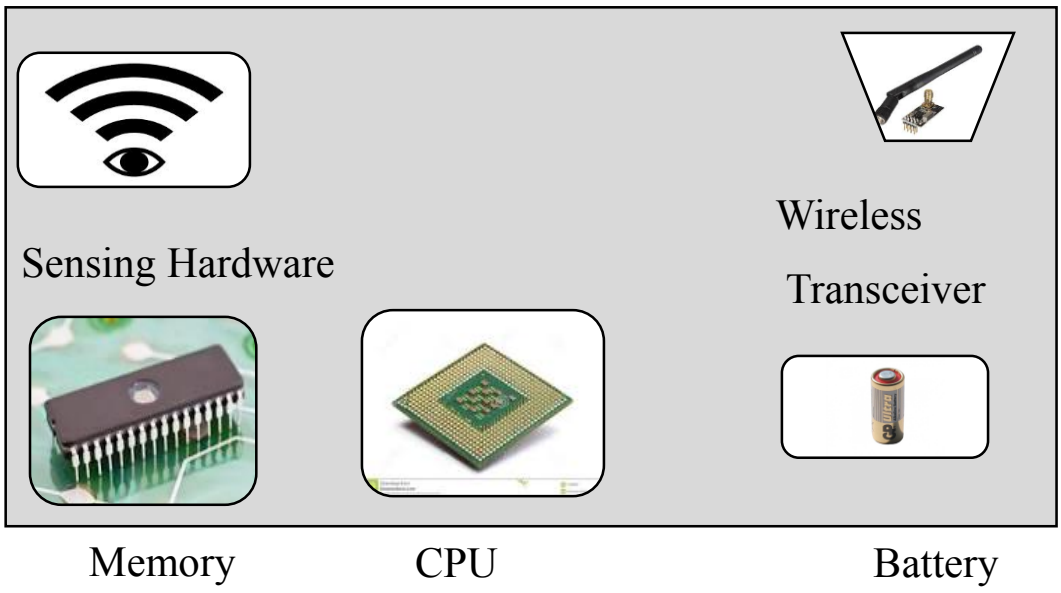

FIGURE 5 Hardware of a wireless network sensor components.

2.5 Hardware of a Wireless Network Sensor Components

The wireless sensor network communication operation process shown in Figure 6 is performed as follows:

- The sensor nodes collect the required measurement around the sensors, form a wireless connection over the available medium, collect data and route them back to user via the sink which act as a base station.
- The sink or the base station which located closer acts as message receiving center routes data between sensors nodes to the internet and users.
- The task manager node handles the data storing, analyzing, displaying and controlling process plus the interfacing requirements.

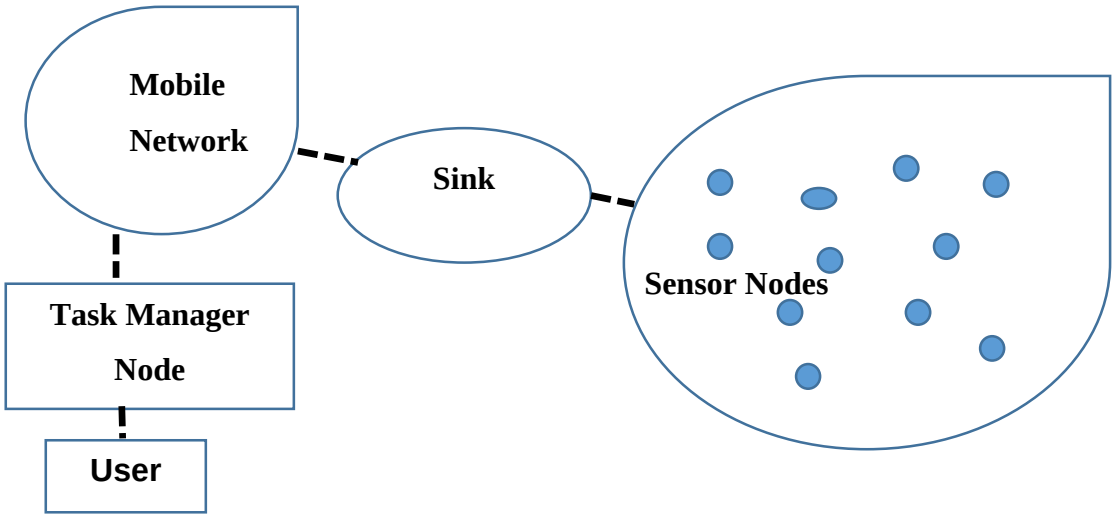

FIGURE 6 Wireless Sensor Network Node Communication

2.6 Wireless Sensor Functional Process

As shown in Figure 7, the sensed information will be driven through the sensor inputs to the signal processing units of the CPU of the node, the signals will be processed and evaluated by multiplexing and amplification circuity hardwires

then converted to its applicable forms through the analogy/digital conversion. These processed information are kept within the memory to be send via the transceivers to the required destinations within the WSNs nodes.

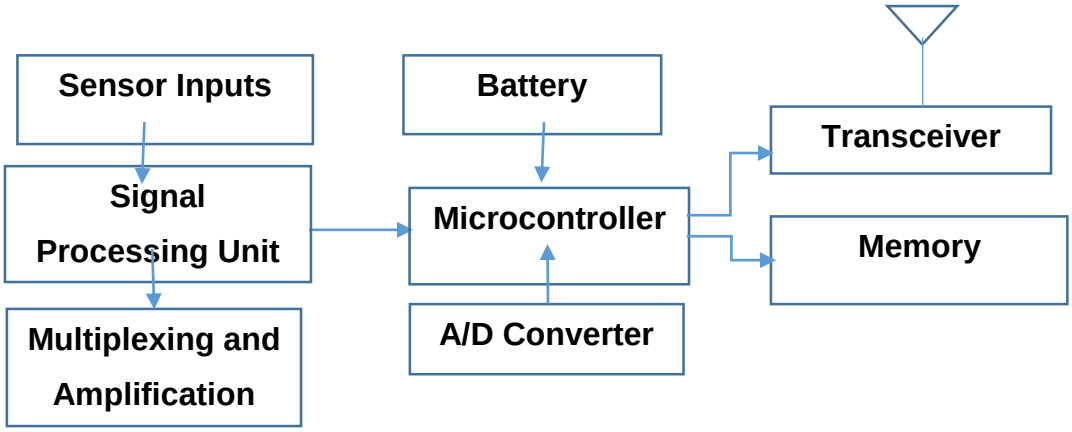

FIGURE 7 Sensor functional block diagram

2.7 Wireless Sensor Network Topology

Networks can be defined according to their physical or logical geometry arrangement which called topology.

