University of Mohamed Khidar Biskra
Faculty of Sciences and Technology
Electrical Engineering Department

MASTER'S THESIS

Sciences and Technology
Branch: Electronic
Option: Embedded Systems

Ref.: …………..

Presented and Prepared by:

CHIHI Mosaab

Djediai djamel eddine

On: 23/juin/2022

Design and implementation of a wireless sensor network for agricultural irrigation system control, case study palm trees

Jury:

Dr.	TARGHINI Warda	MCA	**University of Biskra**	**President**
Dr.	BARRIR Zineddine	**Pr**	**University of Biskra**	**Examiner**
Dr.	DIBILOU Abderrazak	**Pr**	**University of Biskra**	**Supervisor**

Academic Year: 2021 – 2022

University of Mohamed Khidar Biskra
Faculty of Sciences and Technology
Electrical Engineering Department

MASTER'S THESIS

Sciences and Technology
Branch: Electronic
Option: Embedded Systems

Theme:

Design and implementation of a wireless sensor network for agricultural irrigation system control, case study palm trees

Presented by:

CHIHI Mosaab

Djediai djamel eddine

Favorable opinion of the supervisor:

Pr. DIBILOU

Favorable opinion of the Jury President:
M.TARGHINI Warda

Stamp and signature

University of Mohamed Khider Biskra
Faculty of Sciences and Technology
Département of génie électrique

MASTER'S THESIS

Sciences and Technology
Branch: Electronic
Option: Embedded Systems

Theme:

Design and implementation of a wireless sensor network for agricultural irrigation system control, case study palm trees

Abstract (English and Arabic):

Most of the water used by man goes to irrigation. Palm trees are one of the plants that use the most water. Thus, it is necessary to find an economic irrigation controller that can adapt the daily water application to the plant's needs. In this thesis, we present an automatic irrigation system based on a Programmable logic controller, the main aim of the proposed system is to monitor and control a PLC-based system wirelessly. A wireless sensor network is made to get all the data that the palm needs for its irrigation, Status of palm farm is sent to the user by PLC via RF module using LoRa technology based on the input status of the sensors that are placed at the farm and this simulation of this project will be carried out by using INTOUCH HMI to let the farmer see the status of his farm and also controls the irrigation process manually.

Keywords: Wireless sensor network, PLC, RF module, INTOUCH HMI, LoRa technology.

يذهب معظم الماء الذي يستخدمه الإنسان للري. تعتبر أشجار النخيل من النباتات التي تستهلك أكبر قدر من المياه. وبالتالي ، من الضروري العثور على جهاز تحكم اقتصادي للري يمكنه تكييف تطبيق المياه اليومي مع احتياجات النبتة. في هذه الأطروحة ، نقدم نظام ري أوتوماتيكيًا يعتمد على وحدة تحكم منطقية قابلة للبرمجة ، والهدف الرئيسي للنظام المقترح هو مراقبة نظام قائم على PLC والتحكم فيه لاسلكيًا ، حيث يتم إنشاء شبكة استشعار لاسلكية للحصول على جميع البيانات التي تحتاجها النخلة في ريها ، يتم إرسال حالة مزرعة النخيل إلى المستخدم بواسطة PLC عبر وحدة RF باستخدام تقنية LoRa بناءً على حالة إدخال المستشعرات الموضوعة في المزرعة وسيتم تنفيذ هذه المحاكاة لهذا المشروع باستخدام INTOUCH HMI للسماح للمزارع برؤية حالة مزرعته وأيضًا التحكم في عملية الري يدويًا.

كلمات مفتاحية: شبكة الاستشعار اللاسلكية, تقنية لورا, PLC, RF module, INTOUCH HMI .

Dedication

To my mother and all my family

CHIHI MOSAAB

To my family and all my friends

Djediai djamel eddine

Acknowledgment

First and foremost, praises and thanks to Allah, the Almighty, for His showers of blessings throughout my research work to complete this thesis successfully.

I would like to express my deep and sincere gratitude to my thesis supervisor Mr. Debilou Abderrazak for giving me the opportunity to do this work and providing invaluable guidance throughout this research. His vision, sincerity, and motivation have deeply inspired me. It was a great privilege and honor to work and study under his guidance. I am extremely grateful for what he has offered me. I would also like to thank him for his friendship, empathy, and a great sense of humor.

Besides my supervisor, I would like to thank my committee members who were more than generous with their expertise and precious time. A special thanks to Ms. TERGHINI Ouarda, my committee president for her hours of reflecting, reading, patience throughout the entire process, as well as Mr. BAARIR Zineddine for agreeing to serve on my committee as an examiner.

I am extremely grateful to my parents for their love, understanding, prayers, caring and sacrifices for educating and preparing me for my future, also I express my thanks to my brothers and sisters, for their support and empathy.

I would like to also thank my great friends, Ammar and Abdelhak for their wonderful friendship and educational helps, Oussama also, despite the distance, the love of learning did not prevent us from studying new things together, my great friends also from the high school days till now, Islam, Zine Edine and Smail, I wish them all the best luck in their life

Table of Content

List of Figures

List of Figures

List of Tables

List of Abbreviations

WSN: wireless sensor network **PLC:** programmable logic controller **HMI:** Human machine interface **LoRa :**long range **OS :** operating system **OPC:** Open Platform Communications **WPAN:** Wireless Personal Area Network **ISM:** Industrial, Scientific and Medical radio **LR-WPAN:** Low-Rate Wireless Personal Area Network **CSMA/CA:** Carrier Sense Multiple Access with Collision Avoidance **POS:** personal operating space **FFD:** full-function device **RFD:** reduced function device **Wi-Fi:** Wireless fidelity **WLAN:** wireless local area networks **AP:** Access Point **IEEE:** the Institute of Electrical and Electronics Engineers **MQTT:** Message Queuing Telemetry Transport **UART**: universal asynchronous receiver-transmitter **JSON:** JavaScript Object Notation **PTO/PWM**: Power take off /Pulse Width Modulation **CPU:** Central Processing Unit.	**BSS:** Basic Service Set **ESS:** extended service set **CRC:** cyclic redundancy check **MAC:** Media Access Control **LoRaWAN:** Long Range Wide Area Network **IoT:** Internet of Things **DSA:** Direct Sink Access **IDS:** Integrated Defence Staff **RTU:** Remote Terminal Unit **TCP/IP:** Transmission Control Protocol/Internet Protocol **IP:** Internet Protocol **ICMP:** Internet Control Message Protocol **UDP:** User Datagram Protocol **TCP:** Transmission Control Protocol **DHCP:** Dynamic Host Configuration Protocol **PPP:** Point-to-Point Protocol **ARP:** Address Resolution Protocol **PC/ABS:** Polycarbonate/Acrylonitrile Butadiene Styrene **AES:** Advanced Encryption Standard **ADC:** Analogue to Digital Converter **4G LTE**: fourth generation long-term evolution. **CSV:** Comma Separated Value **FTP:** File Transfer Protocol **LTE-FDD:** Frequency Division Duplex-Long Term Evolution

Chapter I: General Introduction and Background

I.1 Introduction

As it is known that the flood irrigation method is accompanied by many water losses, so the problem of decreasing water resources, water poverty and less rain fall, may push us to search for alternatives to fill the water deficit, and this requires replacing the current flood irrigation systems with water-guiding systems such as sprinkler irrigation, drip irrigation and others But at the same time, modern irrigation systems or what we call “smart irrigation” represent a saving of the soil from the disadvantages of flood irrigation represented by soil stress and does not give it the opportunity to breathe. It also saves crops, as the focus will be on them and not on the soil itself. Fertilizers are evenly distributed over them by dissolving them in water [1].

Therefore, it was necessary to make optimal use of water resources, reach the highest productivity, recycle water from sewage and agricultural water and re-exploit it again. This will only happen by using typical methods, whether in agriculture or using crops with high genetic potential and giving them the required water meter, and this It requires the use of modern smart farming systems, through the developed irrigation technology and the use of modern soil sensors, which will provide 20 to 25% of the water used in agriculture because it is the only way now to exploit the limited space and water through technologies to reach the highest productivity [1].

Algeria is a fundamentally agricultural country, which registered an area dedicated to the agriculture of 8 million hectares out of a total of 44 million hectares. According to Director of Real Estate Planning and Regulation and Reclamation at the Ministry of Agriculture and Rural Development, that's why we design a system that helps maximize production and minimize costs and resources is necessary in a country like Algeria. Because of this, in this project a system of Smart Irrigation based on wireless sensors and that send data through modules radiofrequency is used. In this project, we will highlight the watering of palm tree, so we designed and implemented a scalable network topology, along with a programmable logic controller integrated with a human machine interface that served as an interface for the user could monitor the system in a way easy and friendly. The whole system provides the user with the necessary indicators for the making decisions regarding irrigation or adjustment system manual. Finally, the system is able to make the appropriate irrigation decision, making use of irrigation curves and environmental parameters measured in the crop.

I.2 Background

Palm trees can withstand thirst for a certain period, and they can live even in the harshest climatic conditions, but this will be at the expense of their growth and fruits. Therefore, in order for these to grow well, and to be able to give an excellent crop, they must be provided with sufficient quantities of irrigation water.

Palms need abundant amounts of water, especially during the summer fruiting season, and palm trees can be irrigated with fresh water, and it can also be irrigated with water that contains a small percentage of salts such as chlorine, sodium carbonate and magnesium, at a rate of about 0.1-3%, where such water cannot be Its use in irrigating other types of fruits, such water can only be used for irrigating palm trees.

Studies have shown that a palm tree usually needs half a liter of water per minute throughout the year. The amount of water needed to irrigate the palm depends on the nature of the land, the depth of the roots, the prevailing weather conditions, the type of palm and the size of the leaves. It is usually irrigated every 10-14 days in light lands, and this period is increased to 30 days in yellow clay lands.

In general, it can be said that palm trees need irrigation during the summer, from April to November, at a rate of once every 4-15 days. In winter, trees are irrigated at a rate of one irrigation every 10-20 days [2].

I.3 Problem Statement

In Algeria, especially in the south, an area called TOLGA, where there are oases and where palm plantations are spread; irrigation depends on surrounding the palm in one basin filled with water and then transferring it to another and so on, a process that takes a lot of time and effort.

In the endless sprawling and harsh, hot and dry climatic conditions, the palm needs to repeat this process, but the citizens' disengagement from its performance made the farmers in those areas suffer greatly. We hear requests from various southern states, and from farmers who have been exhausted by the traditional irrigation method, especially after "the failure of the drip irrigation technique", and its ineffectiveness and feasibility in palm cultivation, has been proven.

The suffering of watering large areas filled with large numbers of palm trees, compounded by the difficulty of delivering water through the traditional incision of water courses in the ground [2].

Before presenting our smart irrigation system solution we would like to mention some of the following problems:

- **Traditional manual irrigation:** obviously results in high labor, low work efficiency, and uneven irrigation.

Figure I. 1: Traditional manual irrigation *[3]*.

- **Not automated irrigation:** compared to the traditional manual irrigation. Not automated Irrigation can improve working efficiency but farmers must manually control the pump and can't accurately irrigate crops it will waste extravagant resources [3].

Figure I. 2: Not automated irrigation *[3]*.

- **Traditional automatic irrigation:** is the groundbreaking method but it has some

Problems such as complex equipment installation .additional cable cost and cabling chaos and high equipment maintenance cost.

Figure I. 3: Traditional automatic irrigation *[3]*.

All of these irrigation methods have pain points and many drawbacks, such as wasting water, irregular water distribution, time problems, so that each palm can't get the water of its need, because the system will be out of control.

After an in-depth study of the requirements of palm cultivation and its water needs, we noticed that there are several problems centered on this topic. The proposed solution in chapter four calculates the amount of water that palm tree needs, climate change must be taking into consideration, its temperature, humidity, wind, and rainfall and so on—over hours to weeks, which are essential factors in the irrigation process.

I.4 Motivation and Challenges

Present methods of irrigation systems are considered ineffective and poorly performing systems with irrational water consumption and many drawbacks. It is necessary to combine a set of criteria such as:

- An effective management and control of the irrigation water system.
- Good selection of irrigation system.
- And automation of irrigation in order to save water.

- Increase irrigation system performance.
- Develop and improve production [4].

Therefore, using a wireless sensor network in irrigation systems supports irrigation very well. In this thesis, our proposed solution is based on the development of a new smart irrigation system based on WSN, with the development of monitoring techniques and amelioration of decision-making capabilities during irrigation.

The proposed irrigation system combines a drip irrigation system technique. Wireless sensor network integrated with programmable logic controller to develop a new irrigation modality. To implement this system, we present a new model based on the technique of monitoring soil parameters and weather properties in real time using a set of specific sensors.

I.5 Structure of thesis

Introduction: the first chapter of the thesis will be an introduction, this will contain several sub-section, various sub-headings like project description, background, problem statement, motivation and challenges are discussed, this is the main starting part of the thesis so this will provide all the description about the project in every aspect.

Wireless sensor network overview: The main aim of the second chapter is to give an overview of Wireless Sensor Networks (WSNs) technology by presenting firstly an overall structure definition. Then in the next section we will mention several components that form the WSN, including, the sensors, controller…etc., which will then be integrated into a network in order to respond to a particular application. Then, we will see the different types of network topologies that can be implemented in certain environment. After that we will discuss the communication protocol that allows the data to be routed in the network. Various applications will be indicated in the last section.

System design: In this experimental chapter, we will dive more into advanticsys' wireless sensor network. This chapter is divided into two sections. In the first section, we are going to plug, configure and play the wireless sensors. In the second section, we will mention the idea of how to establish a communication with the programmable logic controller.

System implementation: it is the fourth chapter where the final prototype is tested. This is the discussion chapter that includes my own analysis and interpretation of the data that we gathered. Comments on my results and explaining what they mean. We will find. A brief of the how the whole system looks like. In the conclusion and further work section we will be able to provide a complete overview of the work.

I.6 Conclusion

In Algeria, most of the people depend on agriculture. The farmer should be treated as the backbone of Algeria. Food is the main need for anyone in the world. And nowadays the population also increased and for that more production must be needed.in this chapter we gave a general idea for the existed methods for irrigation systems nowadays and we discussed the solution for the aim of help the agriculture irrigation.

Chapter II: Wireless Sensors Network Overview

II.1 Introduction

Wireless Sensor Networks (WSNs) are progressively invested revolutionizing the way we obtain information in various fields such as agriculture, environmental, healthcare, civil, and military and many more domains. WSN technology has a vast potential to improve resource use efficiency. A wireless sensor network is for deploying a large number of wireless sensors and collecting information from them. By using wireless, wiring is not required and cable and installation costs can be saved. In addition, it can be constructed by making the sensor network wireless, which was not possible in the past due to restrictions on the installation location and cost issues.

II.2 Overall Structure Definition

A sensor network is an infrastructure comprised of tiny sensing units knows as nodes, these nodes include embedded CPU, limited computational power, some smart sensors and communication elements that give the ability to instrument [5], observe, and react to events and phenomena in a specified environment. The administrator typically is a civil, governmental, commercial, or industrial entity. The environment can be the physical world, a biological system, or an information technology (IT) framework. Network sensor systems are an important technology that will experience major deployment in the next few years for a plethora of applications. Typical applications include, but are not limited to data collection, monitoring, surveillance, and medical telemetry. In addition to sensing, one is often also interested in control and activation [6].

A sensor is a capturing tool that used to gather information about a physical process and converts the signals falling on it into electrical impulses that can be, measured, processed, analyze into a signal that is read by an observer or by an Instrument, like temperature, pressure, light, sound, motion, position, flow, humidity, radiation etc. [7]. A microprocessor processes the electrical impulses to provide outputs that correspond to a set of measures. The system sends the output to the recipients in the designated devices.

The communication between the nodes is necessary to have a centralized system. The necessity of this system leads to development of the notion of internet of things IoT. With the notion of IoT, immediate access to environmental data becomes feasible. So that in numerous processes, efficiency and productivity increases dramatically [5]. If the communication system in a Sensor Network is implemented using a Wireless protocol, then the networks are known as Wireless Sensor Networks. As noted earlier, WSN is an infrastructure-less wireless network that is deployed in a large number of wireless sensors that used to monitor the system, physical or environmental conditions, and cooperatively pass their data through the network to a main location or sink where the data can be observed and analyzed [8].

A sink or base station acts like an interface between users and the network. One can retrieve required information from the network by injecting queries and gathering results from the sink. Typically a wireless sensor network contains hundreds of thousands of sensor nodes [9].

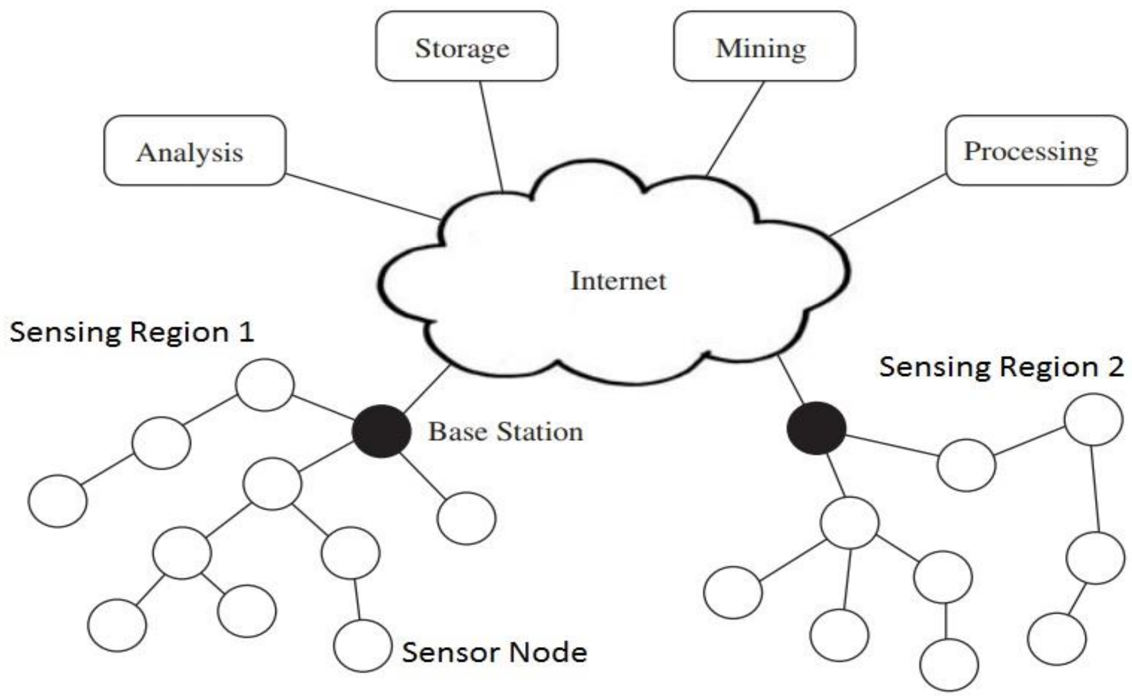


Figure II. 1: Wireless Sensor network *[9]*.

When a large number of sensor nodes are deployed in a large area to monitor a physical environment, the networking of these sensor nodes is equally important. A sensor node in a WSN not only communicates with other sensor nodes but also with a Base Station using wireless communication. The base station sends commands to the sensor nodes and the sensor node perform the task by collaborating with each other. The sensor nodes in turn send the data back to the base station. A base station also acts as a gateway to other networks [6].

II.3 Wireless Sensor Network Components

As we mentioned in the previous section, the main objective behind Wireless Sensor Network is to collect data that is define physical measures state from desired locations. A WSN is typically composed with many wireless sensor nodes, each node is able to sense its environment and collaborate with other nodes to route the sensed data to the base station in other words, wireless sensor nodes collaborate together in order to give a broad vision of the sensing area to end-user. WSN can be considered as a special type of Ad-hoc network, where two types of communication are used [10]:

- From the base station to wireless sensor nodes (multi-cast).
- From a set of sensor nodes to the base station (converge-cast).

In this section of our thesis we are going to describe the main component that forms what's called a wireless sensor network.

II.3.1 Sensor Node

This is the main modules of any WSN. A sensor node is a low powered small device. Although it has limited energy resources, it has synchronized processing feature and also it has a low cost. Figure I.2 has shown the components of a sensor node. Data collection and data transfer steps are accomplished by specific units of a sensor node [5].

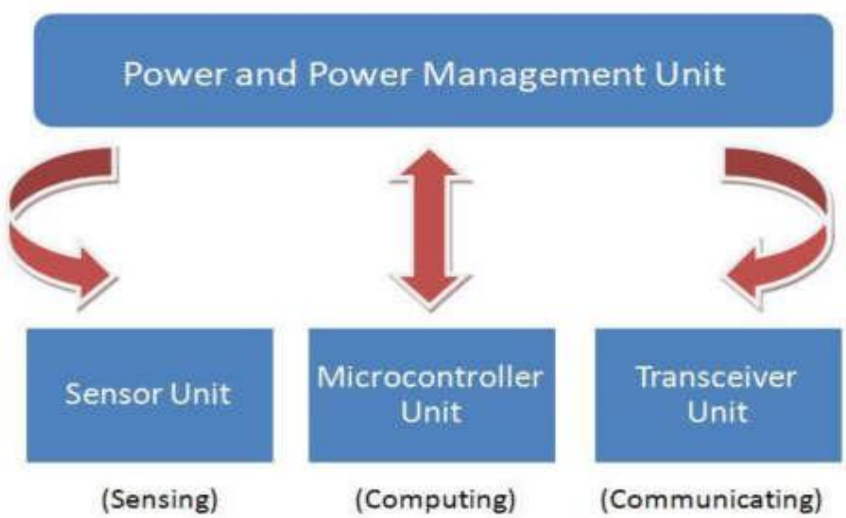


Figure II. 2: Components of a WSN *[5]*.

➢ **Microcontroller**

Typically, this component is the CPU which is the electronic brain of a sensor is composed of a microprocessor and some flash memory. A lot of the CPUs include connectors to add external processing units and sensors to the main unit easily. Making decision and dealing with collected data can be listed as examples for the crucial functions of the CPU. The CPU stores data in flash memory until enough data has been collected. Once enough data is collected by the system, then microprocessor unit of the CPU puts the data in packages or envelopes because envelopes provide great efficiency in data transmission. Then, these packages are sent to the radio for broadcast. In the meantime the Microcontroller communicates also with other nodes in much the same way it deals with data to maintain the most effective network structure. The CPU is connected to the base and it interacts with the sensors and radio [11].

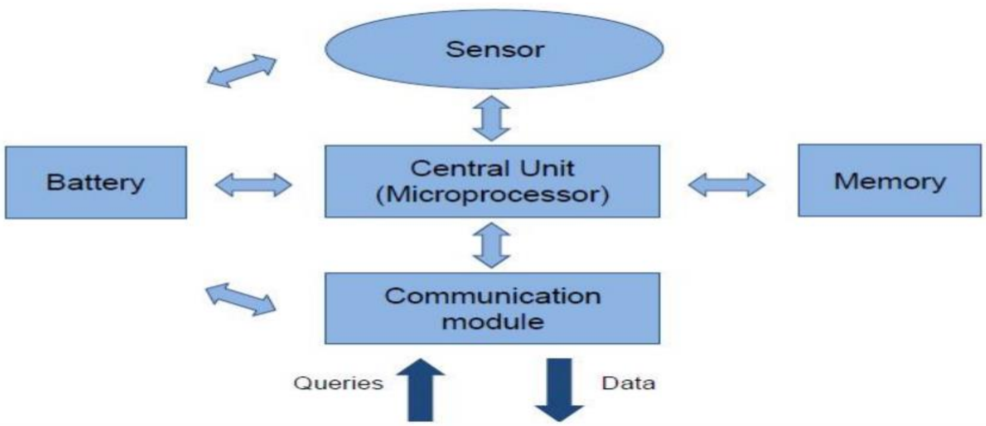


Figure II. 3: Microcontroller Placement *[12]*.