Wireless sensor networks topology is very crucial as energy, range and data rate are important parameters for a successful network. The frequent topologies used in wireless sensor networks are:

- Point to Point piconet as Bluetooth Topology,
- Star Topology, as in WiFi WSNs and ZigBee WSNs technologies.
- Mesh for ZigBee Topology
- Hybrid Technology
- Tree for ZigBee Topology

2.8 Wireless Sensor Network Routing Protocols

Routing protocol is important in WSNs because the parameters can be controlled to be adaptive to the current network conditions and the energy level and the main routing devices are:

a. **Coordinator**: is the "master" device, which governs all the network operations.

b. **Routers**: they route the information which sent by the end devices, by looking to the destination if it's sleeping or awakened up, it will decide to send packets.

c. **End device**: (the notes): they are the sensor nodes, the ones which take the information from the environment

Generally routing in WSNs can be divided into three main categories according to the system architecture and functionality in routing protocols which are explained below:

- Flat based routing, all nodes will be assigned to having an equal role.
- Hierarchical based routing, nodes have different roles within the network.
- Location based routing, the nodes are addressed according to their locations.

One of the main WSNs protocol is the stacking have the following layers:

- Physical layer, its first concern is to minimize energy usage, with the responsibility of modulation techniques by generating the carrier frequencies, frequency selection and signal detection.
- Data link layer, is responsible of multiplexing, frames detection, transmission medium accessing and errors controlling using the MAC protocols of two goals first is to provide an organized communication links between huge number of nodes and second is the efficient sharing of resources between these nodes .

- Network layer, handles the talk between two selected nodes having the priority at the chosen time.
- Transport layer, carry the system to be able to communicate within a wider area.

Application layer, enabling the lower layers to be able to interact in term of software and hardwire applications.

In a real WSNs there will be a gateway or a router as a primary source for outside the network clients to communicate with sensor nodes, shows web servers the retrieved data to be published on the internet. The communicator which demonstrates communication process within the nodes, dealing with so much messages as time delay, packet information, controlling process having the ability to determine the priorities.

2.9 WSN Applications

Two of the most common wireless sensor networks technologies which are available are Wi-Fi (IEEE 802.11x) and ZigBee (IEEE 802.15.4x). There are 3 main factors determining which wireless technology to choose for a particular application, these are power, bitrate and range.

There are potentials applications based on WSN, but these applications can be summarized mostly in the following uses:

- Energy consumption optimization by reducing the device power usage control
- Automated control of equipment in industrial factories and
- Condition monitoring of buildings
- Real time monitoring of homeland security
- Consumer goods wireless facilitations
- Environmental monitoring as weather foresting

- Supply chain management through object tracking, distribution location monitoring
- Water, air quality measurement

As becoming a major advanced technology in health, security and agriculture the wireless sensor networks can play a big role in delivering smarter, green and an efficient planet for us to live in

The Figure 8 *shows some of the current applications of WSNs.*

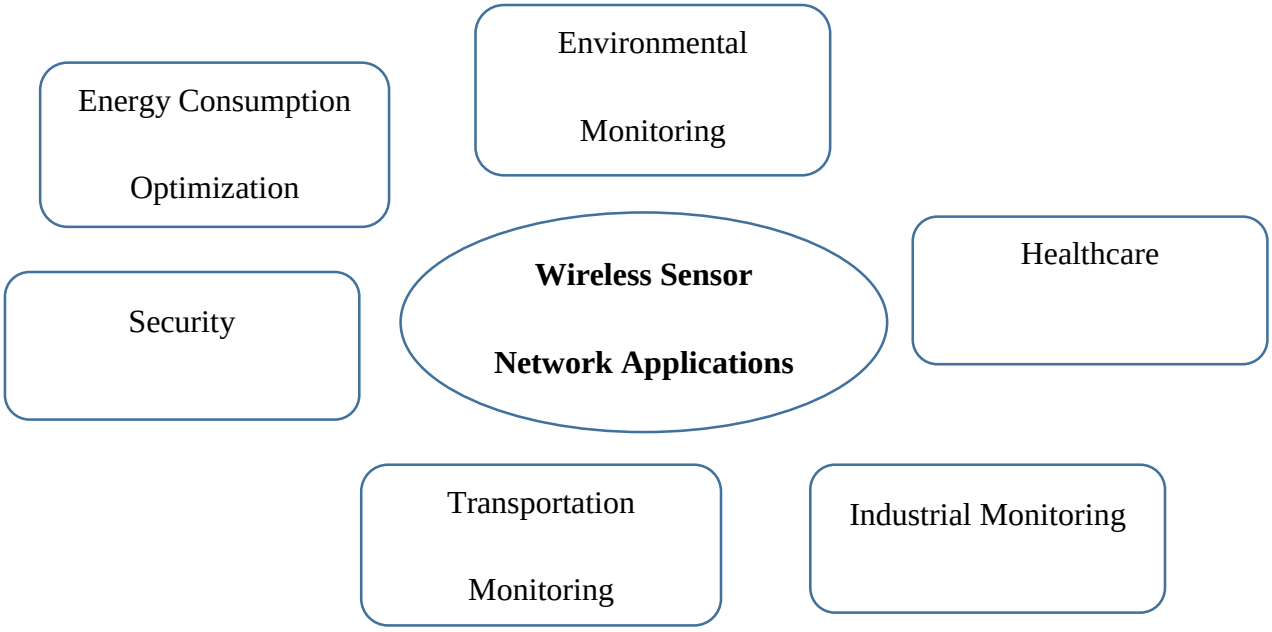

FIGURE 8 Current Applications of WSNs

2.10 Software

Characterized by relatively small memory size, need of high energy optimization, self-organizing, and fast computation to evaluate the environmental dynamic conditions, WSN software design issues like architecture, platforms, and updates recovery are very important.