➢ **Power supply unit**

Power supply is placed to the sensor node's base. It supplies energy for various units of sensor nodes like sensing units (sensors), CPU and radio. In order to continue to perform sensing, computing and communicating tasks; energy is needed. Therefore, ambient energy harvesting techniques (from external resources) are used to power small sensor nodes. Power resources can be AA batteries, watch batteries, solar cells or smart systems. Ambient energy harvesting can be accomplished in various ways such as through the conventional optical cell power generation and through miniature piezoelectric crystals, micro oscillators and thermoelectric power generation elements, etc. [13]. For any sensor nodes the energy resources are limited and energy is crucial to perform all tasks. Therefore, nodes spend as much as 99% of their time in sleep to conserve energy. They only wake up to record data, to send data and to receive data.

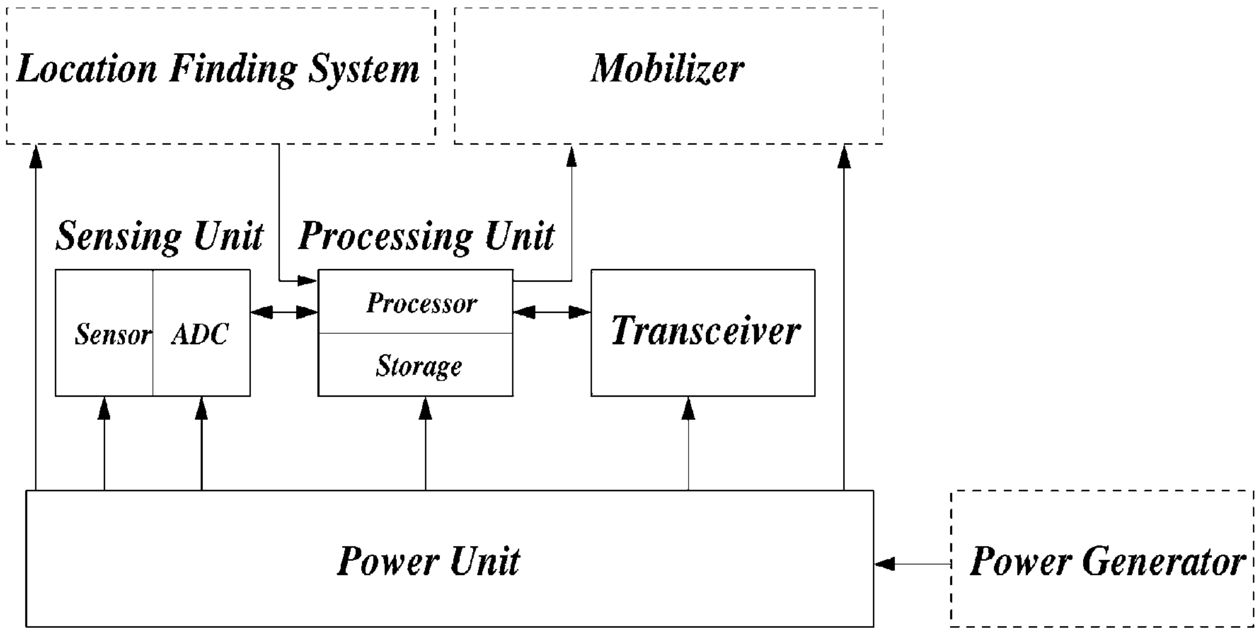


Figure II. 4 : Components of a sensor node *[14]*.

- **Sensor Transducer**

The main part of a WSN is the sensors. Sensors translate environmental variables like light, smoke, heat, and sound etc. into electrical signals. In the past two decades, there has been quick increase in numerous sensing technologies which eased the way of the sensors being produced:

- Micro-electro-mechanical systems (MEMS) such as gyroscopes, acoustic sensors, accelerometers, smoke sensors, magnetometers, chemical sensors, pressure sensors, and piezoelectric sensors.
- CMOS-based sensors such as chemical composition sensors, humidity sensors, temperature sensors, and capacitive proximity sensors.
- LED sensors such as chemical composition sensors, proximity sensors, and ambient light sensors [5].

These advancements have made sensors widely in use in daily life notably in sensor nodes. A typical node consists of three types of sensors which are temperature, vibration and moisture. But some nodes can have extra features such as taking photographs of surroundings, sensing motion, sensing pressure, sensing smoke, sensing light, etc. [5].

- **Transceiver**

It is responsible for the wireless communications of a sensor node. Transceiver has mostly four operating states which are Receive, Transmit, Idle and Sleep. As a wireless media, Radio Frequency (RF), Infrared and Laser can be chosen in transceiver. Among these wireless communication technologies, RF is widely preferred for WSNs. Typical operation range of RF (for the operation frequencies of WSNs) is 10s of meters indoors and 100s of meters outdoors.

- **Operating System**

The OS acts as a resource manager for complex systems. In a typical system these resources include processors, memories, timers, disks, mice, keyboard, network interfaces, etc. The main job of the OS is to manage the allocation of these resources to users in an orderly and controlled manner [15]. Tiny OS, Contiki, MANTIS, BTunt are the examples of operating systems that are used for WNSs. Among these systems, Tiny OS is the one that is open source and energy efficient. Instead of multithreading, Tiny OS uses event driven programming methodology.

II.3.2 Gateways

Gateways let the system administrators to interface nodes to Personal Digital Assistants (PDAs) and Personal Computers (PCs). Gateways can be in three different states as active, passive, and hybrid. Active gateway lets the nodes to send its data actively to the gateway server. Passive gateway cannot act free as the active gateway does. It sends a request to sensor nodes to send its data. Hybrid gateway is the combination of these two gateways, which can operate in both of the states.

According to [16], Gateway is the devices that acts as a connection interface between devices and allows sharing resources between two or more computers.in chapter three our proposed system use the gateway UCM-316 that contains the LoRa and Ethernet or Cellular protocols. This gateway obtains all the transmitted data through the LoRa protocol, these data are then transmitted through Ethernet or Cellular allowing them to be found on the Concordia platform. In this platform it is possible to display the data separately from each node. Knowing when it made its last transmission, the frequency of transmission of each device and its measurements.

II.3.3 Task Managers:

They connect to the gateways by some defined media such as satellite link, or Internet. Task Managers consist of two sections: Client Data Browsing/Processing and Data Service. Task Managers can be considered as an information processing and retrieval platform. All collected sensor data is stored and analyzed in this part. Users and administrators can use an interface to get and analyze these data locally and/or remotely [17].

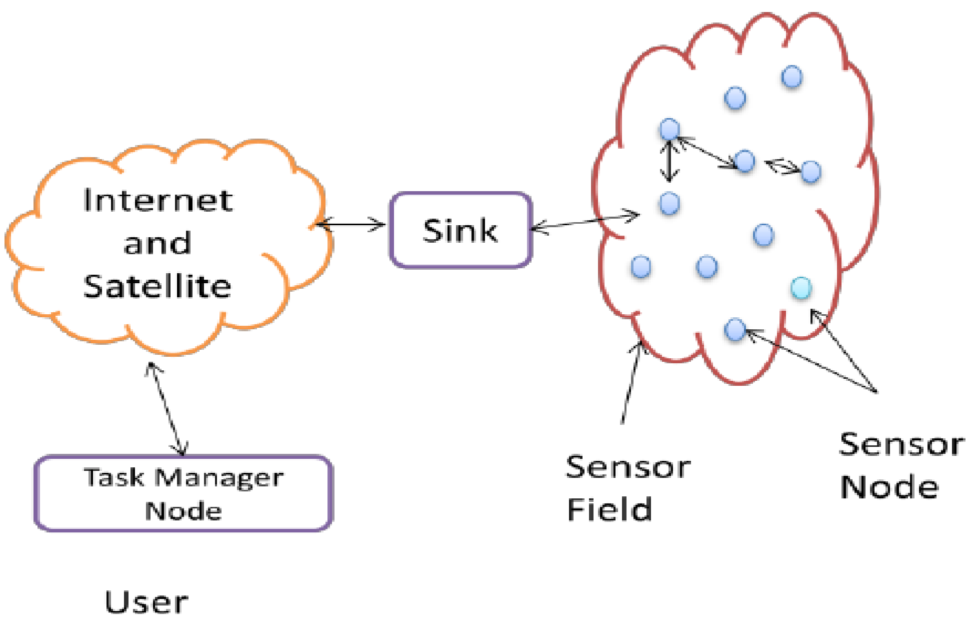


Figure II. 5: A typical sensor network with sink and task manager [18].

II.4 Network Topologies in WSN:

Wireless sensor network has many kinds of implementations. There are such applications have a special feature, if each sensor node is connected to the base station, it is known as Single-hop network architecture, in which they have one data gathering point, namely sink (gateway). however there are also applications where sensor nodes have not only to send information to sink, but to exchange data between themselves using wireless channels and do not have the need for common infrastructure or centralized control, which known as a multi-hop networks.

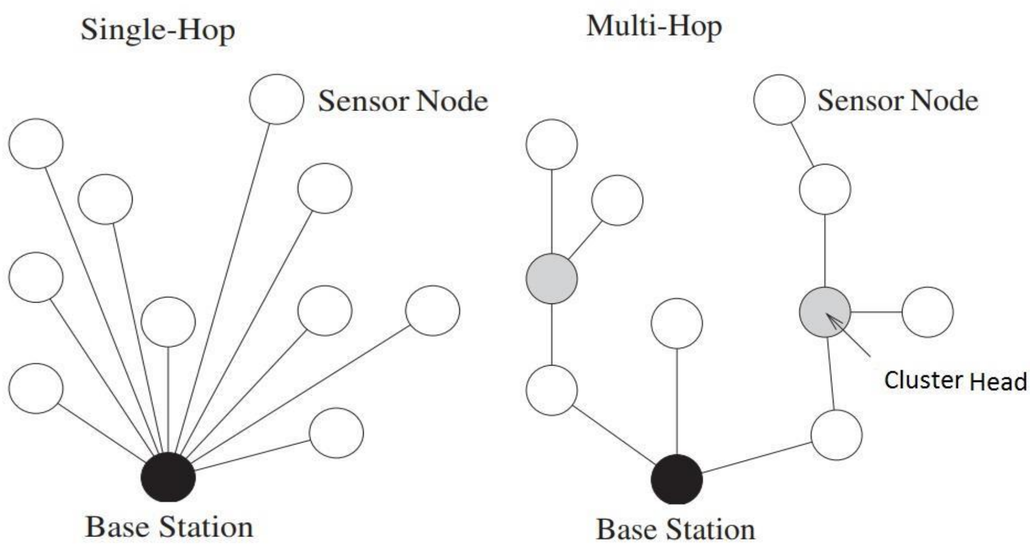


Figure II. 6.A WSN can be either a single-hop network or a multi-hop network *[19]*.

This is why there are different schemes of interaction between sensor nodes within WSN. These schemes are called network topologies. The main types of network topologies for WSNs are: star, tree and mesh. Different WSN standards support different types of network topologies. The following are a short discussion of the network topologies that apply to wireless sensor networks.

II.4.1 Star network (single point-to-multipoint)

A star network is a communications topology where a single base station can send and/or receive a message to a number of remote nodes. The remote nodes are not permitted to send messages to each other. The advantage of this type of network for wireless sensor networks includes simplicity, ability to keep the remote node's power consumption to a minimum. It also allows low latency communications between the remote node and the base station. The disadvantage of such a network is that the base station must be within radio transmission range of all the individual nodes and is not as robust as other networks due to its dependency on a single node to manage the network [20].

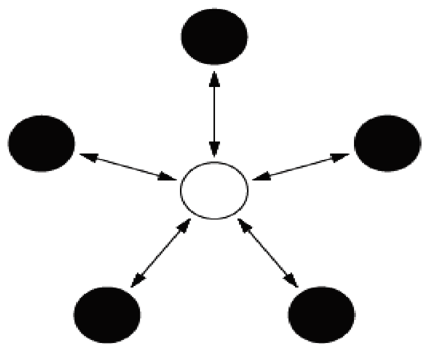


Figure II. 7 : A Star network topology *[21]*.

II.4.2 Mesh network

A mesh network allows transmitting data to one node to other node in the network that is within its radio transmission range. This allows for what is known as multi-hop communications, that is, if a node wants to send a message to another node that is out of radio communications range, it can use an intermediate node to forward the message to the desired node. This network topology has the advantage of redundancy and scalability. If an individual node fails, a remote node still can communicate to any other node in its range, which in turn, can forward the message to the desired location. In addition, the range of the network is not necessarily limited by the range in between single nodes; it can simply be extended by adding more nodes to the system. The disadvantage of this type of network is in power consumption for the nodes that implement the multi-hop communications are generally higher than for the nodes that don't have this capability, often limiting the battery life. Additionally, as the number of communication hops to a destination increases, the time to deliver the message also increases, especially if low power operation of the nodes is a requirement.

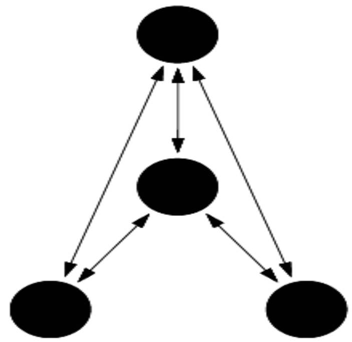


Figure II. 8: A Mesh network topology. *[21]*.

II.4.3 Hybrid Star – Mesh network

A hybrid between the star and mesh network provides a robust and versatile communications network, while maintaining the ability to keep the wireless sensor nodes power consumption to a minimum. In this network topology, the sensor nodes with lowest power are not enabled with the ability to forward messages. This allows for minimal power consumption to be maintained. However, other nodes on the network are enabled with multi-hop capability, allowing them to forward messages from the low power nodes to other nodes on the network. Generally, the nodes with the multi-hop capability are higher power, and if possible, are often plugged into the electrical mains line. This is the topology implemented by the up and coming mesh networking standard known as ZigBee.

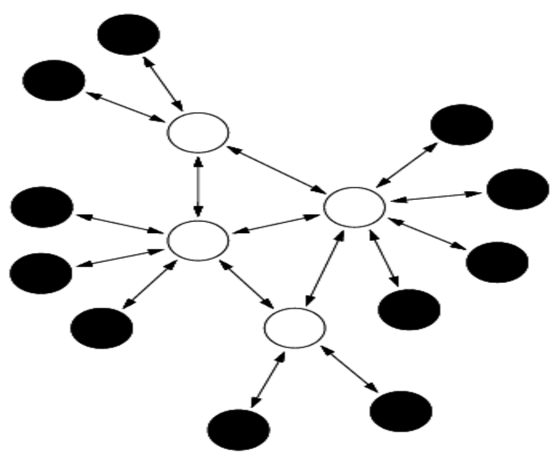


Figure II. 9: A Hybrid Star – Mesh network topology *[21]*.

II.5 Communication structure of a wireless sensor network:

The sensor nodes are usually dispersed in a sensor field as shown in Figure II.5. Each of these dispersed nodes has a typical radio consists of a radio transmitter and a radio receiver. During the transmission of data, the radio receives data from the brain and broadcasts it to other sensor nodes. During the reception of data, the radio receives data from another node's radio and it transmits data to the brain. All data collected by the sensor node is routed to the parent node. This parent node is connected to a multi-functional computer so as to make other nodes' data accessible by user's computer interface. Data are routed back to the end user by a multi-hop infrastructure-less architecture through the sink as shown in Figure II.5. The sink may communicate with the task manager node via Internet or Satellite. If the user gives orders, these orders will be sent over the Internet to the multi-functional computer. This computer will send these directives to the main node also known as parent node and parent node will send the same message to its children nodes. [22] [20].

II.6 The Architecture of the Protocol Stack for WSNs:

The protocol stack used by the sink and the sensor nodes is specified in the Figure II.10. This protocol stack combines integrates power with routing awareness, integrates data with networking protocols, it communicates through the wireless medium power and promotes cooperative efforts of sensor nodes [11]. The protocol stack contains of the following layers and planes: 1) Physical Layer, 2) Data Link Layer, 3) Network Layer, 4) Transport Layer, 5) Application layer. a) Power Management Plane, b) Mobility Management Plane, c) Task Management Plane.

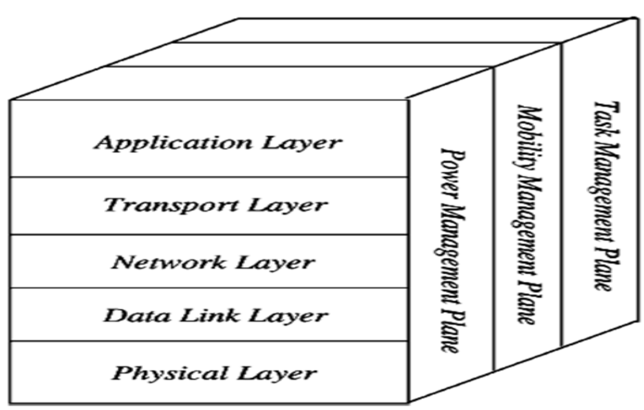


Figure II. 10: Protocol Stack for WSNs [23].

- **The Physical Layer** is planned to handle frequency selection, frequency generation, modulation, transmission and receiving techniques, data encryption.
- **The data link layer** is responsible for multiplexing of data streams, frame detection, Media Access Control (MAC) and error control. This layer ensures reliable end-to-end connections in a communication network.
- **The network layer** takes care of routing the data provided by the transport layer, specific multi-hop wireless routing protocols between sensor nodes and sink.
- **The Transport Layer** helps to maintain the flow of data to keep WSN operable when needed.
- **The application layer** can be built and used Different types of application software depending on the sensing tasks.

In addition, (**the power**, **mobility**, and **task management** planes) .monitor the power, detect the movement and organizes the events among the sensor nodes successively. These planes help the sensor nodes coordinate the sensing task and lower the overall energy consumption. Thus, not all of the sensor nodes perform the sensing tasks at the same time and at the same area.

II.7 Standards and Specifications

The backbone of the Wireless sensor network devices is connectivity. It's through communication with one another that the devices are able to exchange data. The wireless sensor standards have been advanced with the important strategy necessity for low power consumption. The standard defines the functions and protocols necessary for sensor nodes to interface with a variety of networks.

In this section we will explain in more details the concept of the most commonly used wireless communication protocols and we provide a study of these popular wireless communication standards, evaluating their main features and behaviors in terms of various metrics, including the transmission time, data coding efficiency, complexity, and power consumption [24].

II.7.1 Wireless Protocols comparison

We can divide the wireless communication protocols into two categories; a short range which includes (Bluetooth, WI-FI, and ZigBee). And long-range that has the technology of LoRa

The short-range is currently held by three protocols: Bluetooth, ZigBee, and Wi-Fi, which are corresponding to the IEEE 802.15.1, 802.15.4, and 802.11a/b/g standards, respectively. The major goal of this section is not to contribute to research in the area of wireless standards but to present a comparison of the four main short-range wireless networks.

II.7.1.1 Short Range Protocols

A) Bluetooth:

Bluetooth, also known as the IEEE 802.15.1 standard is based on a wireless technology system designed for short-range and low-cost devices to replace cables for computer peripherals, such as keyboards, mice, and printers. This range of applications is known as wireless personal area network (WPAN). Bluetooth Nodes It is an industrial specification for WPAN It operates in the 2.45 GHz ISM band (Industrial, Scientific and Medical radio) Bluetooth-enabled electronic devices communicate wirelessly over short distances, ad hoc networks known as piconets this connectivity topology is used in Bluetooth the Piconets are established dynamically and automatically as Bluetooth-enabled devices enter and leave radio proximity. A piconet is a WPAN formed by a Bluetooth device serving as a master in the piconet and one or more Bluetooth devices serving as slaves. The piconet master is a device in a piconet whose clock and device address are used to define the piconet physical channel characteristics. All other devices in the piconet are called piconet slaves. Data can be transmitted between the master and one slave. The master switches rapidly from slave to slave in a round-robin schedule [25]. Any device may switch the master/slave role at any time. Bluetooth can cover a communication range of 10-100 m and allows data rates up to 3 Mbps [26] [24].

B) ZigBee:

ZigBee over IEEE 802.15.4, a set of high-level wireless communication protocols, ZigBee technology is simpler and less expensive than Bluetooth. It defines specifications for low rate WPAN (LR-WPAN) for supporting simple devices that consume minimal power and normally work in the personal operating space (POS) of 10m. ZigBee provides self-organized, multi-hop, and reliable mesh networking with long battery lifetime [24]. ZigBee uses the 2.4 GHz frequency band for higher bandwidth, and a (Carrier Sense Multiple Access with Collision Avoidance), (CSMA/CA) access system method [16]. There are three types of ZigBee devices, coordinator, router, and an end device:

- **The coordinator;** ZigBee networks may only have one coordinator initiates network formation, stores information, Manages the functions that define the network, secure it, and keep it healthy. And the coordinator must be powered on all the time.
- **A router;** also knows as full-function device (FFD); act as a messenger for communications between other devices that are too far apart to send information on their own May have multiple router devices in a ZigBee network.
- **The end device;** or (reduced function device (RFD)); contains of the sensors, actuators, and controllers that collects data and always communicates only with the router or the coordinator to be its parent device. It uses less expensive hardware and can power itself down intermittently [27].

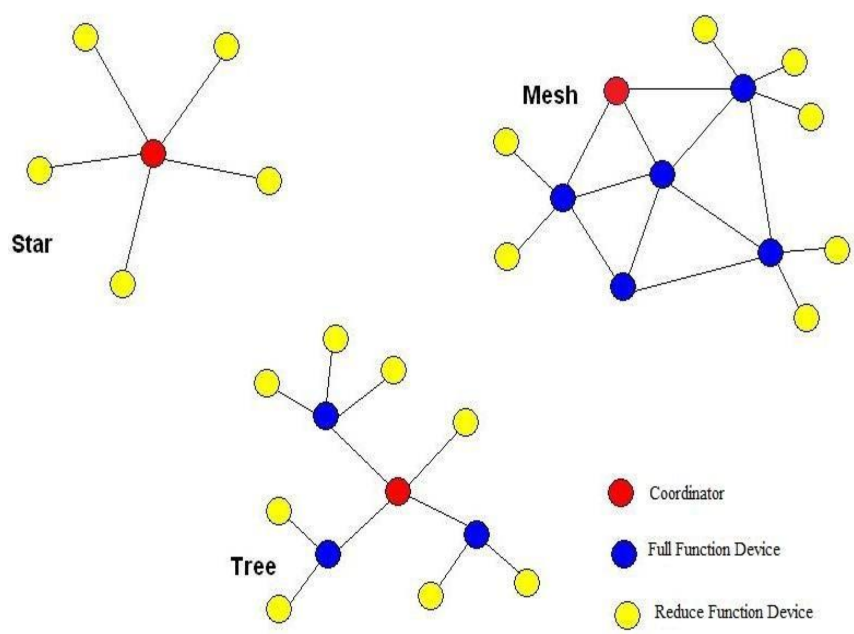


Figure II. 11 : ZigBee Network Topologies *[28]*.

C) Wi-Fi

Wireless fidelity (Wi-Fi) includes IEEE 802.11a/b/g standards for wireless local area networks (WLAN). Wi-Fi is a wireless communications technology that allows devices like laptops, smart phones, TVs, gaming devices, etc. to connect at high speed to the internet without the need for a physical wired connection [24]. Typically Wi-Fi uses the 2.4 and 5 GHz ISM bands as these do not require a license, but it also means they are open to other users as well and this can mean that interference exists. The core of any Wi-Fi system is known as the Access Point, AP. The Wi-Fi access point is essentially the base station that communicates with the Wi-Fi enabled devices - data can then be routed onto a local area network, normally via Ethernet and typically links onto the Internet.