2.10.1 The data Processing Approach

The main three components of data handling are sensing, processing and communications following is how the data is processed:

- The client send or wait for required information within a surface conditions in the area of interest.
- The request will be handled by a proxy via standardized protocols through communication with the distributed nodes using a standard protocol.
- The nodes are deployed in different areas, their received or sensed data collections will be processed and sent it to proxy
- The proxy collects the messages sent it from the nodes, translate the information into standardized protocols, and then send back to clients who are interested about the data.
- The clients are receiving the required information for analysis and produce a useful information to be shared.

These data processing approaches need a flexible architecture of nodes software to make it easy for appropriated interfaces system to diverse applications devices of minimum run time utilization environment, and efficient use of system resources.

To ease the nodes data processing, the node software is divided into three main tasks:

- The operating system, mainly handles device tasks like booting, hardware initialization, scheduling, memory management/processing, the nodes nature determine which part of the operating tasks is needed.
- The Sensor driver task, initializes the sensor hardware and its performance for measurement.
- The Middleware Management Task, handles different modules such as routing, security, etc.

Having the node software into these components make it easier to be managed as each part will be handled separately then linked together statically by scaling

the software which easily optimized the interfaces between several components within a node. Or linked dynamically to exchange components during the run time for example during linking or loading process.

2.11 Power

A deployed WSN is expected to work for a long time without human intervention and must be able to achieve its remote nature in a flexible, efficient, low-cost performance.

The power consumption is very important issue in WSNs operation as is consist of small battery powered sensors of a very long life time requirements so as to be able to ensure the longevity of the deployed network.

This demands a WSN design that, minimizes the overall power consumption through controlling the active/awake time of a device such as radio or microcontroller and limits the current draw when they are sleeping. The networks are varying with respect to the power setting according to the modes of the devices such as always on/standby or hibernation modes.

For example in case of remote temperature, active sensors uses power to collect readings over a long period of time, and return to sleep mode until more sample measurements are taken. At regular intervals, RTCC (the real time clock and calendar) will wake up to check if there is a task to be performed, while in surveillance systems a need of 24/7 stand by is a must.

2.11.1 Transceivers Power Consumption

The most power consuming part of the WSNs is the transceivers which are typically in three modes:

- Transmission, of the maximum power consumption
- Receiving
- Idle, listening and ready to react.

Or neither of the above situation when it turned off, where there is no or least power consumption.

- Nodes components are sleeping while not in use.
- Use renewable sources of energy
- Having good algorithm
- Using energy harvesting technique
- And the most efficient is hardware development

To solve the WSN power consumption problems, more renewable and energy harvesting based autonomous wireless sensor nodes are becoming industrially available.

These devices make it possible to deploy more WSN in very remote and harsh locations, while the energy saving approach could play a major solutions for WSNs energy sources issues in many developing countries.

3 SURVEY OF WSN APPLICATION IN AGRICULTURE IN AFRICA

African agricultural yields remain among the lowest in the World. Sub-Saharan Africa remains the only region in which per capita agricultural output has not seen a sustained increase over the last four decades. There are increases in Latin America and South Asia, while East Asia and the Pacific have increased agricultural production per capita by almost 80 percent over the last 45 years. (Mette Wik1, Prabhu Pingali2, and Sumiter Broca, Global Agricultural Performance, Past Trends and Future Prospects, 2008).

The following section explain the researches that have been surveyed.

3.1 Frost Monitoring and Weather Forecasting in Africa

This is a WSN project supported by NASA and USAID using a Geographic Information System (GIS) and remote sensing data to monitor the weather situation by detecting the possible incoming frost within Aberdere and Mount in Kenyan tea growing areas.

This will improve the monitoring process of tea farmers, when they are able to know the weather situation.

The system collects data about frost situation. Farmers use this information to plan their planting schedules, choose the type of crops and locate the best areas.

This project provides weather information for the Ministry of Agriculture and Kenya Ministry of Water and Irrigation, its shows where are the frost expected areas.

The project is aiming to be developed and have the ability to provide warning of 72 hours in advance of a frost event and having online maps of different geographical locations.

According to project planners, this will benefit tea's growers in Kenya to face the frost problems and promote sustainable economic growth within the community. (Kit Batten, April 2014).

The research helps tea farmers in Aberdares and Mount of Kenya to identify crops like cabbages are high tolerance to low temperature. This gives them the opportunity to schedule their crops according to the weather situation. Also it determined that, wind below is the main reason for frost

3.2 Technology coupled with Agriculture will catapult Africa out of poverty

It's founded by Brenda Mareri who is an active supporter in dissemination of information technology and its use in Africa aiming to change life of many individuals. (Brenda Mareri, October 2014). Date of retrieval 12.04.2015.

The idea is to set up a real-time WSN monitoring system which is able to send information about soil moisture level obtained by sensors to farmers mobile.

Using the information received farmers will select the necessary fertilizer and be aware of the irrigating water levels for the crops.

The target group to operate the system are the unemployed youth who will be recruited to install and maintain the system.

They will be utilizing their talents and reserved technologist to help their communities.

This is a good example of research in Africa for using WSN application, because it targets unemployed youth and farmers to cooperate. Also the research encourage farmers to be loyal to the project by paying 10% of the total cost, because they will have the feeling of ownership.

The project also predict the production will triple by using WSN application in agriculture.

3.3 Wireless Farming

It's a master thesis project been conducted as a research work to investigate and identify how farmers in Ethiopia can use their mobile phones in conjunction with WSN to monitor their farms.

The research has found the methods used by farmers in this part of Ethiopia to monitor their farm field. Using the information obtained, the researcher advocate the of WSN applications in combination with mobile phones.

A mobile and Wireless Sensor Network based application to create farm field monitoring and plant protection for sustainable crop production and poverty reduction.

The results obtained from the survey have delivered a proposed prototype to be designed.

Through a mobile application the farmers or users can access data from the WSN farming system. (Elias Edo Dube, 2013).

3.4 Monitoring the Performance of Agriculture and Food Systems

It's a global initiative from the United Nations to have a sustainable development solution network using technologies like GPS (global positioning systems) and GIS (geographic information systems) benefiting from the **remote sensing** technology by applying its application in farming monitoring system and having a global agricultural data base for information sharing.

The life monitoring of weather forecasting, soil information using technologies like GPS, GIS and WSN provides a database system analysis and information sharing which will include the rural areas like African farms with main benefits as.

- Satellite images through remote sensing will help governments and farmers to manage the land.
- Global sharing of African Soil Information.