In essence these devices are wireless routers. Essentially there are two basic types of Wi-Fi network. **LAN** based network and an ad hoc network [29].A LAN based network stand for (Local area network) Wi-Fi Access Point, AP is linked onto a LAN to provide wireless as well as wired connectivity, often with more than one Wi-Fi hotspot.**ad hoc network;** these are formed when a number of computers and peripherals are brought together. They may be needed when several people come together and need to share data or if they need to access a printer without the need for having to use wire connections. In this situation the users only communicate with each other and not with a larger wired network [30].

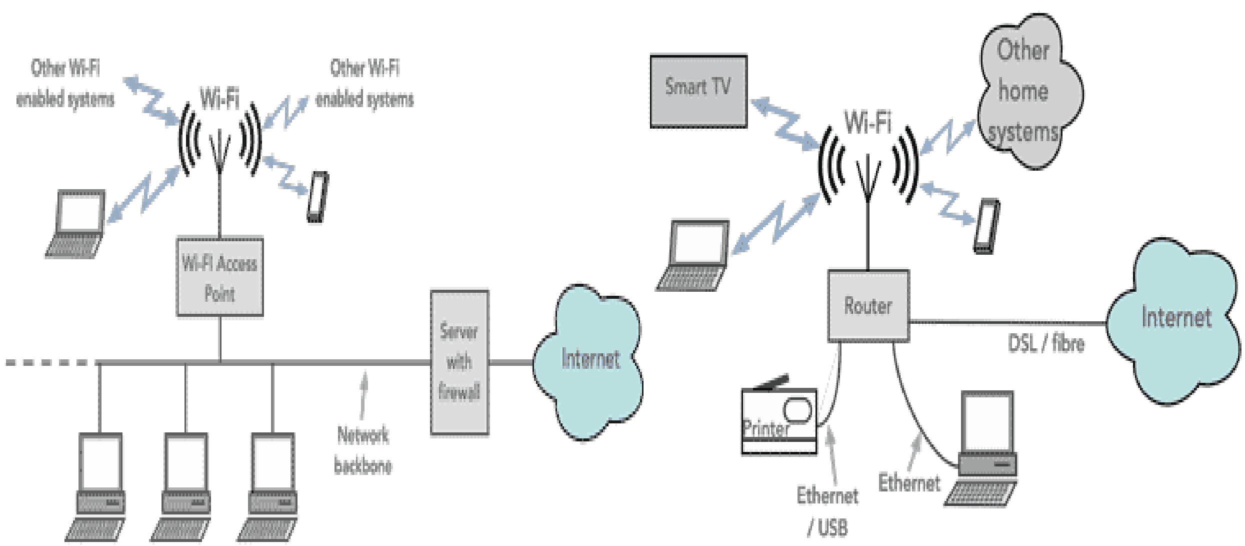


Figure II. 12: WI-FI communication.

➢ Comparative Study:

Tab II 1, reviews the main differences among the three short range protocols. Each protocol is based on an IEEE standard. Clearly, Wi-Fi provides a higher data rate, while Bluetooth and ZigBee give a lower one. In general, the Bluetooth, and ZigBee are intended for WPAN communication (about 10m), while Wi-Fi is oriented to WLAN (about 100m). However, ZigBee can also reach 100m in some applications [24].

Standard	Bluetooth	Zigbee	Wi-Fi
IEEE spec..	802.15.1	802.15.4	802.11a/b/g
Frequency band	2.4GHz	868/915 MHz; 2.4 GHz	2.4 GHz; 5 GHz
Max signal rate	1 Mb/s	250kb/s	54Mb/s
Nominal range	10 m	10-100 m	100 m
Nominal TX power	0 - 10 dBm	(-25) - 0 dBm	15 - 20 dBm
Number of RF channels	79	1/10;16	14(2.4GHz)
Channel bandwidth	1MHZ	0.3/0.6 MHz; 2 MHz	22MHz
Coexistence mechanism	Adaptive freq. hopping	Dynamic freq. selection	Dynamic freq. selection transmit power control (802.11h)
Basic cell	Piconet	Star	BSS
Extension of the basic cell	Scatternet	Cluster tree mesh	ESS
Max number of cell nodes	8	> 65000	2007
Data protection	16-bit CRC	16-bit CRC	32-bit CRC

Table II 1: Comparison of the Bluetooth, ZigBee, and Wi-Fi Protocols. *[24]*

II.7.1.2 Long Range Protocols

LoRa is a short for Long Range; it’s one of the major long-range wireless communication systems established by Semtech Corporation. It is a specification for low power and wide-area networks, LPWAN, designed specifically for low power consumption devices, operating in local, regional, national, or global networks [31], While LoRa & LoRaWAN are commonly mistaken to be the same thing. Lora is a radio frequency carrier signal based in the physical (PHY) layer that translates the data it receives into signals. Unlike LoRaWAN whereas a protocol is located in the Media Access Control (MAC) layer that promotes LoRa signals to wider applications. The topology of LoRa is point-to-point, there is a gateway or hub and one or more nodes, the gateway oversees reading all the packets that are on that frequency. The nodes are devices that transmit small information frames to avoid high consumption of energy.

In Algeria, LoRa uses the 915 MHz frequency. In Figure 13, an example of a satellite map of Beaulieu El-Harrach, Algiers in Algeria is shown in the (THE THINGS NETWORK platform) where we can have an outline of the approximate positions of the main sensors so that it serves as a basis for taking measurements. Unfortunately, this map is not helpful to get an idea of the green areas, buildings, or constructions, pedestrian and vehicular routes and the approximate total area where the sensors are located since the owner of this gateway has no longer activated it.

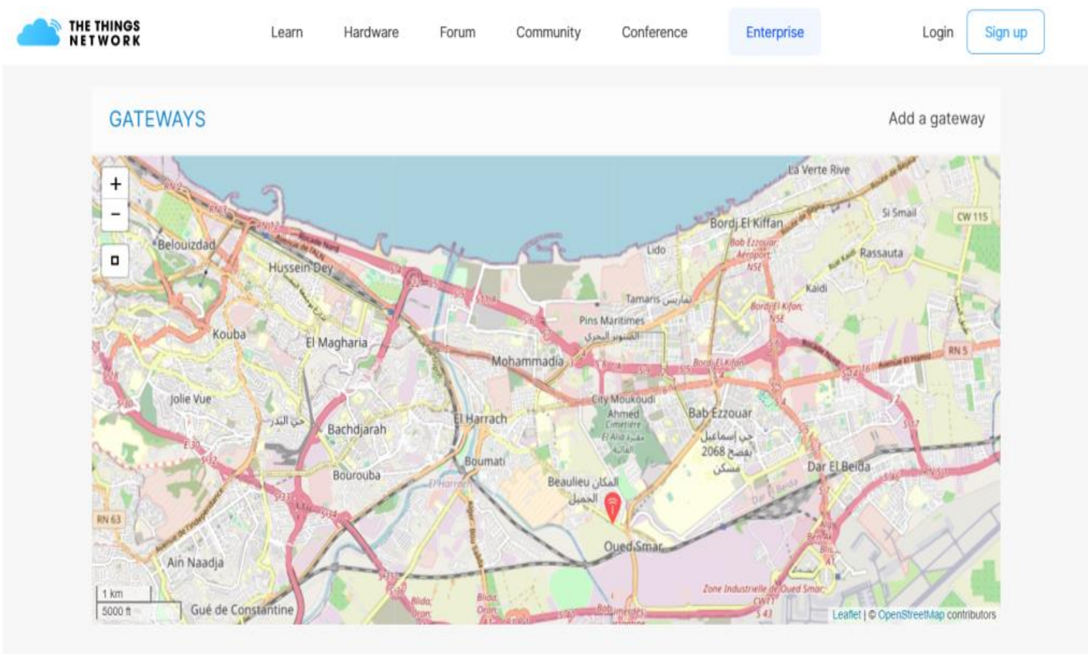


Figure II. 13: Network Gateway position along EL-Harrach city. *[32]*

In addition LoRa is a **type of hardware** that supports long range wireless communication, whereas LoRaWAN refers to a **network protocol** based on LoRa. Together, LoRa & LoRaWAN permit long-range, low-power applications to be built for IoT, enabling wireless transmission over distances of up to 15km! Among other benefits and features shown below, they are also suitable for a wide range of applications indoors and outdoors.

The LoRa technology has several features are shown the figure:

Features	Description
Long range	Connects devices up to 30 miles apart in rural areas
Low power	Requires minimal energy, with prolonged battery lifetime of up to 10 years
Secure	Features end-to-end AES128 encryption, mutual authentication, integrity protection, and confidentiality.
standardized	Offers device interoperability and global availability of LoRaWAN networks for speedy deployment of IoT applications anywhere
Mobile	Maintain communication with devices in motion without strain on power consumption
Low cost	Reduce infrastructure investment, battery replacement expense, and ultimately operating expense

Table II. 2: Key features of LoRa technology *[31]*.

LoRa is appropriate for use in numerous monitoring applications including healthcare, agriculture, smart cities, irrigation .Thus, it’s mostly believed that the applications of LoRa are limitless, but there are indeed a few states where its abilities truly shine. Such applications include agriculture, or environmental monitoring in rural areas where there is no satellite signal for cellular communication, nor the infrastructure for short-range communications like Wi-Fi routers and access points [33].in fact here where it comes the power of LoRa, This significantly reduces the cost of network infrastructure when it compare to Wi-Fi .Furthermore, LoRa much more suitable for indoor usage, which is a scenario where cellular connectivity commonly struggles.

II.8 Types of WSN:

Wireless sensor network are currently deployed on land, underground, and underwater Depending on the environment. There are generally five types of WSNs: terrestrial WSN, underground WSN, underwater WSN, multi-media WSN, and mobile WSN

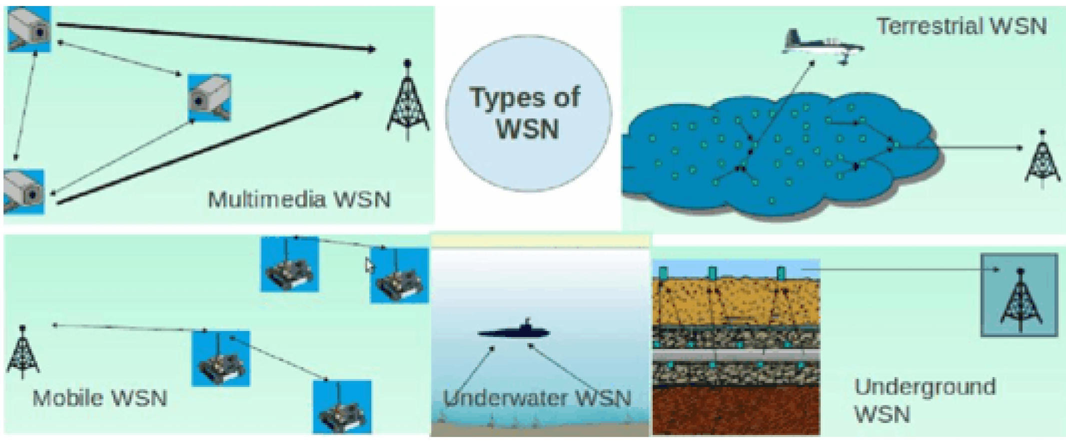


Figure II. 14: Types of WSN *[34]*.

II.8.1 Terrestrial WSNs

Contain of a large number of low-cost nodes, generally deployed in an ad-hoc manner (for example, dropped from a plane). The acquired measurements are sent to a Sink node, which can be at a fixed location or on a vehicle that periodically visits the network each sensor may or may not have Direct Sink Access (DSA). Since battery power is limited and usually non rechargeable, terrestrial sensor nodes can be equipped with a secondary power source such as solar cells [34].

II.8.2 Underground WSN

A number of sensor nodes are buried underground or in a cave to monitor underground conditions [35] Additional sink nodes are located above ground to relay information to a remote sink Increased cost, careful placement of nodes. An underground WSN is more expensive than a terrestrial WSN in terms of equipment, deployment, and maintenance [36].

II.8.3 Underwater WSN

A small number of sensors are deployed underwater for exploration and gathering the data to transmit acoustic waves. Sensor nodes must cope with the extreme conditions. Nodes are equipped with a limited battery so which cannot be replaced or recharged requiring energy efficient underwater communication and networking techniques [37].

II.8.4 Mobile WSN

Mobile WSN consists of mobile sensor nodes that can move around and interact with the physical environment [34]. Mobile nodes have the ability to move on their own. A dynamic routing algorithm must be employed unlike fixed routing in static WSN. Mobile WSNs face various challenges such as deployment, mobility management, localization with mobility, navigation and control of mobile nodes, maintaining adequate sensing coverage, minimizing energy consumption in locomotion, maintaining network connectivity, and data distribution [37].

II.8.5 Multimedia WSN

Multimedia WSN consists of low cost sensor nodes equipped with cameras and microphones, deployed in a preplanned manner. To guarantee coverage nodes are deployed carefully. Multimedia sensor devices are capable of storing, processing, and retrieving multimedia data such as video, audio, and images [35].

II.9 Application of WSN

Traditionally, sensor networks have been used in the context of the high-end applications. WSNs are multi-functional, low-cost, and low-power networks, Wireless sensors can be used where wire line systems cannot be organized (e.g., in a dangerous location or an area that might be contaminated with toxins or be subject to high temperatures). The fast deployment, self-organization, energy harvesting, ability to cope with node failure, mobility of nodes, and heterogeneity of nodes features of WSNs make them multipurpose for military command, control, communications, intelligence, surveillance, reconnaissance, and targeting systems. The most important applications are presented in the following;

II.9.1 Military domain

Military domain have been the initiator engines of research for sensor networks , there exist several studies about realizing WSNs in military applications such as ;

- **Intrusion Detection:**

It analyzes the network by gathering a sufficient amount of data and detects irregular behavior of sensor node(s). This unit is called IDS agent. IDS agent works in three phases and each phase has a unit, (Collection, Detection, and Response) units [38]. Sensor nodes sense the environment and alarm the forces [39].

- **Battlefield Surveillance:**

Sensor networks can obtain information about any enemy activity in the critical areas and borders.it can detect and classify multiple targets [39]. This provides a quick gathering of information provides time for quick response that can send real-time enemy mobility information to a command center [40].

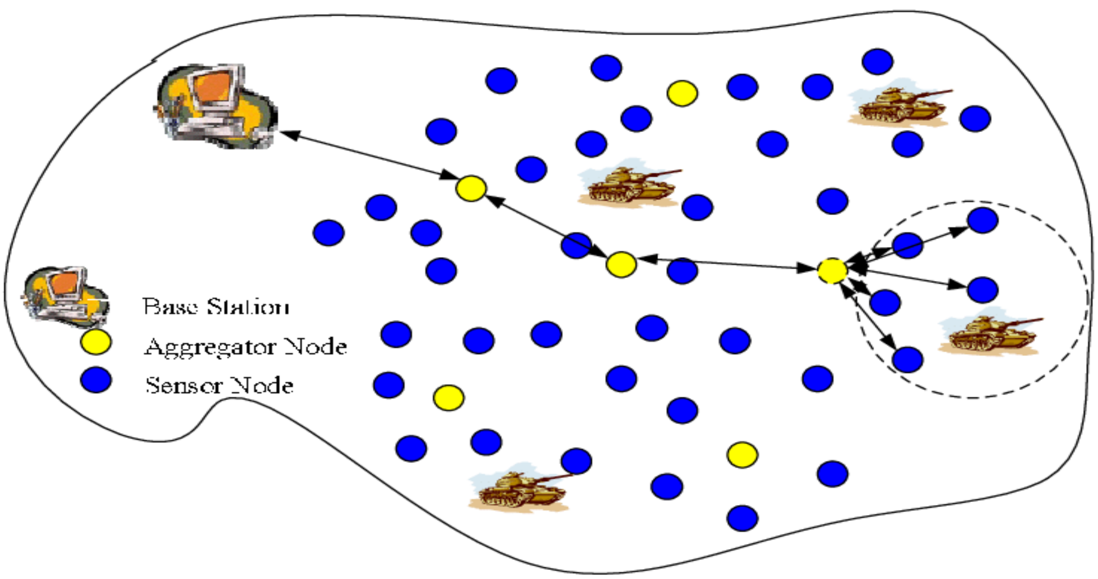


Figure II. 15: WSNs used in Military Applications *[41]*.

II.9.2 Connected Cars

A connected vehicle which is equipped to the internet connectivity can be called a smart or connected vehicle/car [42]. Usually, such vehicles connect to the internet via WLAN (Wireless Local Area Network). It can also share the internet with devices inside and outside the car. As an automatic notification traffic movement, road conditions, speed limits. Car applications such as locking/unlocking the door, opening sunroof, engine start/stop, climate control, headlight on/off and honk the horn. Remote Parking, This feature will come in handy in tight parking spaces, using the smartphone app or the smart key fob, you can get out of your vehicle and control the car to park it in the desired spot. These technologies ensure security and comfort to the driver [43].

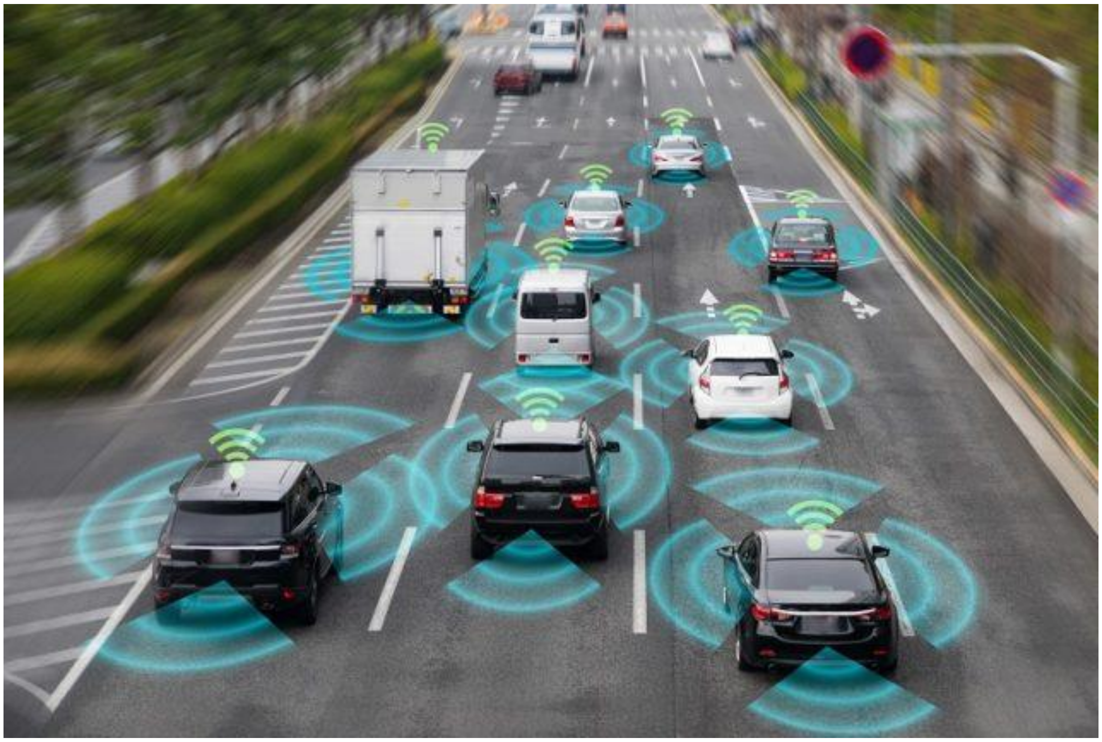


Figure II. 16: connected cars *[44]*.

II.9.3 Agriculture and Environmental Monitoring

Wireless Sensor Networks use dispersed sensors to gather the information and transmit the gathered information using wireless networks. It is mainly used to monitor the environmental changes as well as climatic change, temperature, humidity, soil test. Sensor networks are very small, cheap and can be used even in rural areas [45]. Today, WSNs are also used for the detection of forest fires [46].Precision agriculture monitoring of freshwater quality, disaster detection. The benefit of using WSNs in such applications is mainly due to the need for obtaining large amounts of data in an area that would be costly to obtain using wired technologies.

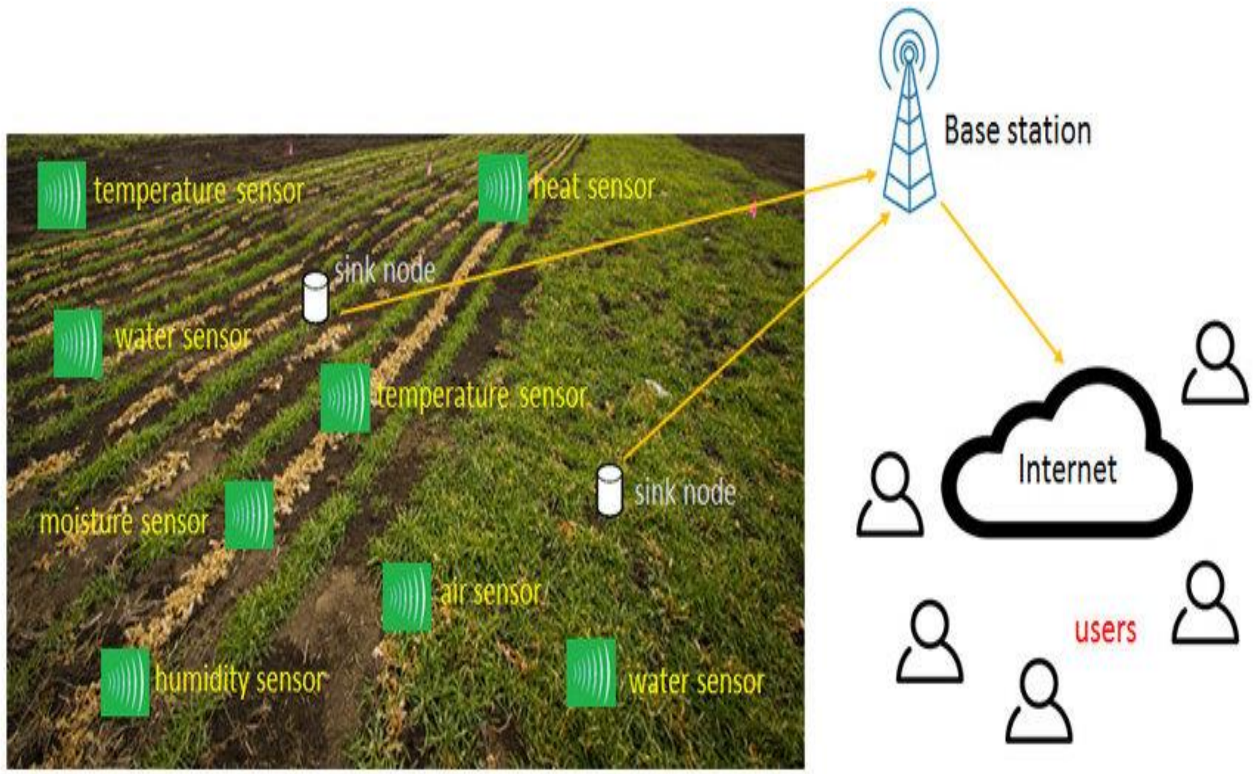


Figure II. 17: Smart agricultural environment based on wireless sensor network (WSN) *[47]*.

II.10 Conclusion

In this chapter, a preliminary study for WSNs overview is presented. First we presented an overall structure for WSNs. Secondly, a brief of the topologies. Thirdly, a comparison of the most popular communication protocols of WSN (WI-FI, Bluetooth, ZigBee, and LoRa). Finally, we presented some of the WSN types as well as some of the most effective applications.