- Global crops yield information
- Tracking of environmental sustainable solutions of governments

(UN Technical report, 2013).

3.5 Sensor Network Business Case for Applications in African Agriculture

It's a master thesis carried out to investigate the scope of African farming by using WSN technology.

The approach was to monitor different parameters such as temperature, humidity and soil moisture the farmers can face the challenges of climate change. WSN can help them to automate the irrigation system. (Rishabh Rastogi, 2011)

3.6 Precision farming solution in Egypt using the wireless sensor network technology

This work published in the Egyptian Information journal on 3rd November 2013 discussing the application of WSN in agriculture.

This paper gives an overview of the use of wireless sensor network in Egypt. It discusses the benefits to use WSN in potato farming, the process will automate the scheduling, fertilizing and planting of potato. This will improve the production and storing process to avoid disease and harmful fungi especially when old land is used.

The research also concluded that the most suitable routing strategy to precision farming in this case is the APTEEN hybrid routing protocol, because it allows comprehensive information retrieval of 6.5 month network lifetime which is more than the potato time needed to be ready. This will benefit other researchers and farmers within neighbouring countries of similar weather situation. (Sherine M.A.E, Basma M. M. E, 2013).

3.7 Deployment of a Wireless Sensor Network for Precision Agriculture in Malawi

This work demonstrated how WSN can be deployed in rural areas of developing countries like Malawi. It was set up in Manja Township, city of Blantyre. It's a self-sustained system using solar energy. The system monitors the soil and activates the irrigation valves to water the plant field.

The experience of this study has exposed several valuable issues like use of solar as source in these rural areas, also it advises a close monitoring within remote locations, possibility to use WSN to control the irrigation process in these areas, the use of technology to improve the socioeconomic conditions of small scale farmers in developing countries and cooperation between universities through research programmes to encourage the use of WSN in African agriculture as this project was funded by the Scottish Government through the University of Strathclyde for providing the equipment deployed in this study. (Mafuta M. 2013).

3.8 Summary of surveyed projects

This thesis survey was concentrated on the successful results of different researches and projects advocating the use of WSN in African agriculture.

Most of these works are research based, but there are some projects that have been implemented in the field or on their way.

The results have shown that, by applying WSN in African agriculture, there will be a positive change in the traditional farming habits.

The survey also found, most of the works were institutions researches based, but not been commercialized.

This thesis advocates commercialization of researches within industries.

Thesis also have some suggestions to implement real and active projects which give more opportunity for WSN applications in African agriculture.

To support the surveyed works done advocating the use of WSN in African agriculture, I am having some suggestions in Chapter 6, Sections 6.1 and 6.2. These suggestions include proposals of industrial WSNs research based approaches by allocating some of the continents local budget, or earmarking some of food aid development funds to be used in technology such as wireless sensor networks in African agriculture. Also a practical WSN agricultural tool kit proposal is discussed in Section 4.7.

Real WSN development projects for African agriculture will improve the governing system, empower the African private farming sector competition, safe the environment, eliminate diseases and increase the production yield.

4 POSSIBLE USES OF WSN IN AFRICA

4.1 Some problems in African agriculture

This thesis advocates the use of WSNs in agriculture for Africa not only to mitigate the agricultural problems, but also to promote the use of technology for resolving many challenges and involve research activities within African agriculture having opportunities to improve the food productivity.

WSN has a significant deployment in different applications which include healthcare and security.

Through the photosynthesis process by using the sun energy and water the plants change carbon dioxide (CO_2) and water (H_2O) into starches and sugar which becoming as plants food, this way we get crops.

In Africa, where the population is growing very fast the use of the same land for long time is common, but the changes of traditional farming to advance one is very slow one. These harmful farming practices have led to soil degradation by losing the most of its fertility. The amount of nutrients is not sufficient which causes a low agricultural productivity in most African countries.

African farm land nutrients are declining which affect the soil fertility.

Soil fertility tests are often done in the laboratory where samples are taken, this process may study only a portion of the total land and also it’s difficult for farmers to have access to it, but the use of some available technology as WSN which is discussed here can ease this process.

The three main mineral nutrients (nitrogen (n), phosphor (p), potassium (k) evaluation and their plant’s support is shown is shown below:

- Nitrogen (N), gives the plants Green leaves.
- Phosphorus (P), help in root growth, keeps seed formation
- Potassium (K), help the plant to build the protein, photosynthesis, fruit quality and reduction of diseases.

The following Sections will address different areas where WSN can be applied.

4.2 Underground Water Detection

The underground water is not equally distributed in earth, because of surface difference, usage and natural disasters which caused water amount to decrease all time. It's important to check underground water availability before planting, especially for irrigation dependent agriculture.

WSNs can be use not only to determine the availability of water but also the quality if it's ok.

4.3 Irrigation

Irrigation is an essential application of supplying water to land to assist the plant to grow and have its production target. Maintaining the landscapes, protecting the plants from cold or hot weather conditions, preventing soil from reducing its volume, and protect plants from dust and agricultural diseases. Efficient irrigation system is very important, is safes water, environment and a real factor for better agricultural management.

There are different techniques to manage the quality of irrigation systems to control the volume and frequent use of water.

4.3.1 Irrigation System in Africa

However when Africa in concern, still there are many problems facing irrigation system. This let the dependency on rain-fed systems to dominate the agriculture in the continent.

Most of African farms production is generated by irrigated agriculture.

If we add the use of advance technology of a low operative cost like WSN, will make it easier to reach the goal of the above target.

Expand technological base irrigation using WSN in this enormous area in Africa could improve productivity and play a big role in African food security.

An automated irrigation system by using Wireless Sensor networks will make it possible to observe, access, control agricultural fields in real time and improve the traditional irrigation system and optimize the water usage.

WSNs offers solutions to Africa's irrigation landscape, this technology can be deployed to automate irrigation system to minimize the use of water by controlling quantity through early temperature and moisture detection around the plants environment which help to save energy.

4.3.2 Technical Approach of WSN in Irrigation

After the land fertility test farming will start, but irrigation process is very important for the plants growth. Using WSNs which capable of data collection for the soil moisture, temperature, and plants leaves wetness. Weather conditions like raining or dryness can be detected.

Knowing these parameters the decision on irrigation system will be provided automatically.

4.3.3 Possible WSN Design Architecture for Irrigation

The traditional irrigation system consists of energy source, pipes and valves.

All are connected to the WSN which makes automated intelligent decisions as shown in Figure 9.

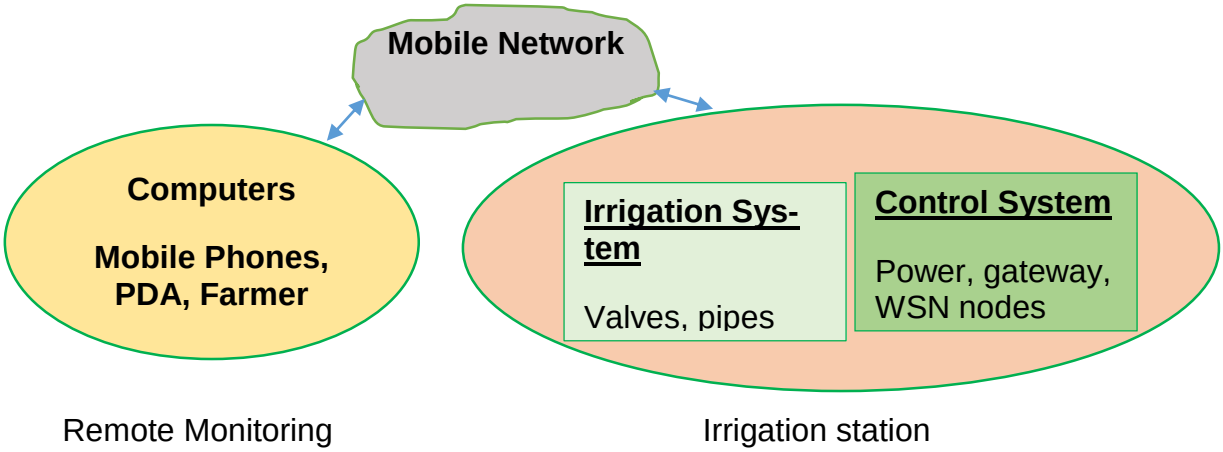

FIGURE 9 WSN Irrigation System

4.3.4 Irrigation Triggering

Due to different situations plants always need water. These situation can be determined by changes in temperature, leave wetness, soil moisture or risk of disease. This fluctuation will trigger the irrigation control system to start an event of irrigation process using the sensor nodes data collected.

The control can be done manually by user's commands from anywhere, or through a scheduled process set through a clock of time interval in different periods which is more independent of being in a real time interaction with the radio communication system.

The scheduled irrigation process using WSN to collect data, then start irrigation its more liable than the real time irrigation process, because if there is no radio connection in case of some problems this data at the real time event are not reliable.

4.3.5 Process of Manual Irrigation

For all automated irrigation systems, there is no need for farmer to start the system. The irrigation system will be managed automatically when to start and when to end the process.

- Farmer check the parameters which indicate the need of water by a hand set device.
- If need of water confirmed the button at the farm unit will be pressed.
- The message will be send through a mobile network medium to the central processing unit.
- The central processing unit which will receive the message, responds to the farmer if the irrigation process will start.
- The control unit will trigger the motor to start for irrigation process.
- The irrigation fields will start dropping off randomly when there is no need of water which can be determine by the same parameters which used to start an irrigation process like soil moisture example. When all the field is irrigated the motor will turn off.
-

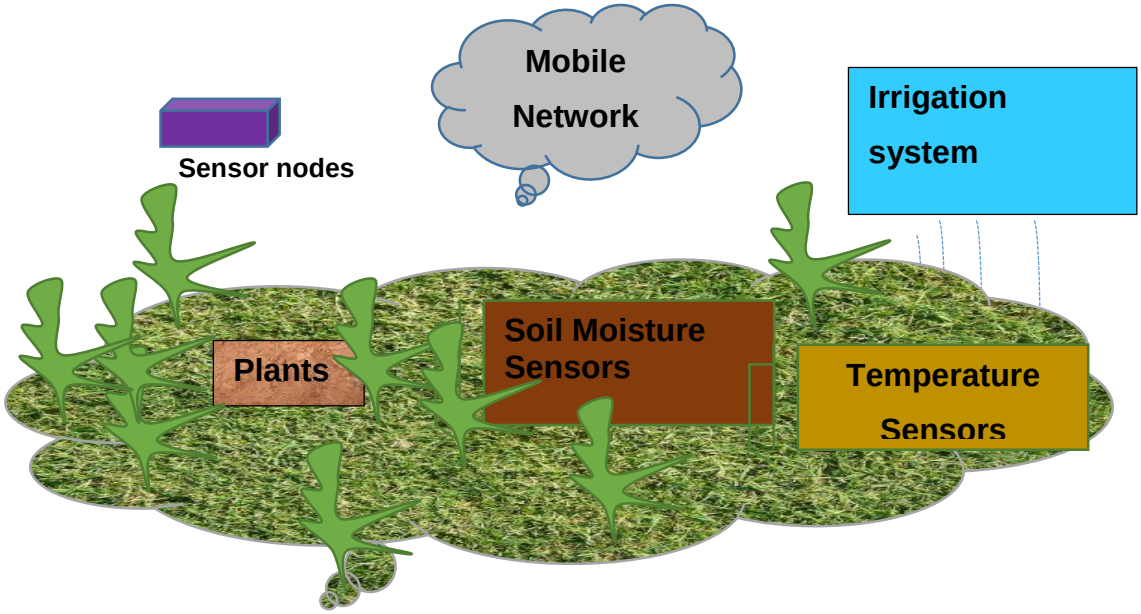

FIGURE 10 WSN controlled irrigation system.

4.3.6 WSN Approach in Irrigation

Through defined time intervals samples of required parameters to determine the irrigation system as soil moisture, temperature or leaves wetness are taken by an equipped sensors.

Using an agreed protocol, the collected samples are send and stored within the coordinator node which organizes the network and maintain data routing process.

The data is sent from the coordinator node to the gateway or router node so as to be forwarded to the remote monitoring station using a mobile network medium. To save energy the coordinator node can sleep when there is no data traffics still is awaken up by a time out or interruption by a sensor. The stored set values within the coordinator will determine whether the irrigation system motor will start and the valves to be opened.