Chapter III: System design

III.1 Introduction

ADVANTICSYS provides a large variety of wireless sensor network based devices. These range from wireless modules, attachable sensor boards and interface boards useful for research & development, to finalized products for the end user [48]. In this chapter we are going to plug and play one of the main industrial IoT Gateway, wireless modbus bridge, and analog/digital inputs modbus modules

III.2 Slave Network Node Architecture

As we mentioned in chapter II, a basic sensor node comprises five main components are shown as follow:

- **Controller**: To process all relevant data
- **Memory**: To store programs and intermediate data.
- **Communication**: Device for sending and receiving information over a wireless channel
- **Sensor interface:** Actual interface to the physical world to observe or control physical parameters of the environment.
- **Power supply**: Some form of batteries necessary to provide energy and some form of recharging by obtaining energy from the environment as well.

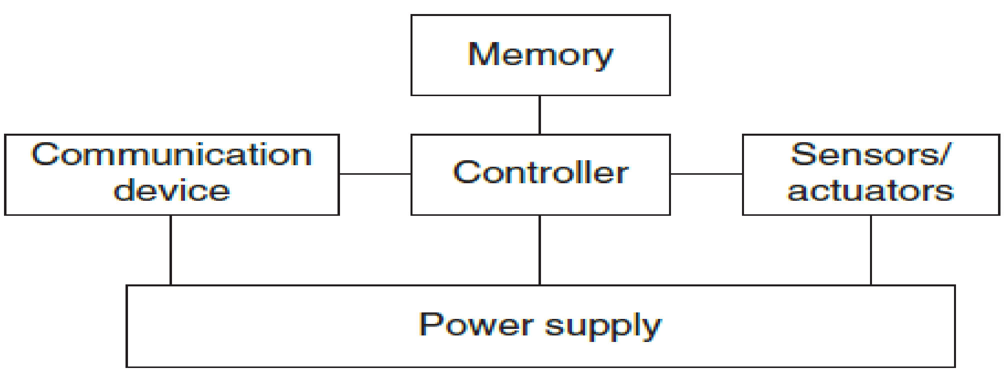


Figure III 1: Components of a WSN Node *[48]*.

The five components of our proposed system are as follow:

III.2.1 The Controller

It is the heart of the node. The **AIM-8** Controller is chosen for its power save functions and its large memory .AIM 8 was designed to measure, record and analyze real time signals. Stored data can be sent to remote users through Ethernet, RS232 or RS485 ports. In case of loss of communication, the data is securely stored in the internal memory until communication is returned, providing safety and reliability to processes and control systems. The selectable communication ports allow us to choose exactly the necessary equipment for each installation.

The table below shows the main characteristics of the AIM-8:

General	**Power Supply**: 9 – 36 Vcc **Overvoltage protection**: 1000V (max. 5 sec) **Power consumption**: 10 VA
Specifications	**Cpu** : ARM7 (55MHz) **Flash**: 2 MB (Up to 8 MB, under request*) Up to 5 years storage
Interfaces	**RS232**: Up to 15m distance **RS485**: Up to 1.2 km distance **USB**:Type B, ver. 2.0 **Ethernet**: RJ 45 up to 100m **Analog In**: Resistance, voltage or current. Up to 8 Simultaneous inputs
Protocols	Modbus RTU, Modbus TCP/IP, IP, ICMP, UDP, TCP, DHCP, PPP, ARP, IEC60870-5-104:2000
Physical characteristic	**Dimensions**: 116x101x33 mm **Weight**: 170 g **Material**: PC/ABS **Protection type**: IP20

Table III 1: Characteristics AIM-8 [48].

Figure III 2: AIM-8 controller.

III.2.2 Memory

In this project, the EEPROM of AIM-8 is used. Due to the non-nature of the EPROM, it is used in most embedded systems for storing configuration information because it does not require power to retain the stored data. It is also used as an immediate storage for sensor readings. For instance, in order to perform feature extraction or filtering of the sampled data, the EEPROM can be used as a processing buffer for these algorithms.

III.2.3 Communication

- **Radio transceiver:** also called a bridge. This low power radio transceiver of small size and hybrid design permits bidirectional transmission and reception. **DM-108** is chosen for this project DM-108 is a DIN-rail installable device which acts as wireless bridge, in the band of 868MHz, inside traditional wired RS485 Modbus RTU installations, providing the limited point-to-point RS485 networks with the versatility and ease of installation of wireless sensor networks (WSN) [48].

Apart from the wireless bridge functionality, **DM-108** act as pulse counter and with its open drain output, it could be used as power manager for other devices.

General	**Power supply:** 9Vdc@80mA to 30Vdc@24mA **Consumption:** <1 W
Radio	**Frequency**: 865-867MHz (India), 868MHz (EU), 902- 928MHz (Americas and Australia) **Sensitivity:** -104dBm typ **RF Power:** Up to +26 dBm **Range:** Up to 1km **Antenna:** SMA Female connector – not included
Interfaces	**microUSB**:(19200 bps UART) **RS485**: Up to 1.2 km distance, speed up to 19.2 kBaud
Protocols	Modbus RTU, Wireless AES128 Encrypted Mesh
Physical characteristic	**Dimensions**: 18x89x59 mm **Material**: PC/ABS **Protection type**: IP20

Table III 2 : Characteristics DM-108*[48]*.

III.2.4 Sensor Interface

WSN platform are equipped with ADC interfaces for data sampling and acquisition .the AIM 8 has Up to 8 analog inputs (voltage, current or resistance). In my thesis we used five types of sensors: Wind speed sensor, Outdoor temperature and relative humidity sensor NBB-EN272501, Brightness sensor, Irradiation sensor.

- **Wind speed sensor**

An anemometer is a device used for measuring wind speed, and is a common weather station instrument. This well-made anemometer is designed to sit outside and measure wind speed with ease [49]. To use, connect the black wire to power and signal ground, the brown wire to 7-24VDC (we used 9V with success) and measure the analog voltage on the blue wire.

The voltage will range from 0.4V (0 m/s wind) up to 2.0V (for 32.4m/s wind speed). That's it! The sensor is rugged, and easy to mount. The cable can easily disconnect with a few twists and has a weatherproof connector.

Figure III 3: Wind speed sensor

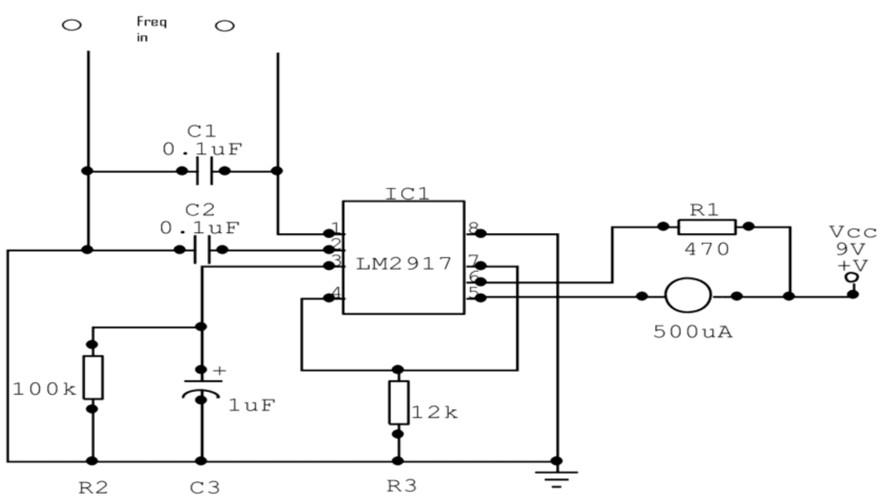


Figure III 4: Circuit diagram for wind speed meter *[50]*.

➢ Industrial Noise Sensor

This noise detector is a high-precision sound measuring instrument with a range of 30dB~120dB; Small size, easy to install, and suitable for industrial noise monitoring. This RS-ZS-*-FL noise detector uses a high-sensitivity condenser microphone with stable signal and high precision. It has the characteristics of wide measuring range, good linearity, easy to use, easy to install, and long transmission distance. Continuous power function and rugged design can simplify your long-term testing. The robust rain and snow enclosure makes it an ideal solution for remote noise monitoring. This noise detector widely used in: Environmental Noise Monitoring Plant Noise Monitoring, Petrochemical Noise Monitoring, Manufacturing Noise Monitoring, OSHA Noise Monitoring [51].

Figure III 5: Industrial Noise Sensor

- **Outdoor MODBUS Temperature and Humidity sensor**

This sensor is designed to measures the temperature and relative humidity in outdoor environments as schools, hotels, commercial buildings, offices, homes… [52].

Figure III 6: EN272501 THEXT *[52]*.

➢ Irradiation Sensor:

Solar radiation sensors are also known as pyranometers. A type of actinometer, these devices are used for measuring broadband solar irradiance as well as solar radiation flux density, which means that they measure the power of the light and heat from the sun. When placed on a flat surface, pyranometers can be used for identifying solar radiation. The term pyranometer comes from the Greek word **pyr,** which means fire, and **ano**, which means sky.

Pyranometers work by measuring the number of small units of light, known as photons that impact a physical or chemical device located within the instrument. Solar radiation sensors are typically not powered due to the fact that the components located in the device either are influenced by or react to solar radiation in a direct manner [53].

Figure III 7: Irradiation sensor.

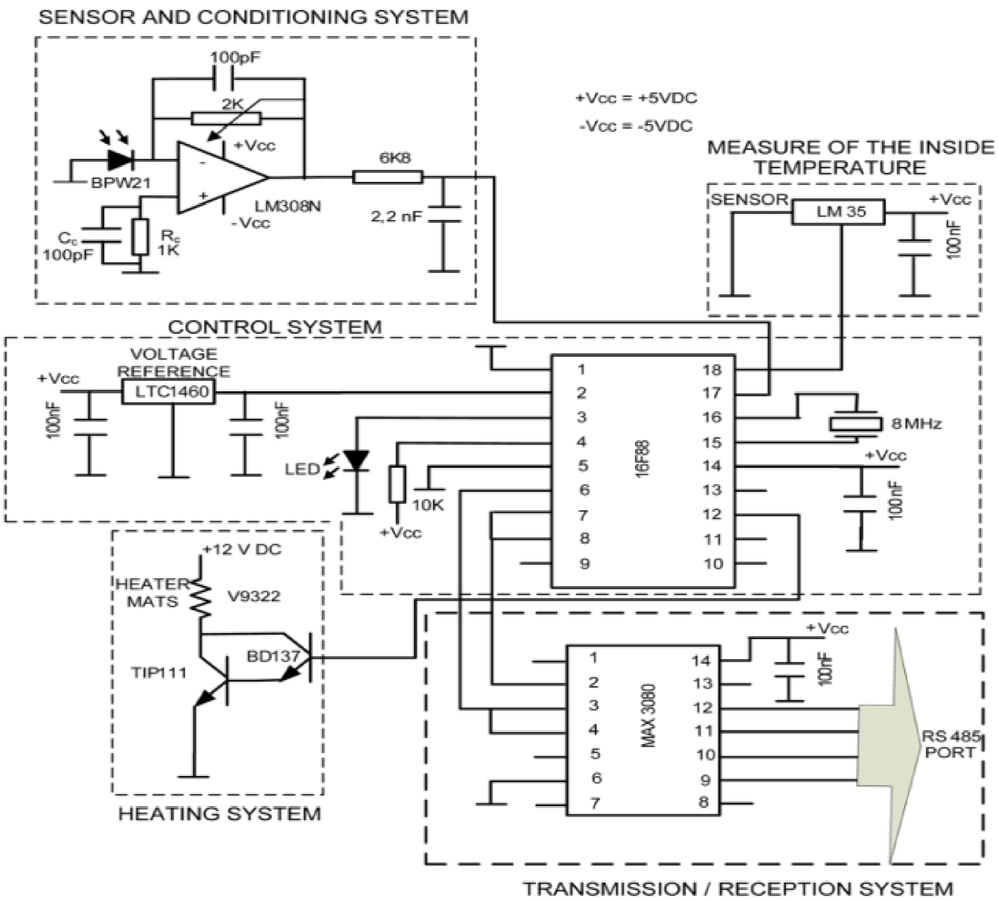


Figure III 8: Pyranometer circuit *[54]*.

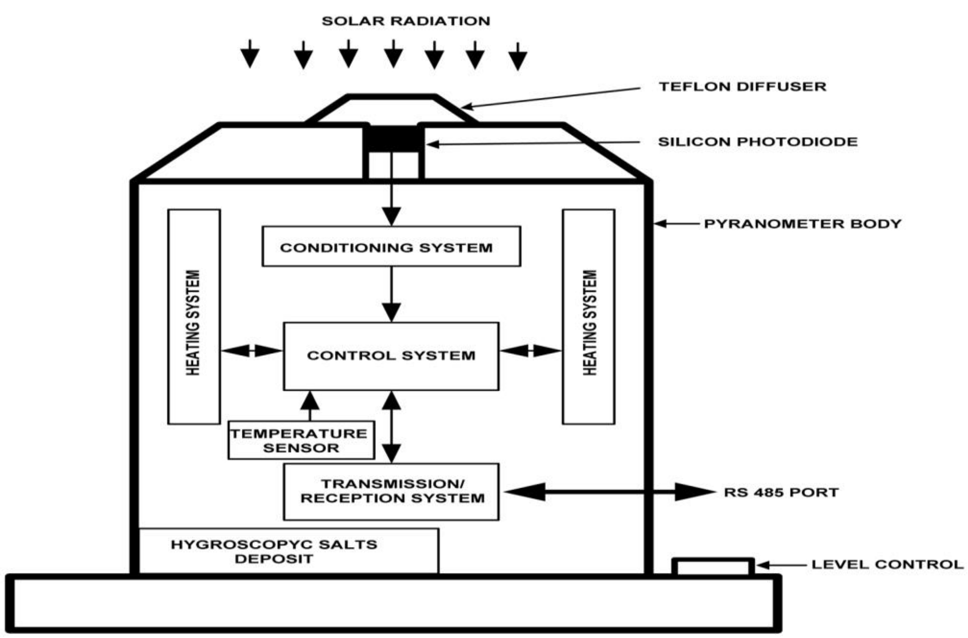


Figure III 9: Pyranometer circuit diagram *[54]*.

➢ Brightness Sensor:

The brightness sensor is a light sensor for the building automation. It is designed with a precise and long-term stable photodiode which is characterized by great industrial performance. It is protected against overvoltage and transients and is suitable for continuous operation. Moreover this brightness sensor can be operated either with DC- or AC supply voltage. The brightness sensor with its analogue output signal (0-10V) can be connected to any commercial automation system. The processing of the measured signal is done through advanced sensor technology. The high sensitivity in a wide range of luminance intensity as well as the wiring makes it possible to use the sensor under very bright lighting conditions [55].

Figure III 10: Brightness sensor.

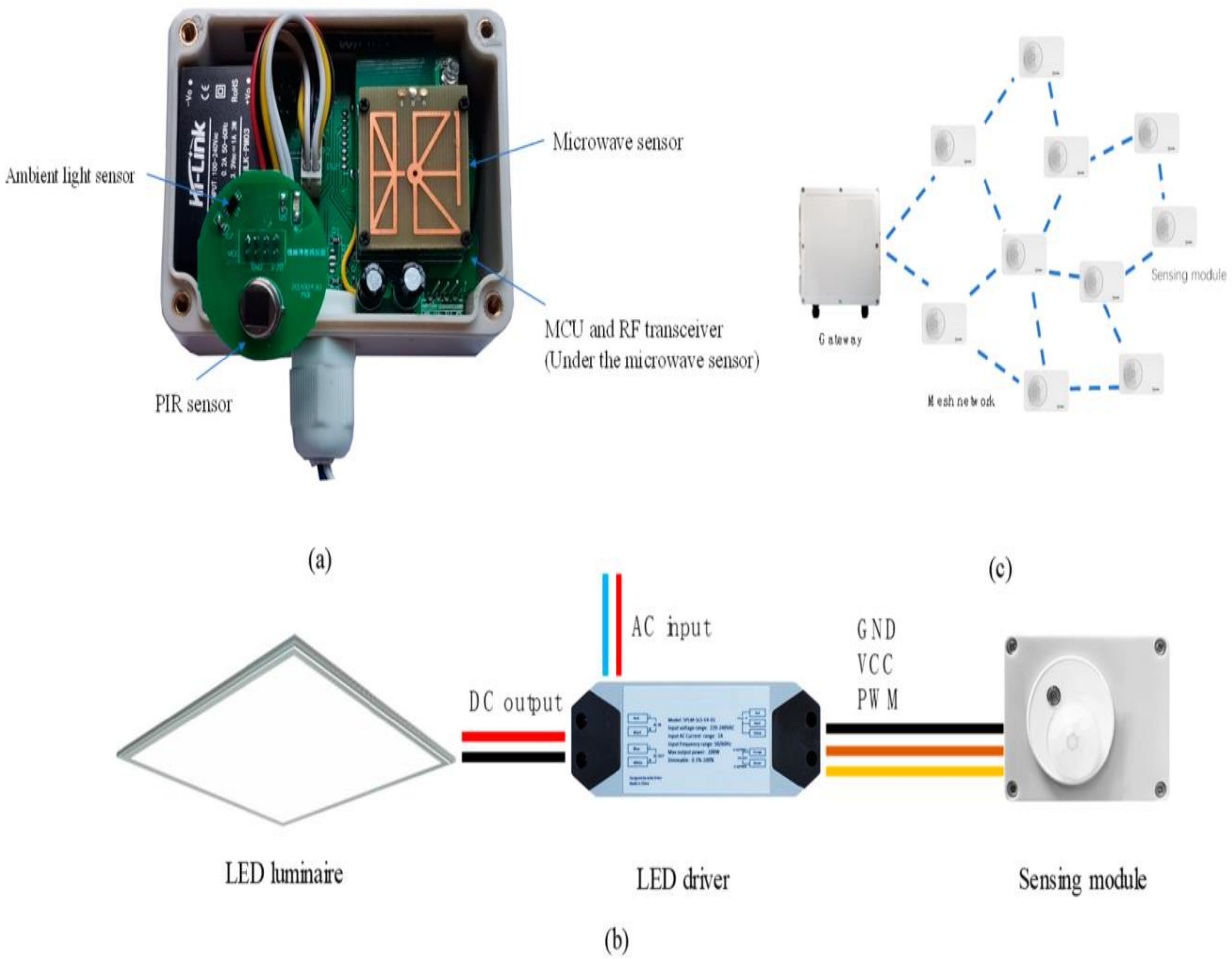


Figure III 11: architecture of the smart lighting system *[56]*.

III.2.5 Power Unit

Power supply is the main determining factor for the size and lifetime of the WSN hardware. The battery or alternative power source is often the largest single component of WSN nodes. MEAN WELL is one of the world's few manufacturers dedicated to standard power supply products [57].

Mean Well DR-30-24 Ac to DC DIN-Rail Switching Power Supply, 24VDC, 1.5A, 36W has been proposed in this project.

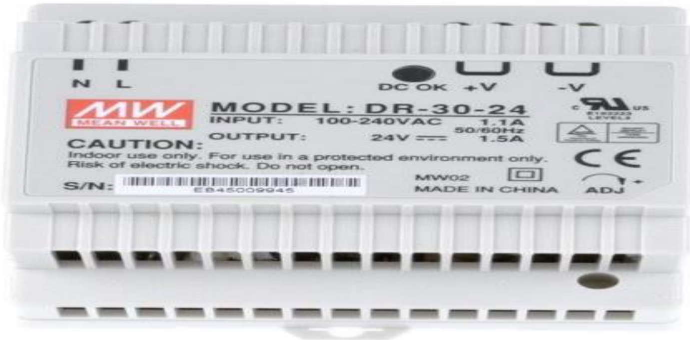


Figure III 12: Power source DR-30-24

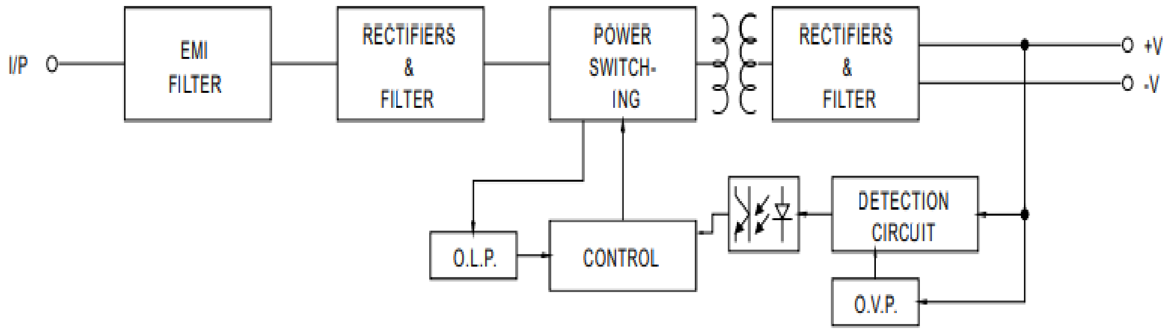


Figure III 13: Block Diagram *[58]*.

In our proposed node we have rechargeable backup battery inside both of the AIM-8 controller and the UCM-316 Gateway.

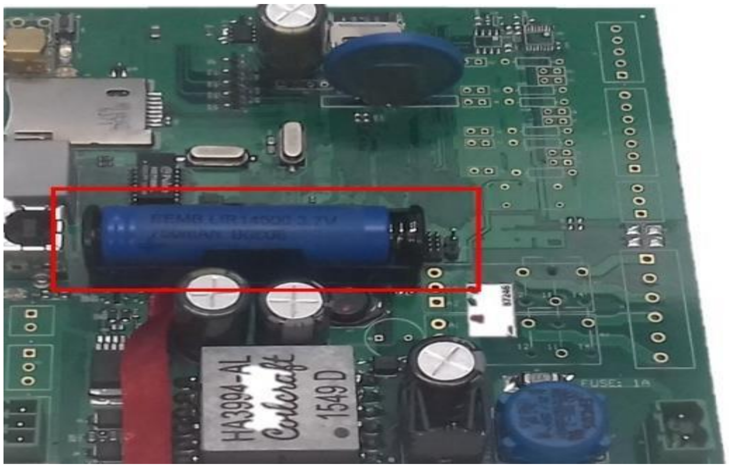


Figure III 14: Internal backup battery.

Rechargeable backup battery provides UCM-316 autonomy of maximum one hour if general power supply is down

Backup battery lifetime can be configured in:

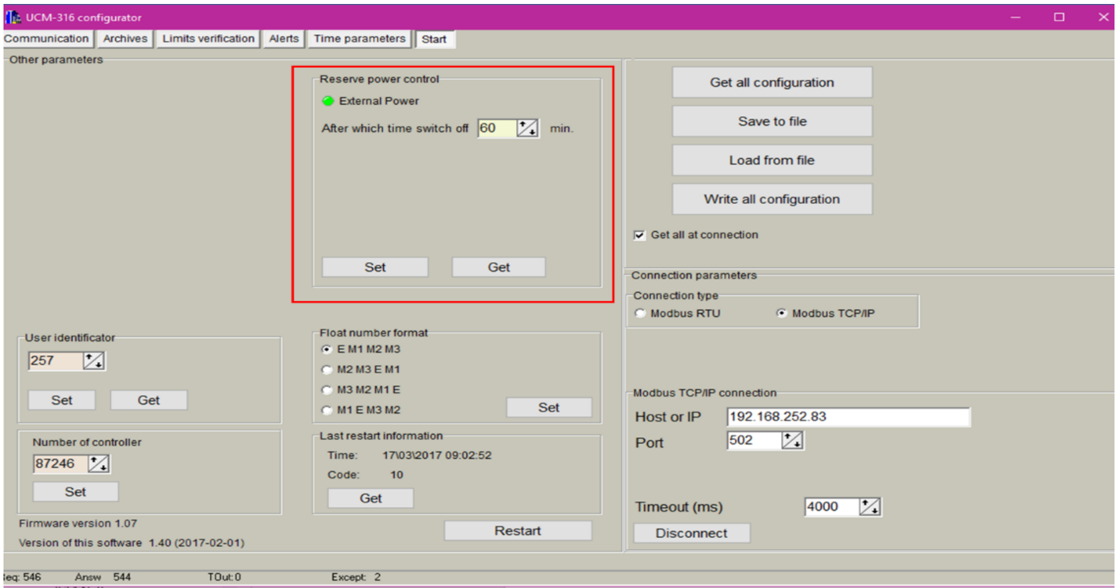


Figure III 15: Reserve power control

III.2.6 Slave Node Board Design:

The figure III 16 shows a diagram of the master network which includes a power supply, controller, analog sensors, modbus sensor and a radio transceiver:

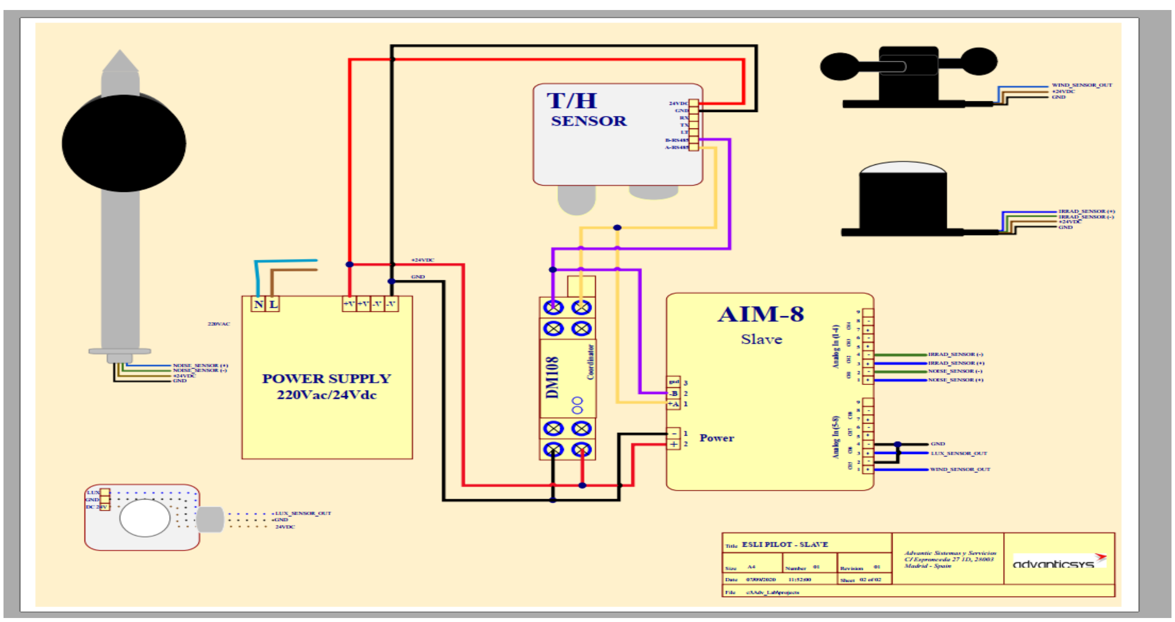


Figure III 16: Equivalent diagram of a single node.

III.3 Master Network

The master is composed by two main components;

- DM-108 configured with the role of radio ‘Coordinator’.
- UCM-316 which acts as network data concentrator and pushes data to CONCORDIA platform.

III.3.1 Gateway

The UCM-316 is chosen for this project. It is a 4G LTE remote datalogger/controller created for measuring and logging data from M-Bus meters, Modbus RTU devices, analog inputs (current, voltage, resistance or PT100 temperature sensors) and discrete inputs (pulses, alarms or events). It also performs control capabilities over discrete outputs [59].

The logged information can be either collected remotely using standard or open protocol Modbus TCP/IP, through cellular communication or sent in CSV file format to remote FTP servers.

Figure III. 17: UCM-316.

General	**Power Supply**: 9 – 36Vcc / 12 50Vcc **Overvoltage protection:** 1000V (max. 5 sec) **Power consumption:** 10 VA **internal battery:** 3,7V 750 mAh
Specifications	**Cpu :** Cortex M4 **Flash:** 8 MB, up to 5 years storage **UMTS/HSPA+:** 2 band, 850/1900MHz, 900/2100MHz **LTE-FDD**: Multi-band B1/B3/B5/B7/B8/B20
Interfaces	**RS232:** Up to 15m distance **RS485:** Up to 1.2 km distance **USB:**Type B, ver. 2.0 **Ethernet**: RJ 45 up to 100m. **M-Bus:** Up to 20 devices
Protocols	Modbus RTU, Modbus TCP/IP, M-Bus, MQTT, FTP server/client
Physical characteristic	**Dimensions**: 147x128x50 mm **Weight**: 400 g **Material**: PC/ABS Protection type: IP20

Table III 3: Characteristics UCM-316

III.3.2 Master Network Board Design:

The figure III 18 shows a diagram of the master network which includes a power supply, Gateway and a radio transceiver:

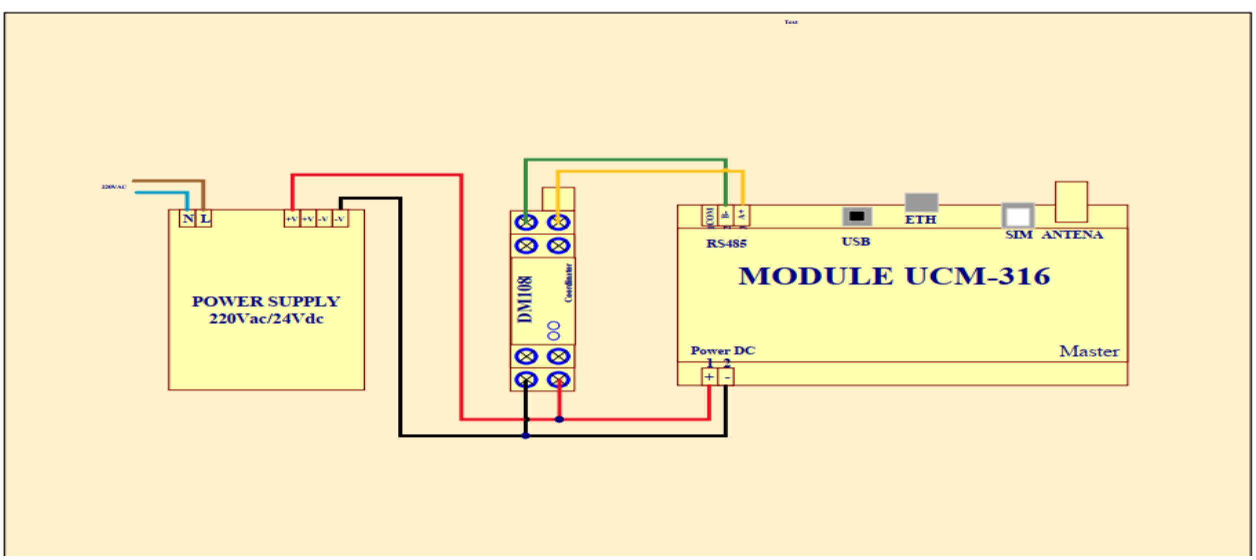


Figure III 18 : Equivalent diagram of master network.

III.4 Pilot Set Up

III.4.1 Design Description.

The proposed pilot is based on Modbus protocol for data collecting. According to the pilot architecture, UCM-316 is working as the network master. UCM-316 main features included are:

- UART RS485
- Ethernet port
- USB port
- 3G modem
- SD card for datalogging.
- Internal backup battery

UCM-316 main performance is:

• To collect data from the analog sensors through the AIM-8 dataloger and from the modbus NBB-THext sensors by using modbus protocol. These data come to the UCM-316 across the wireless modbus gateway DM-108 transparently.

• To build a modbus RTU interface over the UART1 or a Modbus TCP over the ETH interface.

• To build a modbus RTU client in order to set up a communication bus with the modbus devices of the pilot.

• To ask for data to the modbus slaves periodically. A modbus requests table has been configured in order to get data from slaves.

• To save data internally in the user archive memory.

• To build data files in standard formats .CSV - FTP / .JSON – MQTT for sending data to remote servers.

III.4.2 Plug And Play Steps To Be Done

Before starting to collect and group all devices and for the for security reasons, we must disconnect power from any device. Connecting the analog sensors to datalogger AIM8 it has to be done through the AIM-8 analog inputs.

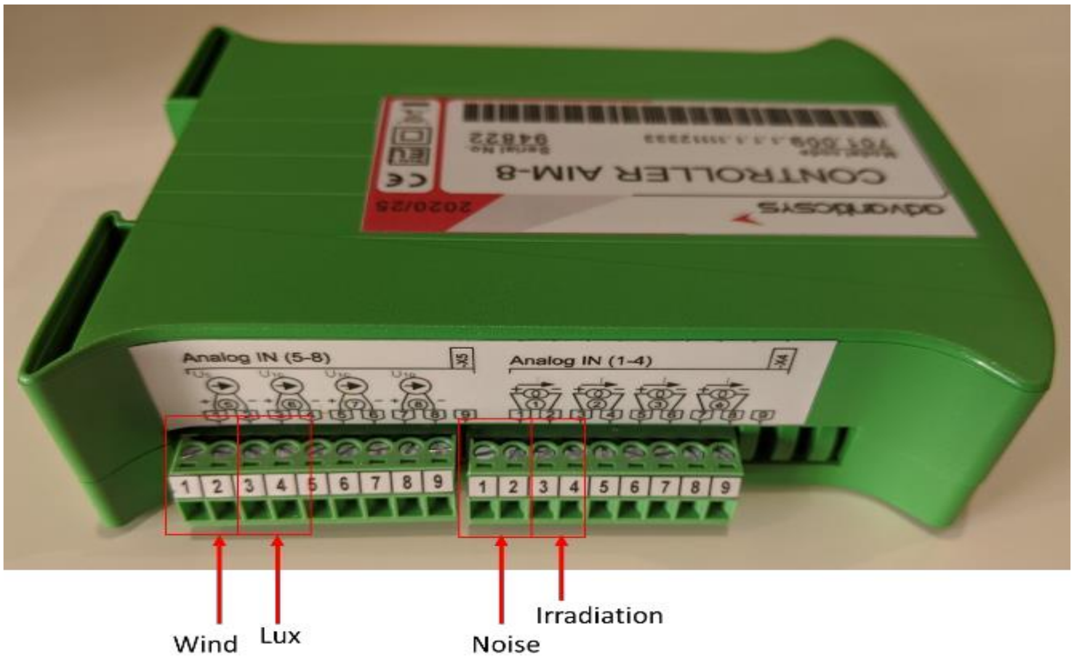


Figure III 19: AIM8 Analog ports.

- **Analog sensors connection**

The table below shows how we connect each sensor wire in the analog ports on the AIM-8:

• Ain1 - > Noise

• Ain2 - > Irradiation

• Ain5 - > Wind

• Ain6 - > Lux

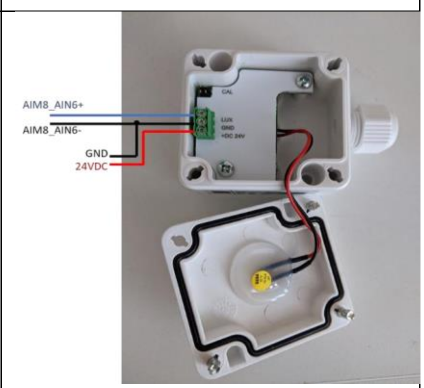
Sensor	Connection	Sensor wire
Irradiation sensor	**Brown ->** +24VDC **Black ->** GND **Blue ->** AIM8_AIN2(+) **Green ->** AIM8_AIN2(-)	
Wind Speed sensor	**Blue ->** AIM8_AIN5(+) **Black ->** AIM8_AIN5(-) and GND(power supply) **Brown ->** +24VDC	
Brightness sensor	**LUX ->** AIM8_AIN6(+) **GND->** AIM8_AIN6(-) and GND(power supply) +DC 24V -> +24VDC	
Noise sensor	Brown -> +24VDC Black -> GND Blue -> AIM8_AIN1(+) Green -> AIM8_AIN1(-)	

Table III 4: sensor wiring connection**.**

- **Modbus connection bus**

Connect the Modbus RTU communication bus. From the master side, connect 'UART1' RS485 from UCM-316 to the Modbus RTU port of DM-108 radio coordinator. From the slave side, connect the DM-108 slave to the AIM-8 datalogger and the NBB-THEXT sensor.

As Modbus RTU standard describes, connection must be "daisy chain":

• B (+) / A (+) -> A

• A (-) / B (-) -> B

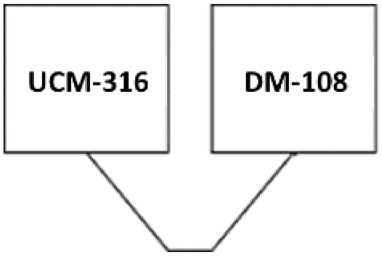


Figure III 20: Modbus Master RS485 connection

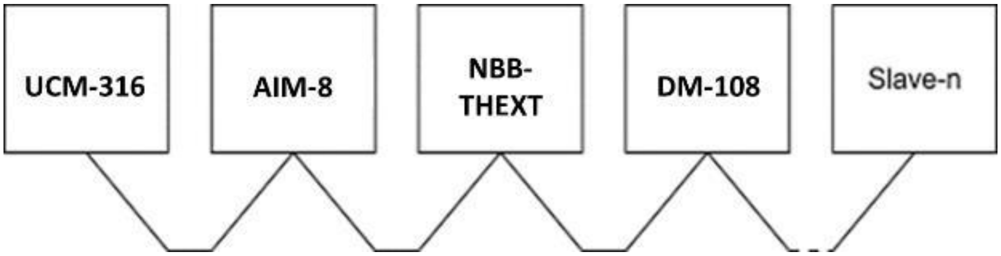


Figure III 21: Modbus Slave RS485 connection

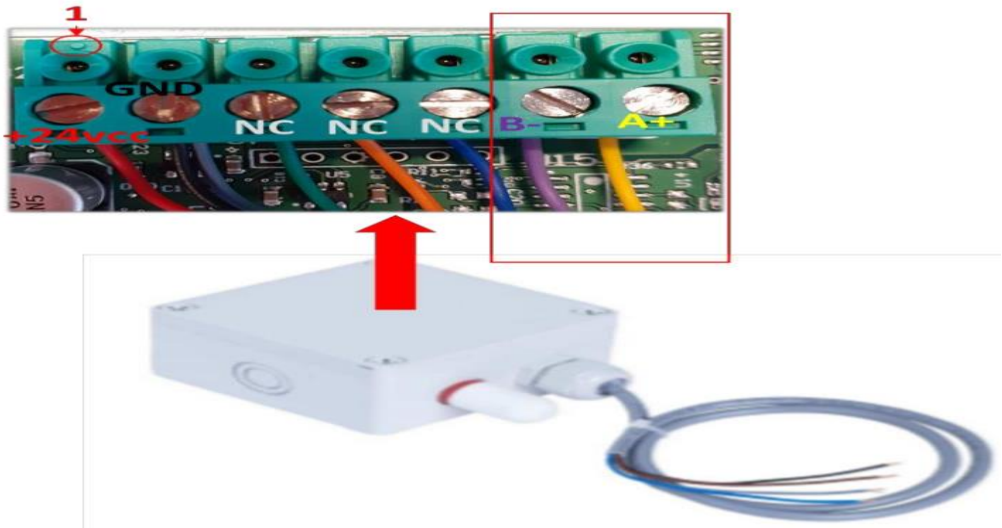


Figure III 22: Sensor NBB-THEXT Pinout.

Figure III 23: AIM-8 UART.

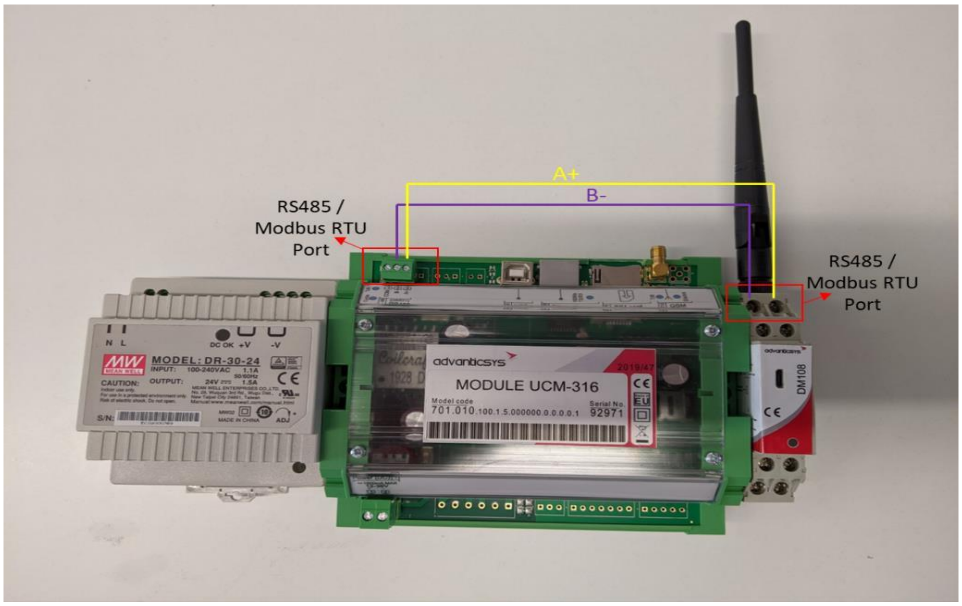


Figure III 24 : PILOT Master UART connection.

- **Power supply connection**

Without switching on power, connect devices power inputs. All devices power supply range is 9-36 VDC

Figure III 25 : UCM-316 power supply input.

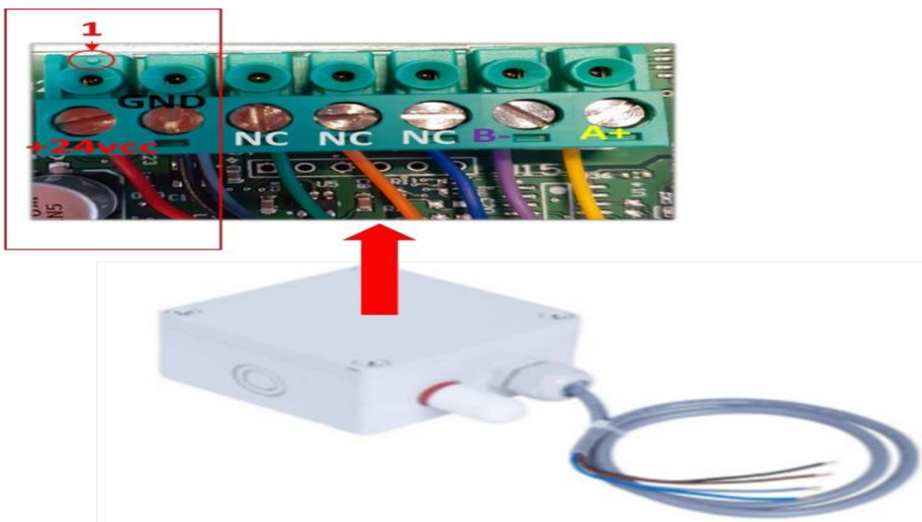


Figure III 26: NBB-THEXT power supply input.

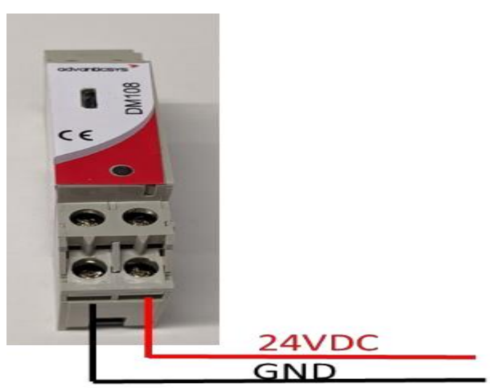


Figure III 27: DM108 Wireless gateway power supply.

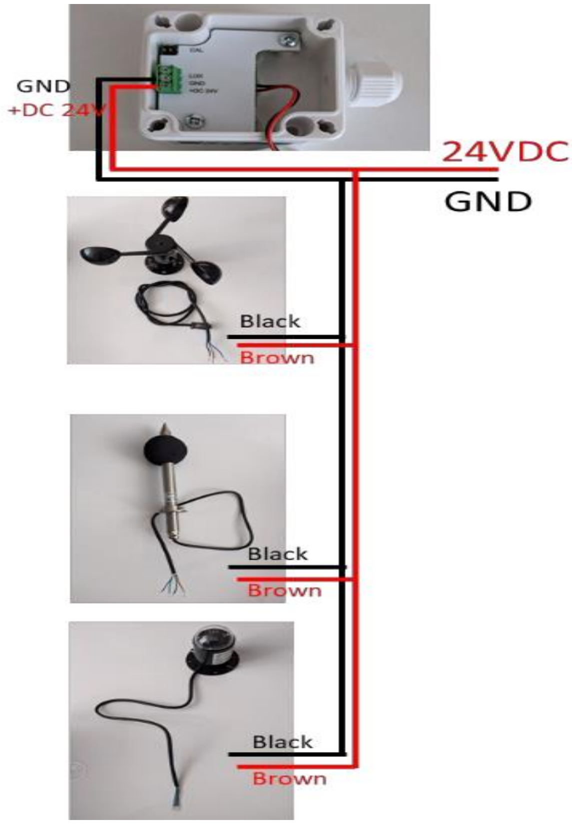


Figure III 28 : Analog sensors power supply.

After connection all devices to the source power we place the internal backup battery of UCM-316

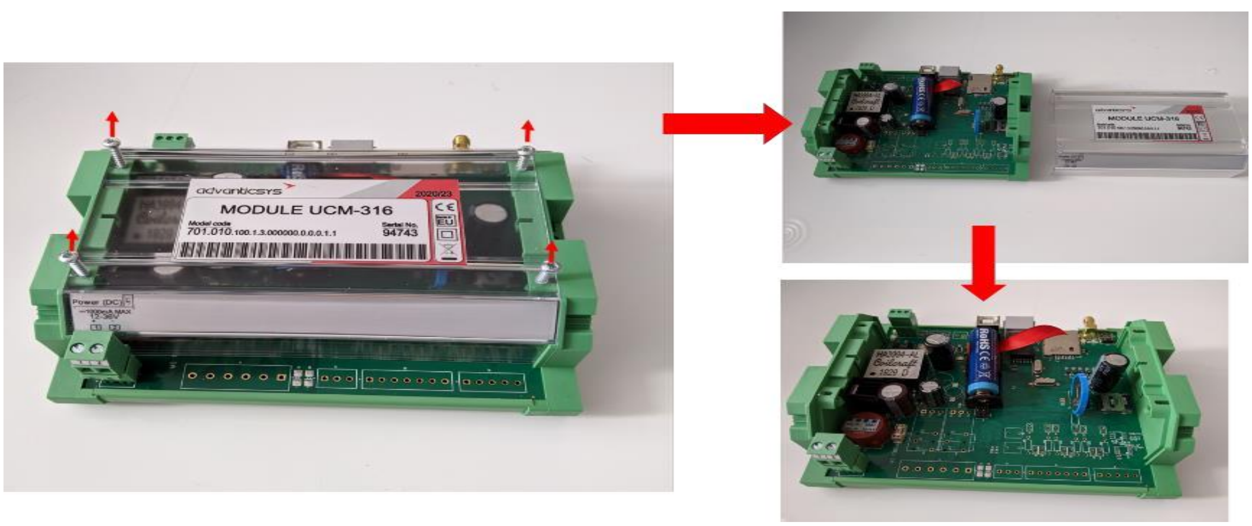


Figure III 29: Battery connection.

Last but not least we connect the antennas in all Wireless devices: the DM-108 and the UCM-316.

Figure III 30: Antennas.