4.3.7 Advantages of WSN Automated Irrigation

The main advantages of automated WSN system are:

- Reducing the amount of water usage
- Control the need off fertilizers
- Reduce the labour force needed
- Real time monitoring and manage the exact amount of water needed for plants

4.3.8 Irrigation System Triggering Parameters

The main parameters to trigger an irrigations system are temperature, soil moisture, plants leaves wetness, weather condition and crops diseases.

The use of WSNs to evaluate some of these parameters for triggering an automated irrigation system is explained below.

4.4 Temperature Measurement

Soil temperature can be determined by estimating it from the weather data or using a temperature probe as explained.

These temperature results will be studied and the soil temperature changes are monitored to help the farmers to make decisions like irrigating the plans or start harvesting. To determine the soil temperature for Monday, using 3 previous days' weather data the mean is calculated by adding Sunday, Saturday and Friday temperatures then divide by 3.

Following this method the soil temperature for a longer period can be determined, but still the results depends on the accuracy of the weather prediction measurement approach.

4.4.1 Using Weather Data

These weather data collected will help to calculate the risk levels and dangers potentials. By having a complete picture of the current weather situations using WSN, farmers will make better plans especially for the most critical locations to avoid the risks.

4.4.2 Using Temperature Probe

Different methods to measure the soil thermal properties have been utilized to assist in the field of agriculture for soil temperature measurement.

Using remote sensors the soil temperature is recorded, sent and analysed for decision making.

Today there are so many soil temperature sensors available commercially, but the main principle of operation is almost the same.

4.5 Soil Moisture

Knowing the soil moisture before planting or during the plant growth is very important. The soil get water both from the surface through rain, mechanical irrigation process or from the ground water which located beneath the earth's surface.

While the amount of water within a planted soil can be decreasing, this needs a quick action by the farmer to sustain the right amount of water. The same time procuration are necessary because if the soil is saturated with water also if a negative factor.

Plants usually shows some signs if there is a need for water. The leaves are the most sensitive part to react to thirsty, but this is an already late sign for a proper plants growth monitoring.

4.5.1 Soil Moisture Sensing

WSN can be used as an appropriate tool for having a real time rapid soil moisture monitoring to observe the wetness, dryness or saturated status.

The soil moisture sensors estimate the soil water amount by measuring the dielectric constant which is the ratio of the permittivity of water to the permittivity of free space.

4.5.2 WSN for Soil Moisture Measurements

The principle is to deploy soil sensors WSN nodes within the agricultural fields. By choosing an appropriated topology the nodes are placed around the area.

When the routers are not sleeping to conserve energy, the following action will be in process.

- Sensors will be attached to each nodes

- Data will be relayed to base stations in a short time interval
- These data are processed then converted to a requested mobile network medium, or internet format.
- The final information are displayed on webs and ready for end users accessibility.

A Soil moisture system block diagram is shown in Figure 15.

The system consists of the following:

- A moisture sensor which send a voltage to the microcontroller,
- A microcontroller will perform main tasks within the sensor nodes network as processing the data, controlling the functions of other components and convert the analogy voltage to a digital format then send it to the transceiver.
- The sensor node transmits to the receiver node which connected to a PC (Personal Computer) via RS232 (serial communication transmission of data) interfacing.

The received soil moisture data will be saved within the database system for further analysis for decisions making.

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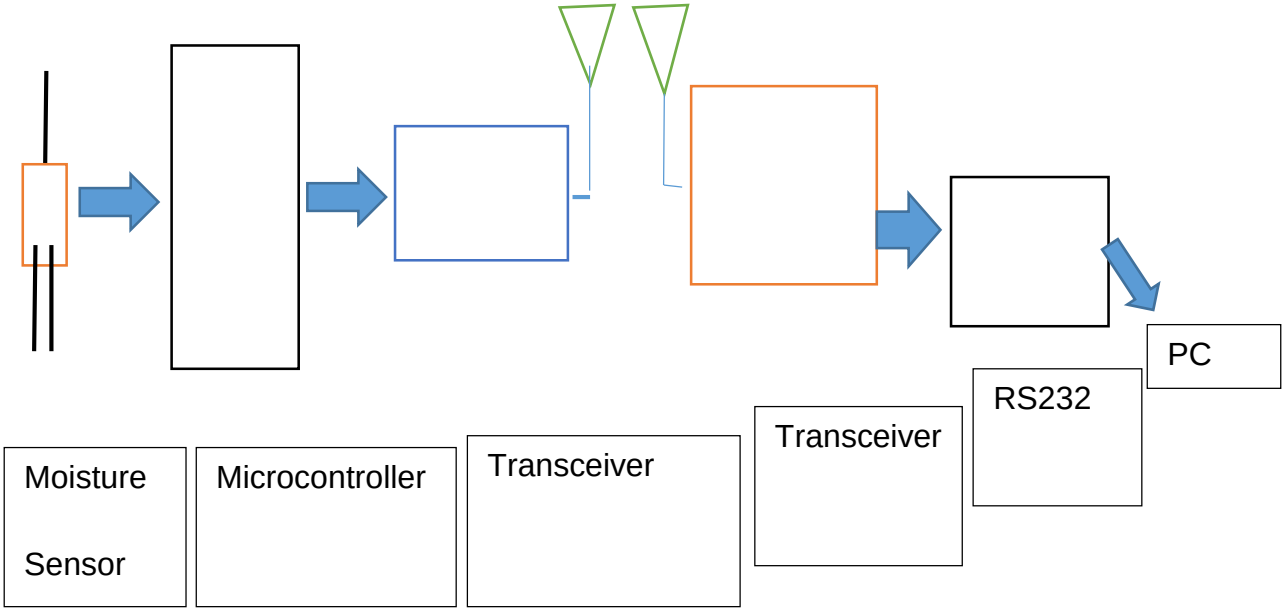

FIGURE 11 Soil moisture system block diagram.

4.6 Weather Forecasting Monitoring

Weather forecasting is very important in agriculture, because it helps in farm planning, irrigation scheduling, and fertilization process, avoiding frosting situation and drought situation, harvesting, and transportation, storage of crops and livestock management.

4.6.1 Farm Weather Stations

The main parameters of weather forecasting are wind speed, air temperature, pressure, humidity, precipitation, and haze or contents of air and solar radiation.

These variables are collected, evaluated then interpreted to analyse the atmospheric conditions.