III.5 Architecture of the pilot

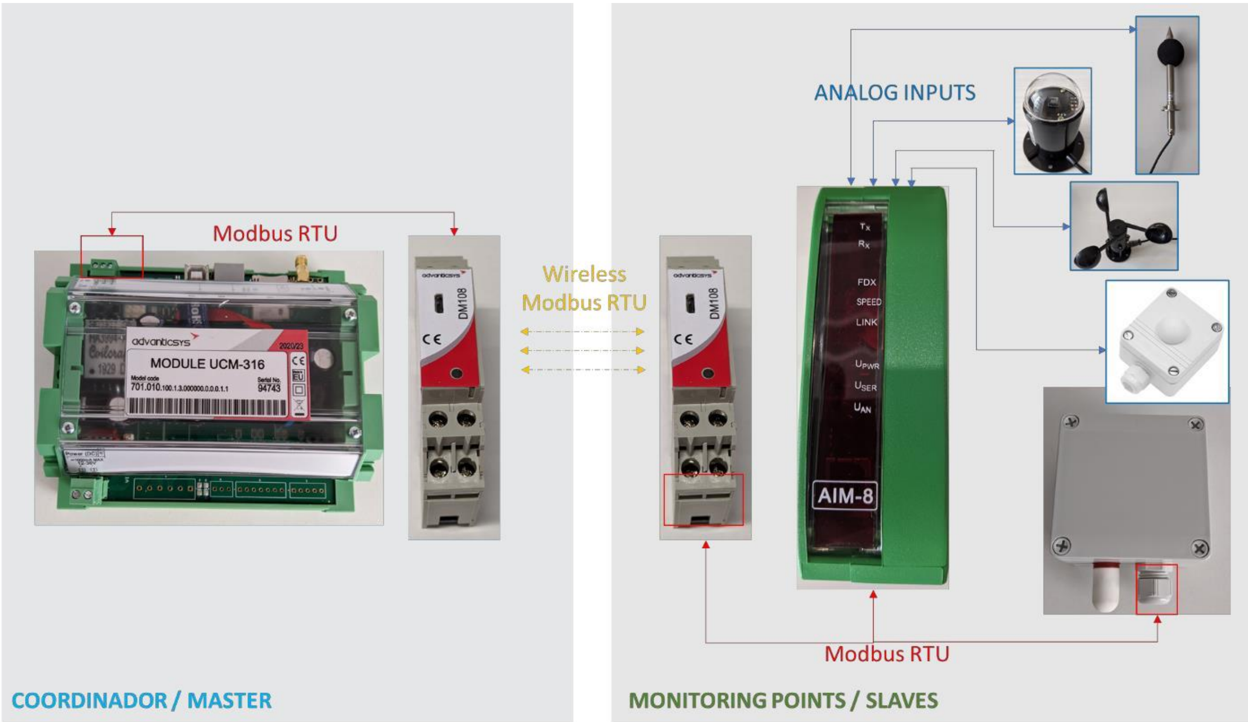


Figure III 31: Communication block diagram.

Figure III 32: single node slave module.

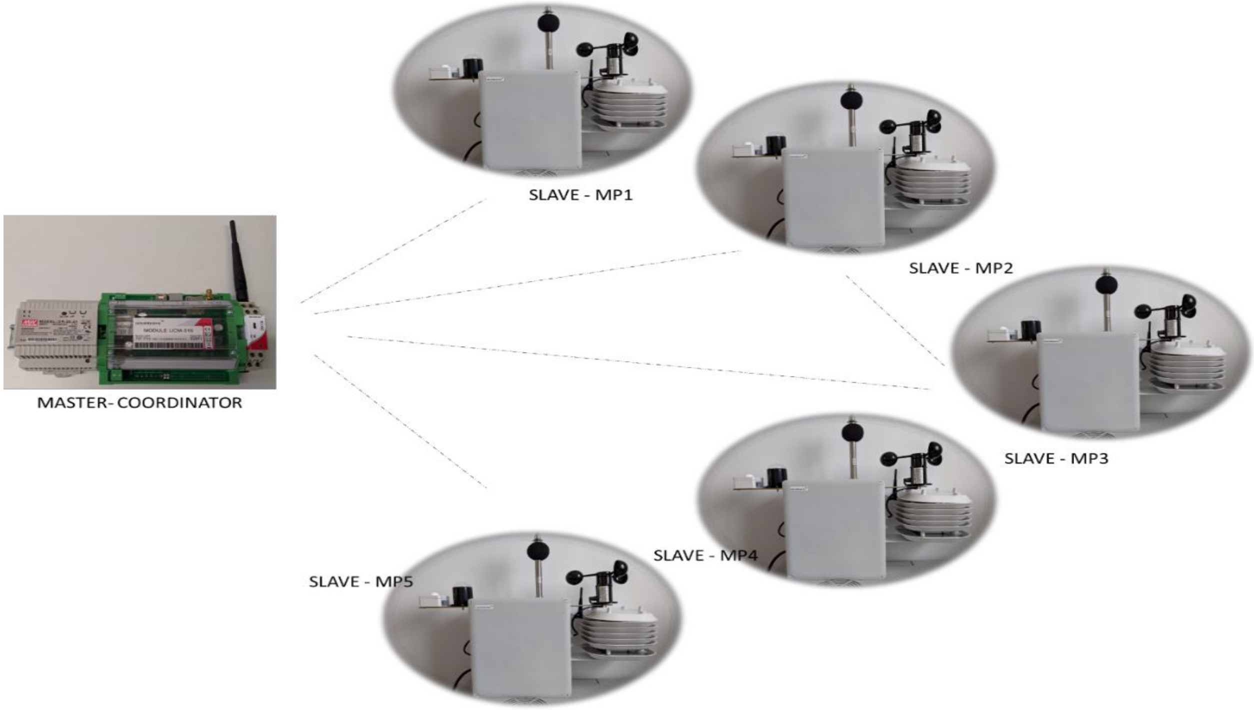


Figure III 33: Pilot block diagram.

The pilot architecture proposed for this use case is the following:

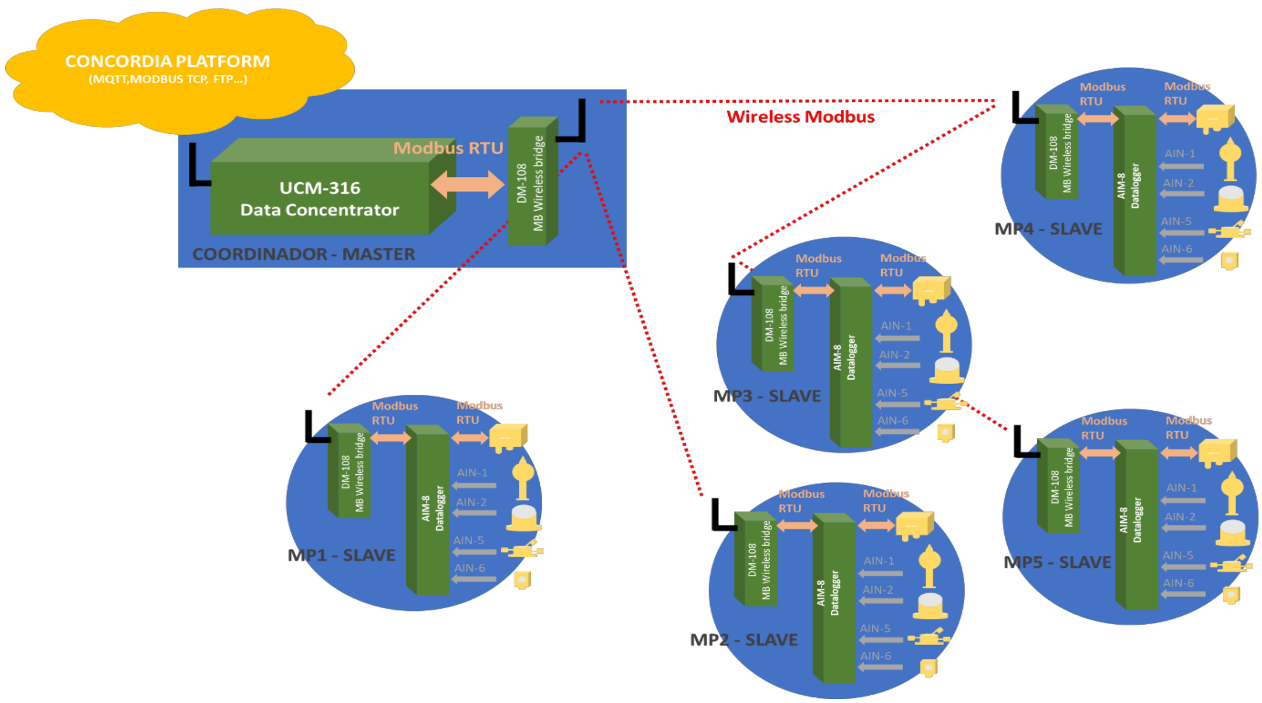


Figure III 34: Pilot architecture.

The proposed pilot consists of collecting data from 25 sensors organized in 5 different monitoring points in CONCORDIA cloud platform. The components of the pilot are the following:

Network Master: The master is composed by:

- DM-108: configured with the rol of radio ‘Coordinator’
- UCM316: which acts as network data concentrator and pushes data to CONCORDIA platform.

Network Slaves: There are 5 slaves groups which are part of the pilot. Each slave point is composed by:

- DM-108: configured with the rol of radio ‘Slave’.
- AIM8 datalogger: which acquires analog signals from the analog sensors.

- NBB-THEXT sensor: which measures temperature and relative humidity and send data by Modbus protocol.
- WIND SPEED sensor: which measures the current wind speed and generates a proportional voltage output.
- NOISE sensor: which measures the current ambience noise and generates a proportional current output.
- IRRADIATION sensor: which measures the current solar radiation and generates a proportional current output.
- BRIGHTNESS sensor: Which measures the current lighting level and generates a proportional voltage output.

Network master is periodically sending Modbus requests for data to the slaves monitoring points. When a data requested has been received by the slave monitoring point, it replies automatically with its sensors data. Once the master receives replies from the slaves, it stores and manages the data pushing to the Concordia platform.

III.6 Devices Configuration

The configuration has been done based on some purposes. In our case, we have been configured only one node, this configuration just affects to devices working under modbus protocol: DM-108, AIM-8, UCM-316 and NBB-THEXT sensor. Analog sensors do not need any configuration. They are working by default.

In our case project, devices have been configured to establish a hybrid (wired/wireless) modbus network. The components of the design system are the following:

A) From the radio communication point of view, it has been defined 2 components:

- **Coordinator**: the radio coordinator will oversee managing the wireless communication. This device, DM-108, receives wireless data and translate them into modbus RTU packets

NOTE: It can be just one radio coordinator in each radio network.

- **End points**: End points, DM-108, are listening continuously for reading commands. When a read command is received, they are in charged of sending the information requested by the coordinator.

NOTE: All end points must have different radio ID between them, and same radio channel and group ID that the radio coordinator has.

B) From the modbus communication point of view, it has been defined two components:

- **Master:** In charged of sending periodically data requests to the slaves, UCM-316.

NOTE: It can be just one master per network.

- **Slave:** AIM-8, in charged of replying the data from the sensors to the master.

NOTE: All modbus devices connected to the same network must have different modbus IDs.

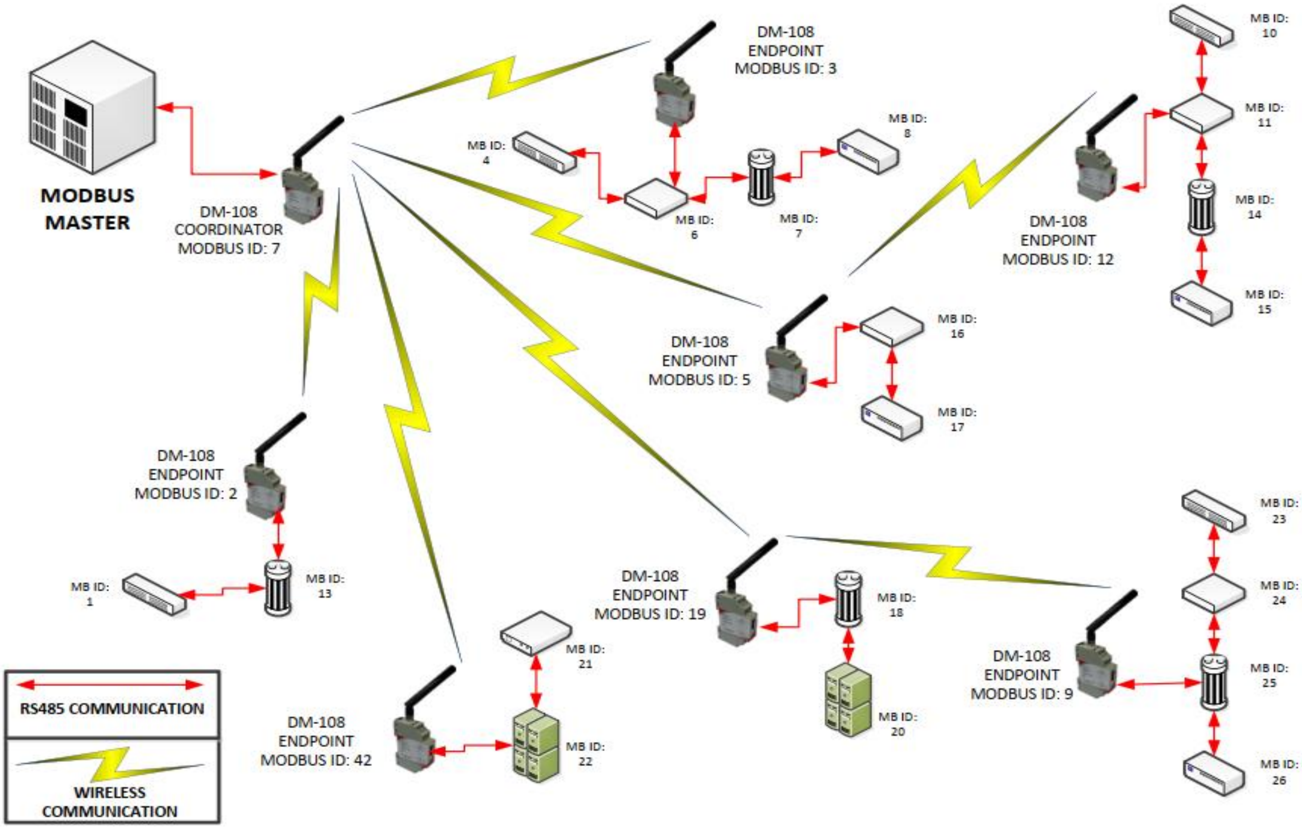


Figure III 35: Wireless MODBUS Network *[59]*.

As shown in the figure The **DM-108** is auto routable, which means that each node automatically selects the best route to forward the data packets, effectively disseminating the Modbus commands to all connected devices. The net is based on the topology Coordinator-endpoint, where the endpoints could be act automatically as repeaters at the same time to connect with others DM-108. It is only possible to have one coordinator in each net or group ID. The maximum number of hops between nodes is five.

III.6.1 DM-108

DM-108 device which are part of the system have been configured as follows:

DEVICE	**SERIALS**	**mbIDs**	**uart**	**PILOT LOCATION**
DM108 master	3848833	1	19200,8n1	Coordinator
DM-108 SLAVE	3848836	2	19200,8n1	End point

Table III 5: Pilot DM-108 pre-configuration

Components needed to program DM-108 configuration are:

- Software configuration "**WMCONFIG. TOOL V 1.078**" tool
- Micro-USB Programming cable.

Figure III 36: DM-108 programing cable.

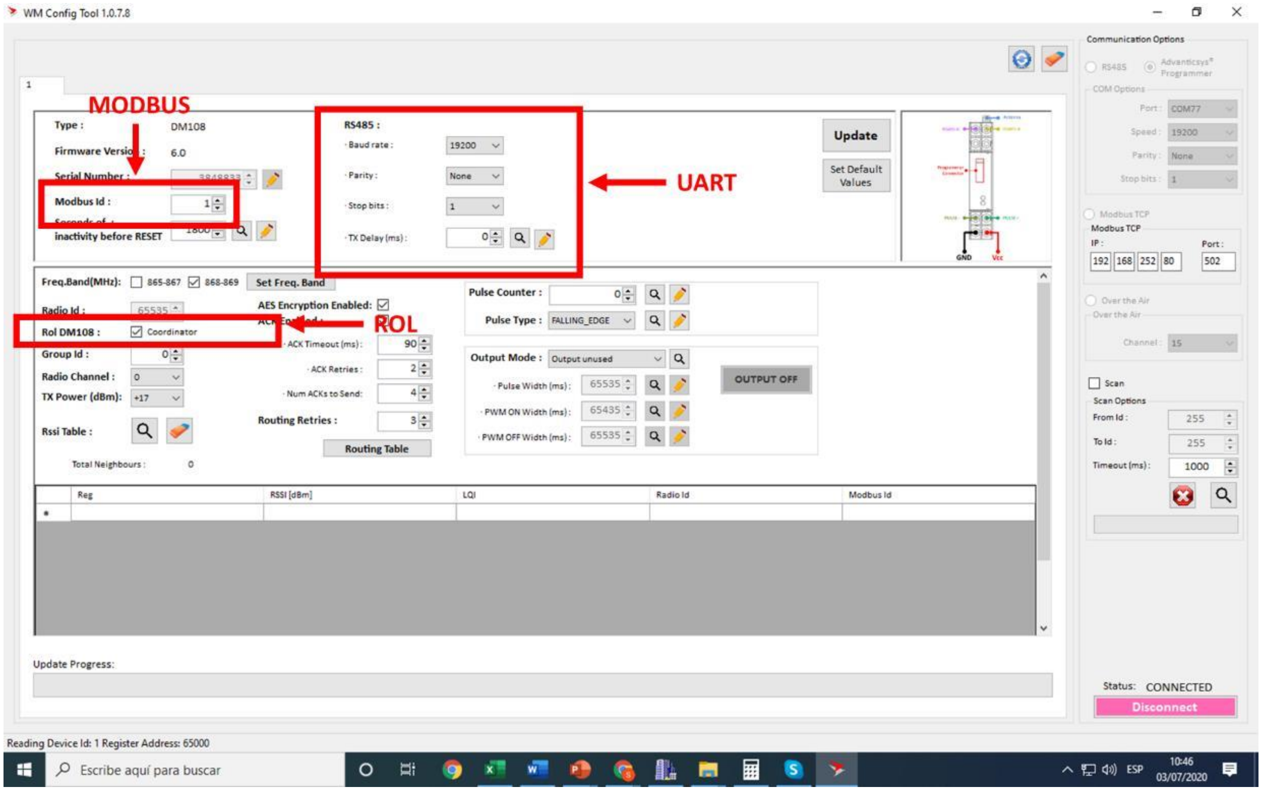


Figure III 37: Example of DM-108 Configuration.

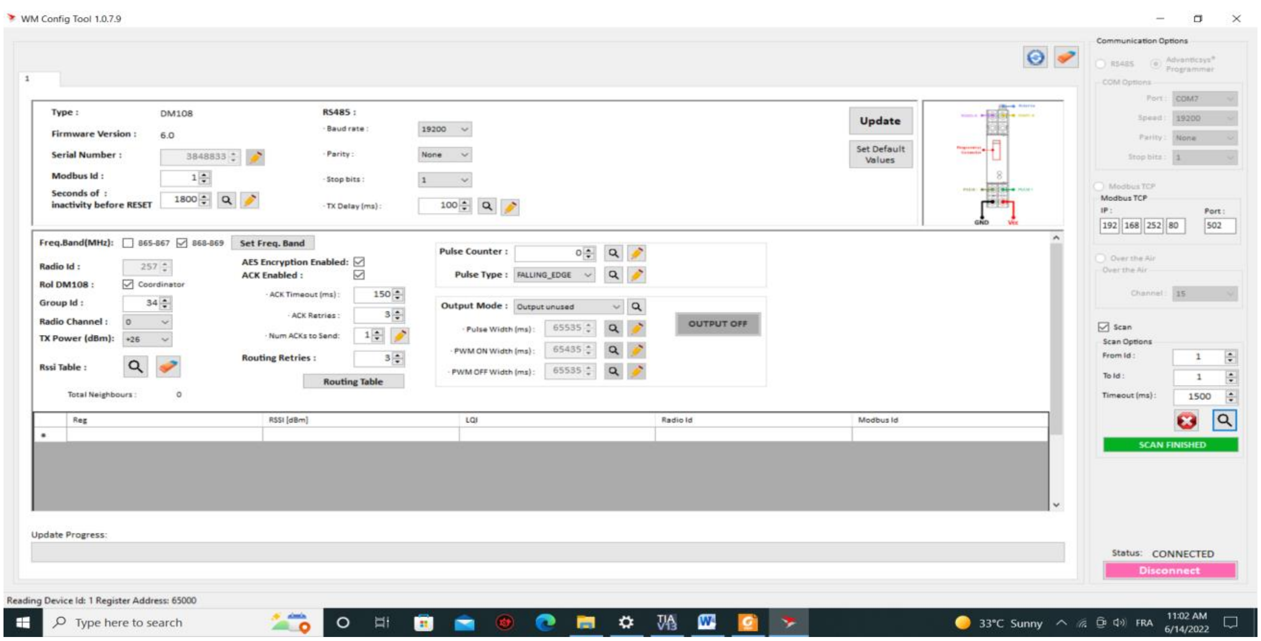


Figure III 38: DM-108 '3848833' configuration (Coordinator).

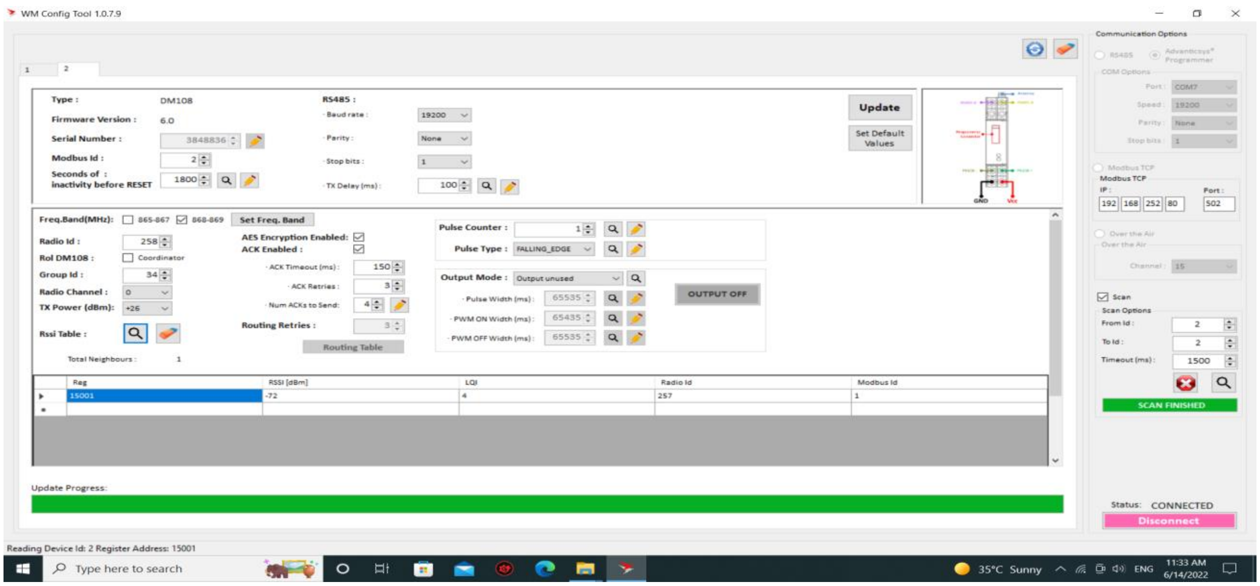


Figure III 39: DM-108 '3848836' configuration (Slave – MP1).