The rainfall is important for farmers during the initial period of the farming activity, WSNs weather stations are deployed to track and rate the expected raining situation.

4.6.2 Weather Change Detection

For example, Ranch Systems LLC provides a system which is a cloud based remote and monitoring system, having base stations configured as WSNs weather stations. These devices are set to talk to servers through mobile networks to send weather information for the specific location.

The information is analysed then stored as available information within the web which can be retrieved using PCs or mobile phones. Ranch Systems LLC. Date of retrieval 02.05.2015.

These weather stations can be spread across farming fields providing the community with up to date's weather information which help them to make decisions.

4.7 WSNs Farming Kits for Agricultural Dissemination

Farmers across Africa use mobile phones for communication and entertainments even within remote villages.

Small and cost affordable integrated WSN device can be introduced for African farmers having some functions of a mobile phone. This device will have a basic functionality of WSN system which enable it to sense, send and receive.

The device can be used as a farmer dissemination kit receiving messages from different information centres where they exchange data which are meant to help farmers. Also have the ability to test the soil fertility, moisture and record some weather forecasting situations.

These devices can be owned by a group of farmers from the same area. They can be as a point of information where messages will be received regularly and broadcast to farmers by assigning a certain frequency to delivery information like weather forecasting, rain falls predications. For example if there are any storms, frost or information about market analysis to help them in harvesting and

distribution of their crops for a right time and locate best markets to avoid crops saturation as this will affect the prices and storing capacities.

5 INTEGRATED WSN APPROACH FOR AGRICULTURE IN AFRICA

5.1 Motivation to use WSNs for Agriculture in Africa

Most of African countries agreeing to increase the public investment in agriculture. Advanced tools like integrated WSN for environmental monitoring applications will be a good technological approach to use.

This approach will improve the traditional farming practices in Africa, increase productivity, Improve agricultural habits, contribute to the income growth of different community and reduce poverty.

Although the telecommunication infrastructure in the continent is still weak there is a rapid growth in this sector within Africa.

Local operators offering different services and the use of mobile phones has become very dominant, not only in big cities, but also deeply in villages.

Farmers are using their mobile phones to run their daily business, but the most use of mobile phones is only for voice communication.

This existing mobile mediums can be used for WSNs for agriculture benefiting from the great applications offered by this technology starting from agricultural land selection to irrigation and harvesting.

The continuous research in IoT (Internet of Things) and USN (Ubiquitous Sensor Network) of intelligent sensors. It’s more becoming commercially available anywhere, anytime, anyplace and for everyone. This is a motivating situation to have the use of WSNs in African agriculture.

5.2 The Use of WSNs in African Agricultural Development

WSN has the capabilities of environmental measurement, control applications characterized by minimum power consumption by applying the energy harvesting methods and benefiting from the cloud computing services.

Integration of different WSN technologies will make it easy for poor infrastructural communication facilities like Africa to benefit from the advantages of its applications and to be applied in agriculture which the engine of economic growth in the continent.

Different ideas can be promoted through a cooperative research work, the successful approaches can be commercialized for small, medium and large scale agricultural projects.

5.3 WSNs Sequential Agricultural Applications Approach

The traditional farming in Africa has been practising the habits of having same crops for the same areas. These approaches and other challenges have reduced the crops yields within different areas in the continent.

The following are some of applications where WSNs can be applied in Africa.

5.3.1 Land Management

Farmers are usually searching for good high yields crops areas, but their methods of observations are very traditional and poor.

WSNs tools can easily analyse the land quality according to its surface clays, fertility and underground water amount.

This method will help them to sustain the land by sectoring it into different parts. Like reserving the high fertility, soft clay with a higher underground water savage land for agriculture while the less of the farming quality land can be assigned for settlement or livestock.

5.3.2 Irrigation System

After plantation when the proper farming land is located using WSNs, irrigation is very important process within the farming lifecycle. It's the most costly factor within the farming cycle, because it consumes a lot of fuel. Unplanned irrigation consumes time, water and increase the cost and affect the plants growth.

The use of WSN will automate the irrigation process by having real time information to make an accurate scheduling, monitor weather forecasting and postpone irrigation process for the time of raining because is not needed.

5.3.3 Harvesting Process

When crops are ready, WSNs can be used to determine the exact and perfect time for harvesting. Through a good monitoring and observation schedule, the crops harvesting will follow the scheduling programme to avoid the change on weather situations like frosting.

5.3.4 Crops Storing Process

Farms in Africa are usually located in a very remote areas, the storing process is very poor. Crops are usually spoiled due the poor storing habits.

WSNs can be used to detect the stores situations, and crops discharging process according to their storing period using the FIFO (First in First Out) method to rotate the stocking process by tagging the containers with electronic detected numbers.

5.3.5 Crops Marketing

Most of the crops are ready within the same period of time. This situation lead to market saturation with the same products.

Most farmers in Africa have limited locations to distribute their products using intelligent WSNs by receiving information of best marketing locations, they will be

able to have better barraging prices or at least sell most of their products reducing space for storing.

5.3.6 Crops Transportation and Logistics

Transport and *logistics* infrastructure in most African countries are very poor especially within the farming areas where the land is wet and muddy during the harvesting time.

Crops are often spoiled due to long time spending on roads before reaching stores or market areas.

WSNs can be used to enable smart logistic system, offering real time tracking of goods, locations and avoid delays. Using smart WSN tools can help the farmers to receive practical directive messages for good roads and monitor the crops real time status while in trucks.

5.4 Advantages reflected to African Agriculture by Using WSN

Today WSN has been applied in different areas around the World. The using of this technology in Africa and especially in Agriculture will have great advantages which can be summarized as follow:

- WSN is an ideal for the non-reachable places, especially for rural areas in Africa as wireless notes can be easily distributed.
- Most of the WSN setups can be done without a fixed telecommunication infrastructure.
- As its very intelligent technology, an accurate measurements can be collected.
- Help to implement a good periodic farming systems
- Real time climate change monitoring

6 POSSIBLE FUTUTRE DIRECTION

The agricultural machinery are among the technologies which are considering the wireless controlled devices as a trend to be adopted in their high-tech precision agriculture.

There are very much encouraged by promotions of internet of things that promise no one will be left out. This technology revolution will give people the opportunity to be connected any time and everywhere.

Africa will be among the happiest to advocate the use of WSNs in agriculture benefiting from its applications not only to ease the communication between different involved partners located in different locations, but also to apply it as a practical tool.

Farms can be located in one area while the owners are in another place, but still the monitoring process will be possible using WSN.

This will give opportunities to research institutions to start projects within their headquarters, while having testing farms scattered around the World. These testing farms can be located in Africa, but automated within a very long distance or globally.

Strengthening capacity of research programmes in WSN use in African agriculture will enhance the opportunity of cooperation between African farmers, governments, academic institutions, industries and donars.

To contribute to the surveyed research which I have studied during this work, here are some suggestions which can benefit the research meant to advocate the use of WSN in African agriculture.

6.1 WSN Funded Research Approaches for African Agriculture

Africa is still hampered by a fundamental lack of transport, energy and water because of poor infrastructure caused by different factors.

These challenges are limiting the continent development and left it to be highly dependent on foreign aid. Unfortunately most of these aids are spend as cash used for consumable food products, which is let it easy to end up into misuses and corruption. The best way to benefit from these aids is to be mobilized for food production technological tools to improve the local farming sources.

There is a big portion of aid going to food support in Africa. If we invest into technologies like WSN in agriculture to increase productivity, this will help the continent to achieve its development goals.

Although the World has been very generous in its aid to Africa, but also many times had to get fierce of criticism, as the food aid also creates dependency culture and laziness.

Today there are new frameworks to increase stable funding for research to help the continent to overcome some of its challenges which are limiting its development. The investment in agricultural research is one of the favourable approaches, I will highlight two of the WSN for agriculture research which can be advocated in Section 6.2 and 6.3.

6.2 Institution Research Based Programmes

There are many food aid's donars to Africa, one of the famous is WFP (World Food Programme). Created by the United Nations in 1962 to save lives of people by offering food during the shortages situation is among the biggest global food aid organizational body.

As an example WFP feeds an average of 90 million a year in 73 countries, most of its operations are in Africa, while it has a large number of employees to run the operations in its headquarter or global offices. (World Food Programme, 2010).

When situations allow, if most of this aid been utilized for food production development in Africa, the population will be self-dependent and produce food by themselves.

Expanding WSN for Agriculture in Africa, by having research programmes within the local institutions to train students to design, test and deploy WSN nodes within different agricultural projects in different areas will help to introduce the technology in wider areas in Africa.

Through feedback and commercialization of the technology within the continent these research programmes can grow and will be self-financed after some time.

This will help the institutions to sustain these programmes and be as advices centres of the future in their perspectives areas.

6.3 Industrial Research Based Programmes

There are many industries which have honourable generosity to give money for food security every year. These aids could be more directed to industrial development programmes. The use of WSN in African agriculture can benefit from these programmes.

They can be industrial based projects to be tested in Africa. Having the research suggestions from institutions, these approaches can be assembled and tested within the fields.

The successful trials can be commercially manufactured then offered to small and medium size farms.

One of the industries which ready to involve is mobile operators, many times they have approached Africa to help in development projects, because of the profit which and Africa is predominant in this business sector.

The mobile operators have the experiences of fast spreading smart technology to include a very remote areas and deeply penetrating within African rural communities, they can be leaders in promoting the use of WSN in African agriculture.

They must be ready to have research in this area as its necessary both for income generation, surviving and profits.

Today not only African agriculture, but also the global farming is experiencing big challenges which lead to food shortages. Collaboration is needed to overcome these challenges.

7 CONCLUSION

This work was very interesting as different materials from different sources have been studied.

Although there are some researches of the same idea been done, the problem has not been tested in a large scale within Africa.

There are some countries in Africa like South Africa, Egypt, Kenya and Malawi which are very much ready to use the WSN in agriculture.

The institutional and industrial research approaches which have been highlighted in Sections 6.2 and 6.3 of this thesis are very good examples of cooperative approaches to help in advocating the use of WSN in African agriculture.

The thesis also is very much theoretical which make it easy to find materials to study as the topic of WSN is very dominant in today's wireless communication as an advance technology, but it could have been more challenging and convincing if there were some prototypes been tested specially for the idea of the African WSN farmer tool kit which have been suggested in Section 4.7.

Africa has a wide land to be cultivated to which is an added value to the global food security solutions. Using advance technology as WSNs will manage the land, reduce waste and increase productivity.

There are many trials projects advocating a wider use of integrated WSNs applications in Africa, but still not to the full implementations.

To empower the use of WSNs in African Agriculture, the global policy makers, leaders, researchers, industries and farmers should come together to initiate collectives opinions to result into different real projects.

These opinions can be filtered out to have research based works within institutions, then offered to industries and business corporations. The industry based projects can be simulated and tested within farms across Africa.

The succeeded projects can be commercialized to different target groups.

By applying appropriate agricultural technologies such as WSN, this will not only increase resources mobilization, but also facilitate and promote public/private partnerships access to delivery real development to the agriculture as a main of source of income in the continent.

Although wireless sensor technology is a very good choice for African Agriculture, but still there are many challenges which delays its deployment.

These challenges are making difficult to deploy sensor nodes in the continent especially in the areas where there is no infrastructure which is making it difficult for nodes to identify its connectivity and distribution by itself.

These challenges can be summarized as:

- Poverty
- Illiteracy
- Harsh environment in Africa
- Standardization problems as there are different technologies available
- Compatibility for commercial and security reasons.
- Poor IT infrastructure in most Africa countries
- The economic impact, as most of the companies are not ready to risk their business and invest in unstable continent.
- Security issues
- Complexity of some stage of the technology.
- Lack of experienced staff in Africa

- Limitation of energy sourcing, which lead to minimization of communication

To overcome some of the challenges to deploy WSN in Africa here are some quotes:

- Have designs where are self-configured nodes of limited computation process and ability to conserve energy.
- Standardization based solutions which allow different technologies in which different products to interoperate within each other by end users.
- Enhancing the energy harvesting approaches
- Advocate the renewable energy methods
- Promote technical education
- Minimizing the cost of deployment which is of paramount importance
- Better Enclosures to protect nodes devices from moisture, heat or other environmental damage causes while there exposed to outdoors.

Through cooperation and business thinking that, the use of WSN in African agriculture will not only limit limiting the food security problem in the continent but also generate profit this advance technology will be dominant in Africa.

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