III.6.2 AIM-8

AIM-8 devices which are part of the pilot have been configured as follows:

DEVICE	SERIALS	mbIDs	UART	PILOT LOCATION
AIM-108	94815	3	19200,8n1	MP1

Table III 6: AIM-8 pre-configuration.

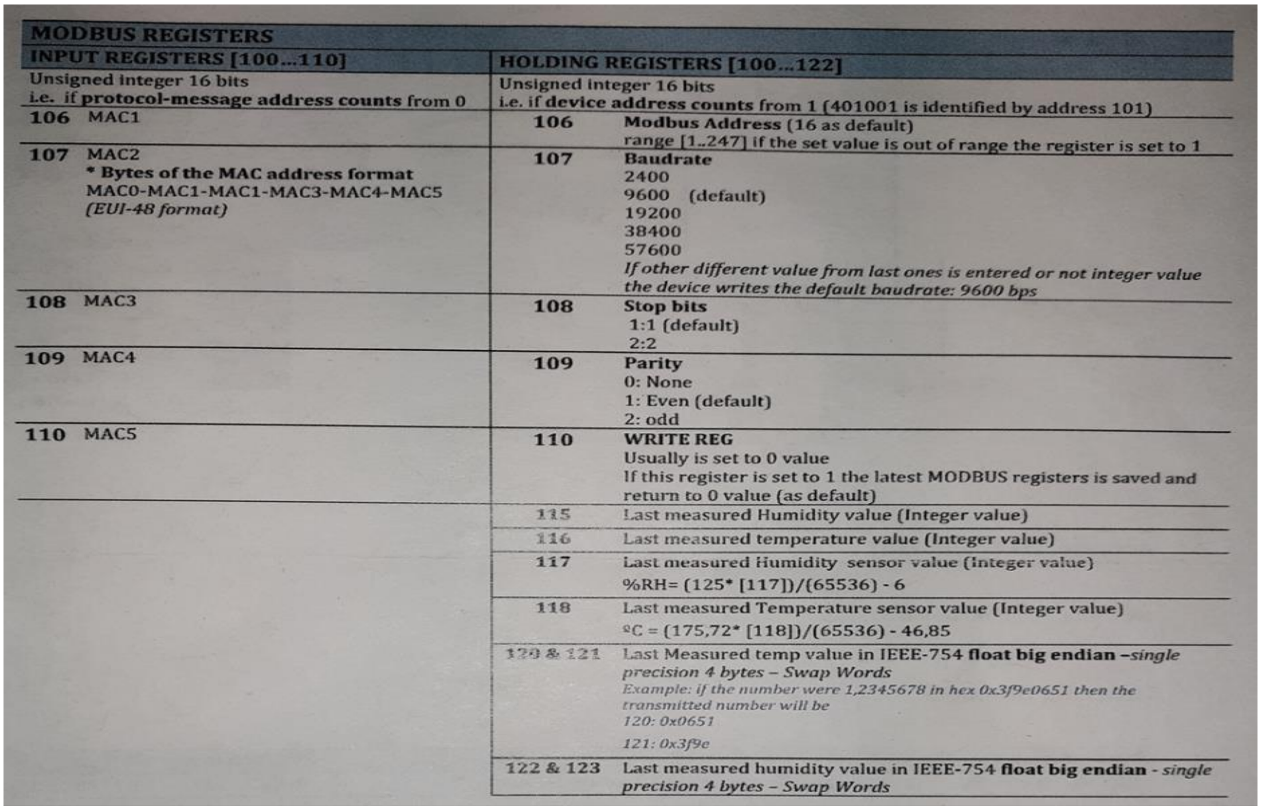
Components needed to program AIM-8 configuration are:

- Software configuration "**AIM8 CONFIGURATOR 1.3**" tool
- USB ClassB Programming cable:

Figure III 40: AIM-8 programing cable.

III.6.3 NBB-THEXT-EN272501

Temperature/Humidity sensors allow to be configured through standard modbus protocol. Register map is the following:



MODBUS REGISTERS			
INPUT REGISTERS [100...110]		**HOLDING REGISTERS [100...122]**	
Unsigned integer 16 bits i.e. if **protocol-message address counts** from 0		Unsigned integer 16 bits i.e. if **device address counts** from 1 (401001 is identified by address 101)	
106	MAC1	**106**	**Modbus Address** (16 as default) range [1..247] if the set value is out of range the register is set to 1
107	MAC2 *** Bytes of the MAC address format** MAC0-MAC1-MAC1-MAC3-MAC4-MAC5 *(EUI-48 format)*	**107**	**Baudrate** 2400 9600 (default) 19200 38400 57600 *If other different value from last ones is entered or not integer value the device writes the default baudrate: 9600 bps*
108	MAC3	**108**	**Stop bits** 1:1 (default) 2:2
109	MAC4	**109**	**Parity** 0: None 1: Even (default) 2: odd
110	MAC5	**110**	**WRITE REG** Usually is set to 0 value If this register is set to 1 the latest MODBUS registers is saved and return to 0 value (as default)
		115	Last measured Humidity value (Integer value)
		116	Last measured temperature value (Integer value)
		117	Last measured Humidity sensor value (Integer value) %RH= (125* [117])/(65536) - 6
		118	Last measured Temperature sensor value (Integer value) ºC = (175,72* [118])/(65536) - 46,85
		120 & 121	Last Measured temp value in IEEE-754 **float big endian** –*single precision 4 bytes – Swap Words* *Example: if the number were 1,2345678 in hex 0x3f9e0651 then the transmitted number will be* *120: 0x0651* *121: 0x3f9e*
		122 & 123	Last measured humidity value in IEEE-754 **float big endian** - *single precision 4 bytes – Swap Words*

Figure III 41: NBBTHEXT register map.

Components needed to program AIM-8 configuration are:

- Standard modbus protocol tool
- USB-RS485 standard converter

Devices which are part of the pilot have been configured as follows:

COMMON PARAMETERS: UART: 19200 @ 8N1

DEVICE	SERIALS	modbusIDs	UART	PILOT LOCATION
NBB-THEXT	9143309	4	19200,8n1	MP1

Table III 7 : Table of pre-configuration.

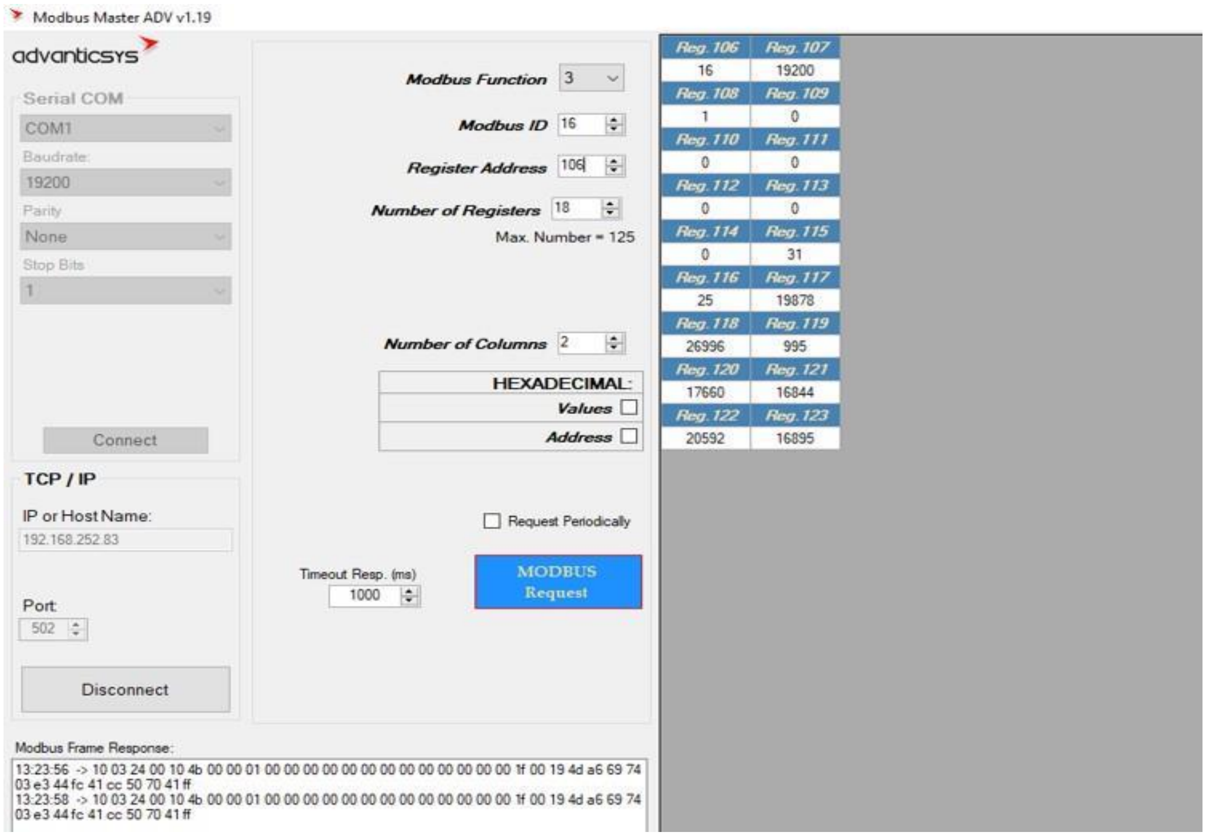


Figure III 42: NBBTHEXT ID=16 Configuration.

III.6.4 UCM-316

Components needed to program UCM-316 configuration are:

- Configuration tool "**UCM-316 v1.86**".
- USB ClassB Programming cable (Figure III 40).

UCM-316 acts as master of the pilot network. Different firmware blocks have been configured:

✓ Physical interfaces:

• UART1: ModbusRTU

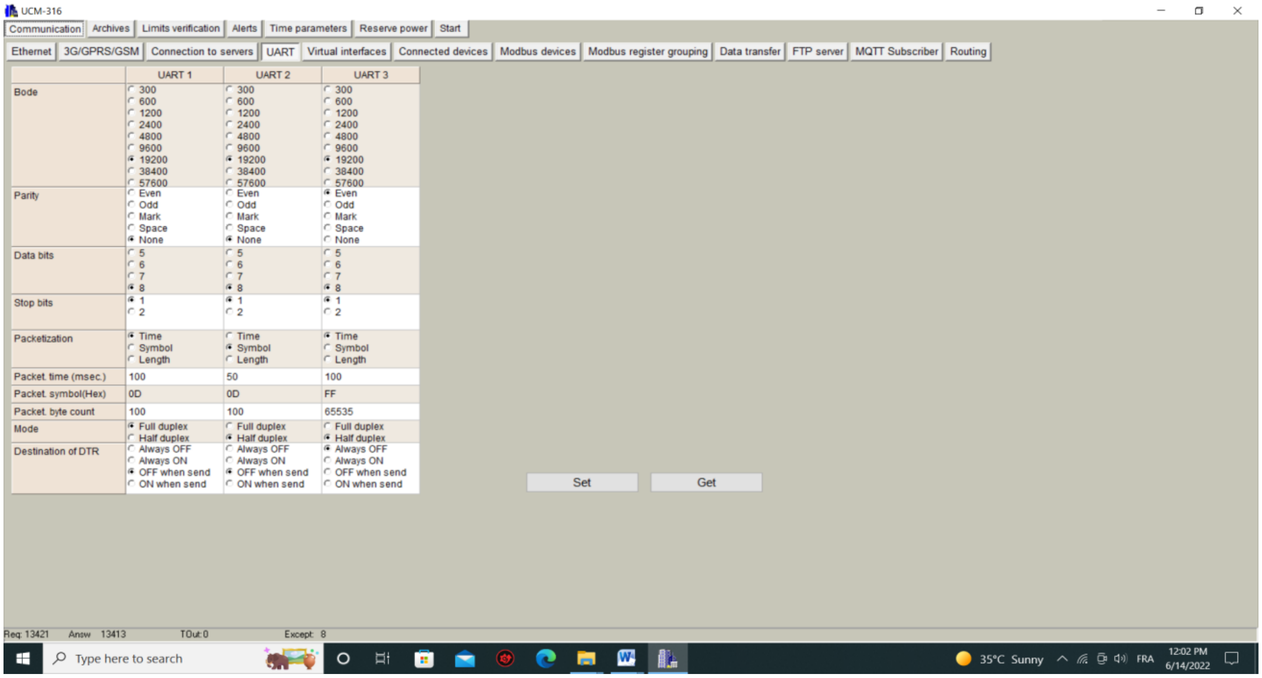


Figure III 43: UCM-316 physical interfaces.

✓ Virtual Interfaces:

- Modbus RTU Client: UART1 -> Modbus RTU

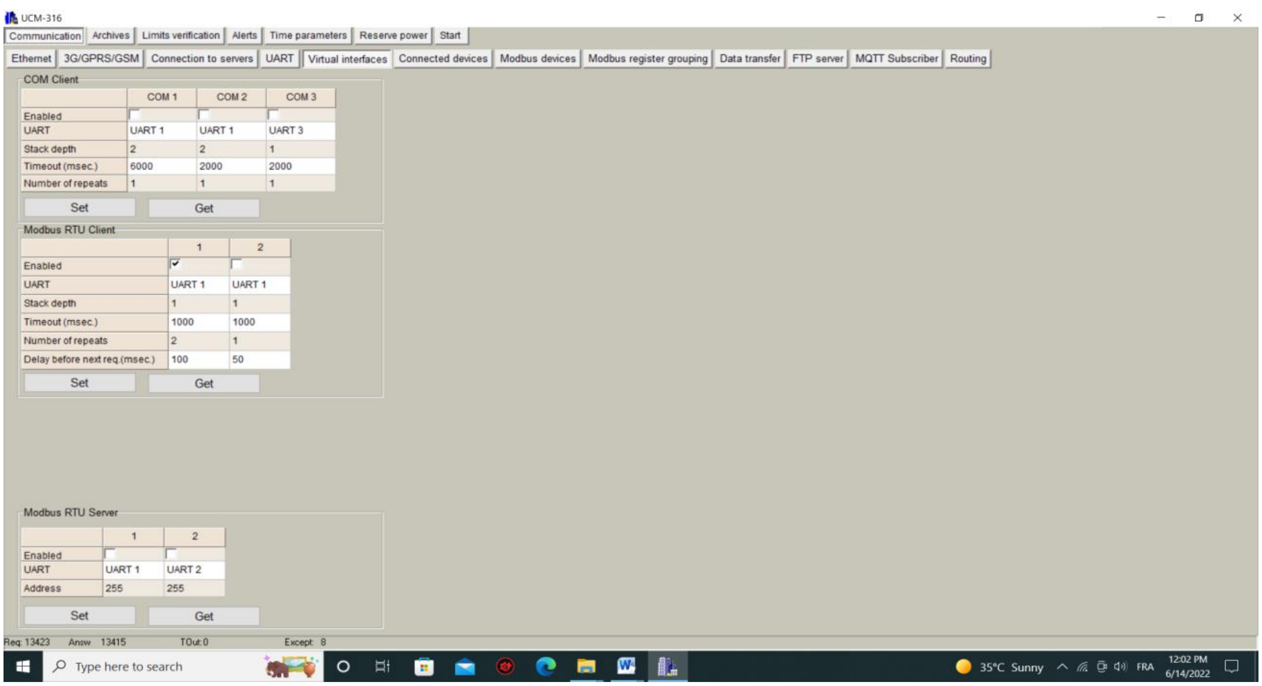


Figure III 44: UCM-316 Virtual interfaces.

✓ Modbus client:

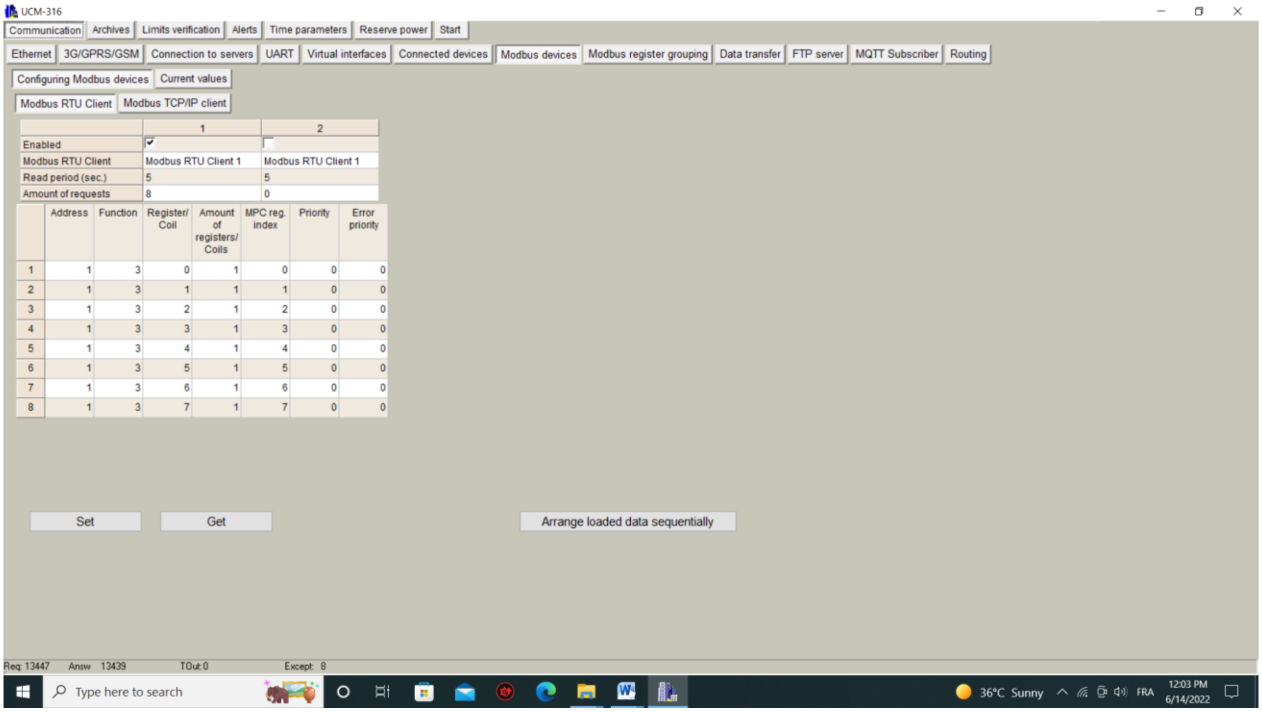


Figure III 45: Modbus slaves addressing.

III.7 WSN Integration with PLC

Due to the complexity of the Profinet protocol, it was not possible to directly link the Gateway with a PLC. We tried to get the collected data directly from the Gateway and link it to our PLC without going through Concordia Platform. After trying several times, we reached to a solution but we don't consider it works effectively.

In this section, an idea of integrating a wireless sensor into industrial control systems without going through the cloud (Concordia platform) was almost impossible implemented. But an inexpensive solution for the industrial gateway was also provided. The main reason for choosing this idea is the high price of annual subscription rights to the Concordia cloud.
To maintain the work of our method and to keep the operation running smoothly, we faced a lot of the connectivity problems including unreliable and inaccessible communication, and different proprietary protocols.

KEPServerEX is the right connectivity platform that we need to establish the communication between the Gateway and the PLC. KEPServerEX can easily allow the connectivity between the Microsoft Excel and TIA PORTAL software.

III.7.1 Dealing with data

Data collected by UCM-316 can be sent in a CSV file through the configuration of an FTP client inside the controller. In the Archive>*User Archive* and *after* configuration is completed the table below will show the Number of registers to be stored in the CSV file.

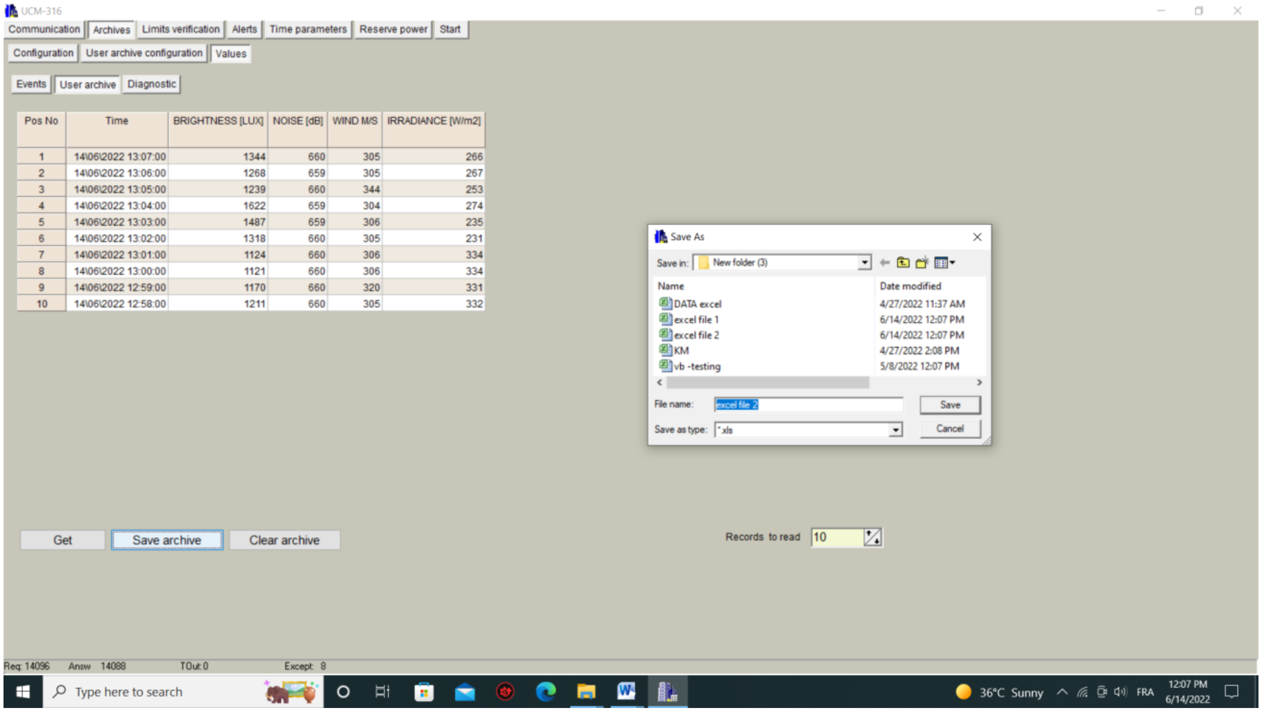
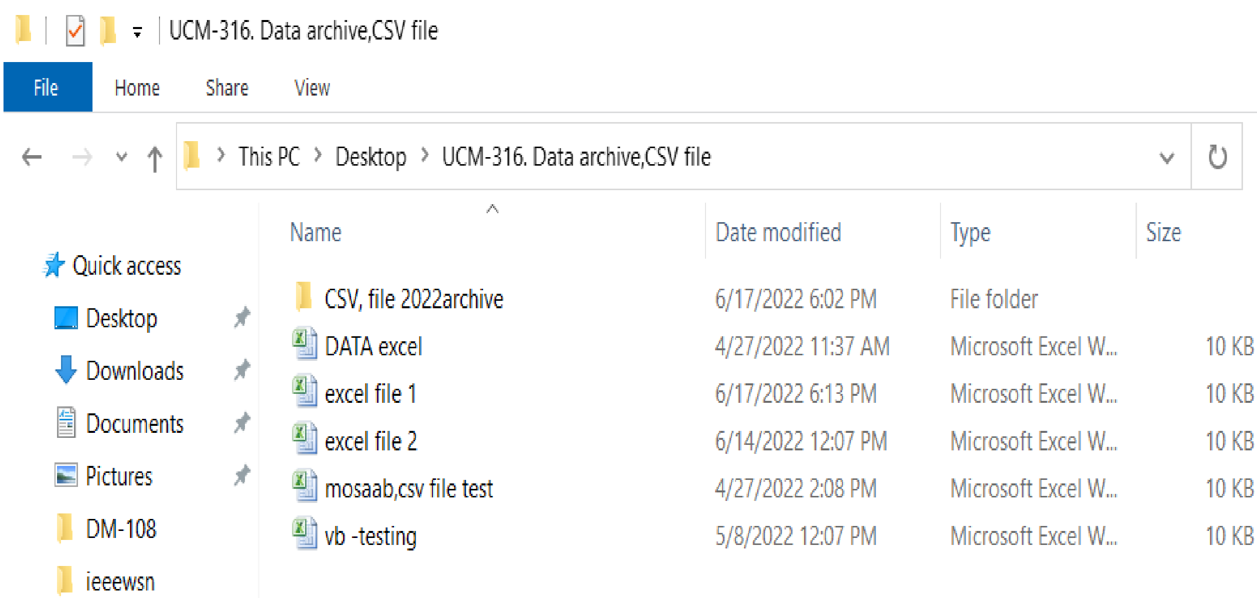
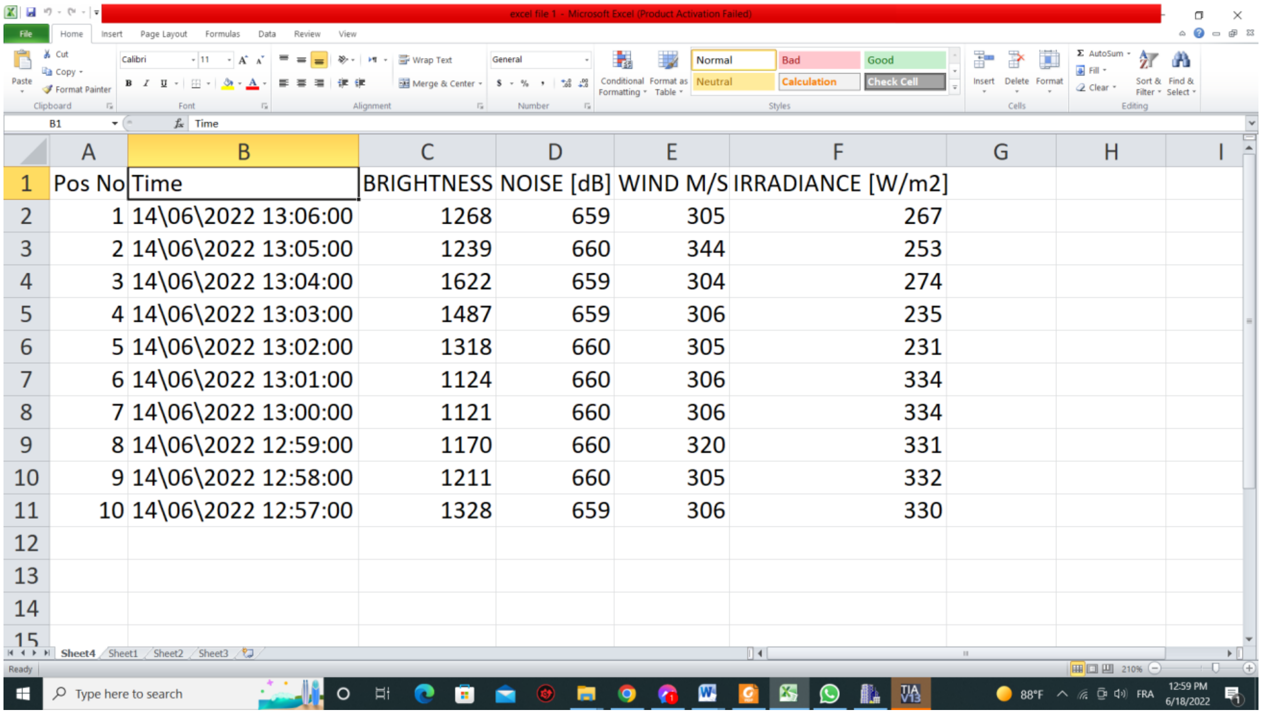


Figure III 46: user archive saving.

Once we click on (save archive) a "CURRENT_DATA.csv" file is stored. We will find all the data generated by the UCM-316 in an Excel file.





Pos No	Time	BRIGHTNESS	NOISE [dB]	WIND M/S	IRRADIANCE [W/m2]
1	14\06\2022 13:06:00	1268	659	305	267
2	14\06\2022 13:05:00	1239	660	344	253
3	14\06\2022 13:04:00	1622	659	304	274
4	14\06\2022 13:03:00	1487	659	306	235
5	14\06\2022 13:02:00	1318	660	305	231
6	14\06\2022 13:01:00	1124	660	306	334
7	14\06\2022 13:00:00	1121	660	306	334
8	14\06\2022 12:59:00	1170	660	320	331
9	14\06\2022 12:58:00	1211	660	305	332
10	14\06\2022 12:57:00	1328	659	306	330

Figure III 47: Excel file for stored data.

Now after we got the excel file. We will be needed the KEPServerEX which can demonstrates how to establish a connection between Microsoft Excel and PLC.

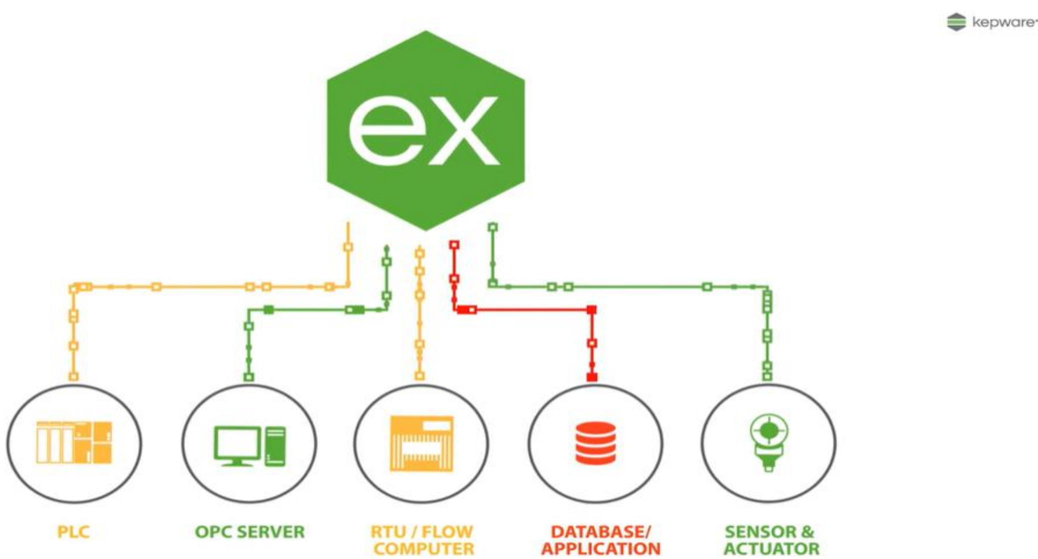


Figure III 48: KEPServerEX connectivity *[60]*.

The figure 49 show an example for connecting TIA portal with excel file using the connectivity platform KEPServerEX

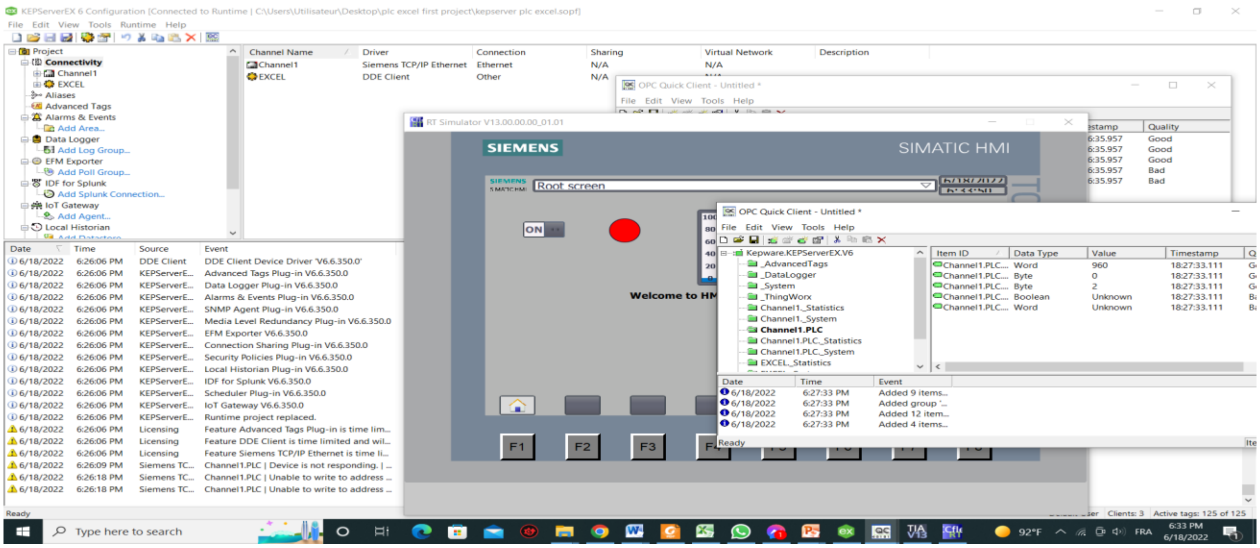


Figure III 49: addressing Excel file with KEPServerEX.

III.8 Conclusion

In this chapter, we provided an advanced wireless sensor network. We get a brief of each sensor and also its circuit. Connection and plugging also have mention. Configuration has been done for each modbus module.in the last section we gave an idea of how to connect this system with the PLC.

Chapter IV: System Implementation

IV.1 Introduction

This work concern with the design of a wireless sensor network system based mainly on two nodes, Weather node and a soil moister node, (it may be extended to several nodes) concerted in a farm palm trees, that includes about 1000 palms. Each node can only gather the data from that specified area. The whole system will give us a study about the farm by the located sensors; temperature, wind speed, humidity, irradiation, brightness, and also some sensors that located in the palm basin (soil moisture sensor). In any area on the field we can get sensors value through the controller, all the data that collected from the agriculture filed will be sent to the gateway then into the Programmable Logic Controller Siemens S-1200.

PLC demonstrates its Software and Hardware implementation in Automated Irrigation Process. Visualization or a Human Machine Interface is made to control and monitor the entire process from one location.

IV.2 Proposed Solution

The proposed system includes a system that gathers data from the sensors and saves information to calculate the amount of water needed for irrigation. The data is obtained through sensors connected to the controller. This data is sent to the Gateway through a wireless Modbus. In a pre-established amount of time, the PLC contains the user program that calculates whether a palm needs water, if it is needed; the system sends a command to turn on the pump and also controls the valve to be open for a period of time as well as the line tube valve.

IV.3 Smart Irrigation System

We will use a considerate irrigation system to save energy and ensure that water is not wasted. Our smart irrigation system is based on wireless sensor networks and drip irrigation. The procedures and steps of the proposed system are described and presented using the model of our proposed system (as shown in figure 1) and a series of steps describing the operation flow of this system (as shown in figure 2), as follows:

IV.3.1 General Architecture

The figure IV 1 shows an introductory scheme of our proposed system, where we have installed an automated system that gets sensor values from farm area and sends it to the PLC which can controls the pump, so it determines the quantity of water, the period of operation, as well as the correct time for operation.

And these sensors are installed in a considerate way on the farm to extract all the data. All the information is been shown on the HMI screen to let the farmer supervise his farm.

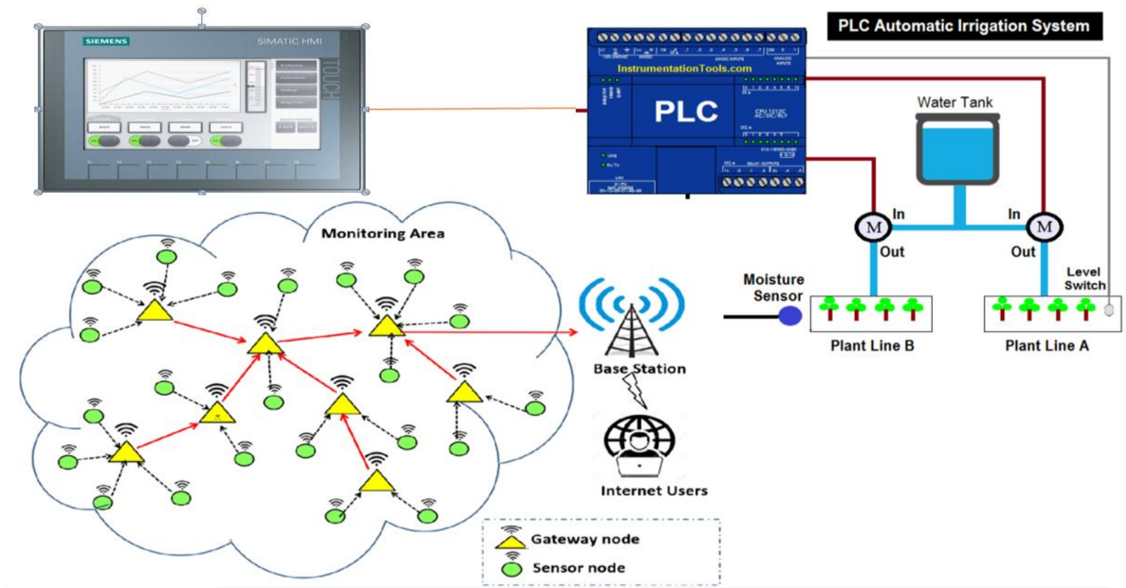


Figure IV 1: General Architecture of the proposed system.

IV.3.2 Detailed architecture

Figure IV 2 shows the detailed architecture proposed system, a smart system for organization and control of irrigation deployed using a WSN to obtain the data and a PLC to control the actuators (electro-valves, pump) and an HMI to control the farm manually and also to let the farmer supervise the farm. This system contains of some components, including weather sensor nodes, soil sensor nodes, a variety of different sensors (e.g. temperature sensors, humidity sensors and wind speed sensors), base station as well as drip irrigation system (tubing, drippers, etc.), control room, and electro-valve.

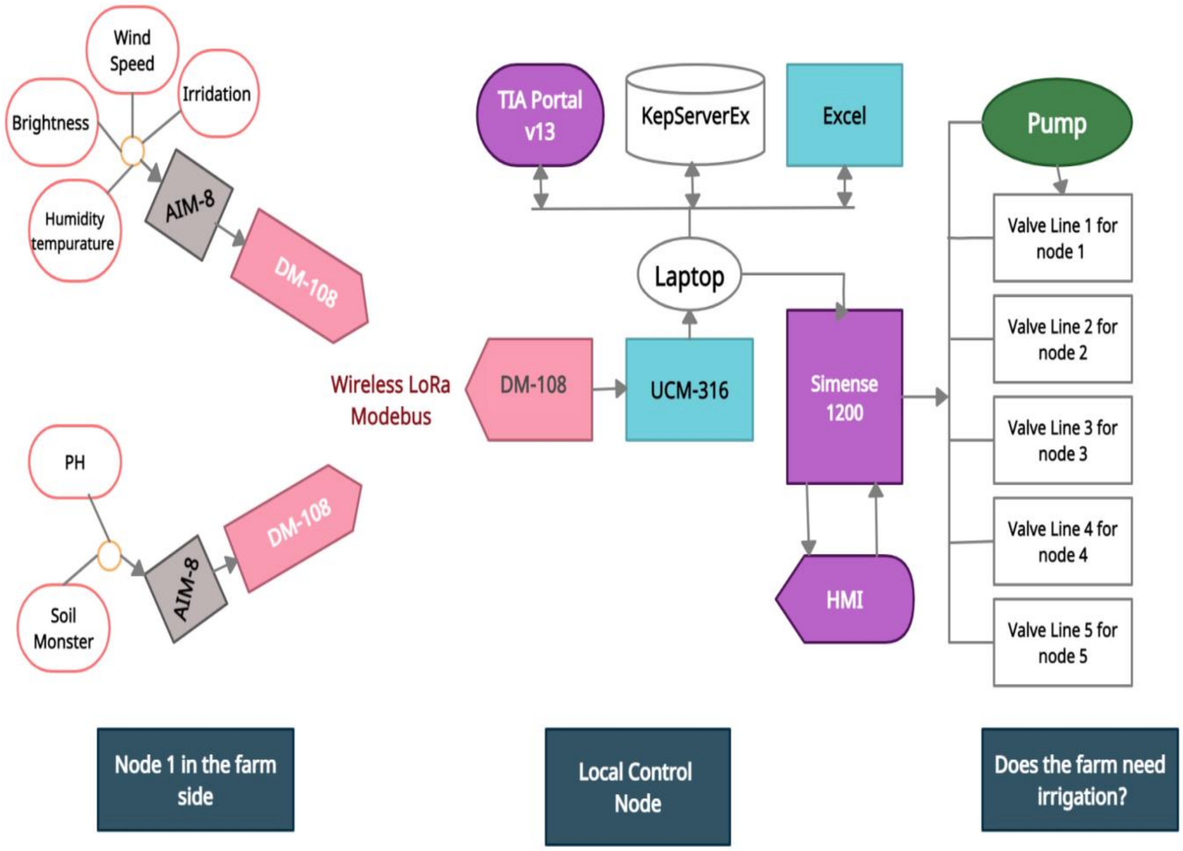


Figure IV 2: Detailed architecture of the proposed system.

- **Weather sensor node:** it's more like a weather station its main purpose is measuring weather parameters such as air temperature, air humidity, and wind speed. It includes a controller, microcontroller, and battery for the power supply. The measured data are routes with a delay to the Gateway via LoRa wireless communication technology.
- **Soil sensor node:** this node is measures soil parameters such as soil temperature, soil moisture, and pH in the soil. This type of node should be dispersed on the soil in the palm basin. Each node routes the measured data from the sensors with a delay to the Gateway via LoRa technology.
- **Control local node:** This is the main part of the overall structure of the system. It allows the collection and analysis of detected and measured data from sensor nodes. Furthermore, the Gateway transmits the collected data to the programmable controller where a wider analysis of the detected and measured data can performed with ease. This

node is used to send commands to the actuators. It also stores the collected data to be read and thus facilitating decision making to activate irrigation or not. A human machine interface allows the farmers for viewing the state of their agricultural land.

The figure IV 3 shows the whole design process for the irrigation system. this diagram gives a brief of how the system work.

Figure IV.3: Workflow of proposed irrigation system.

IV.3.3 Pump control system

In this tutorial, we will be focusing only on the basic instructions, starting with the value of the sensors to the actuators (the pump and the electro-valves).

Ladder language is used to program the system and to control the pump and the electro-valves in an intelligently and automatic manner.

The ladder program in TIA PORTAL software explains how the pump control system works. When the data arrives from the Decision make System, it analyzes and then decides whether the farm needs irrigation or not. Figures 1 2 3 show the programming steps for the system:

- A human machine interface is programmed to show the sensors value and also if irrigation is done.

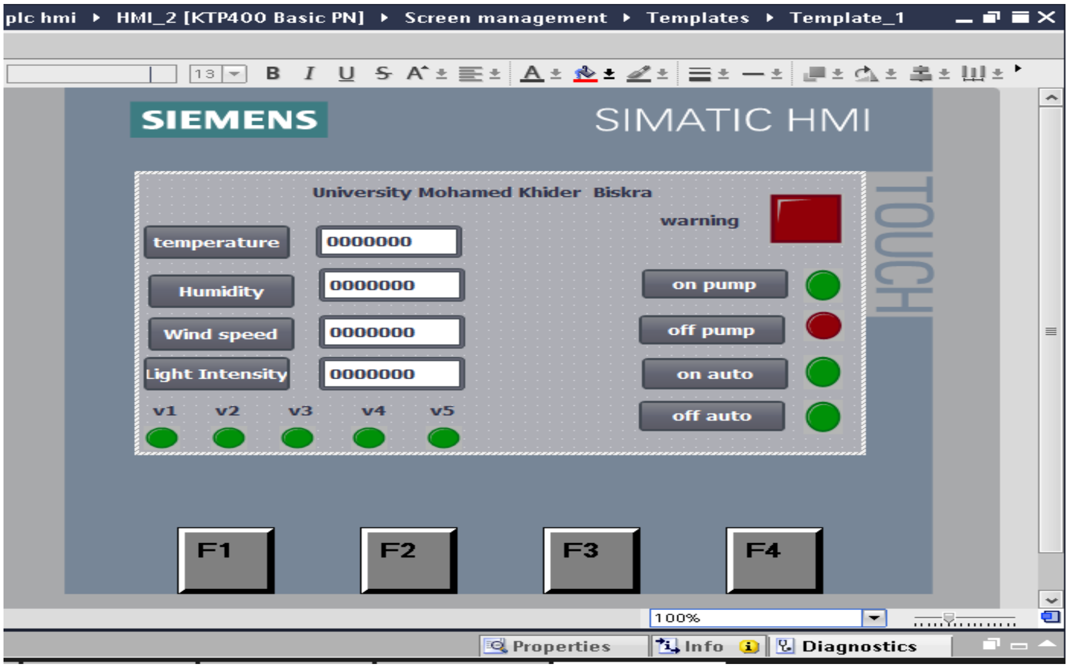


Figure IV.4: The irrigation process on the HMI screen

Network 1: represents some tags:

Tag-7: auto run

Tag-11: Represents the shutdown of the automated system

Tag-9: Manual pump operation

Tag-10: Stop the system in case of manual stop or in the event of a problem.

Tag-2: pump operation

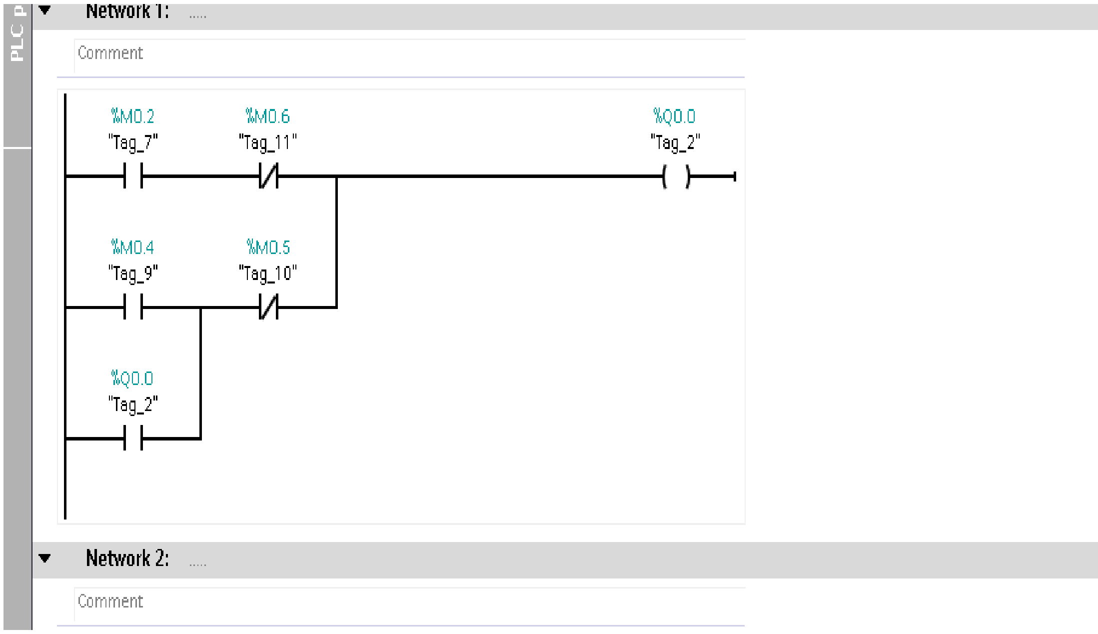


Figure IV.5: nework1 turn on the pump

Network2:

Tag-4: automatic operation

Tag-3: The real value of the sensor

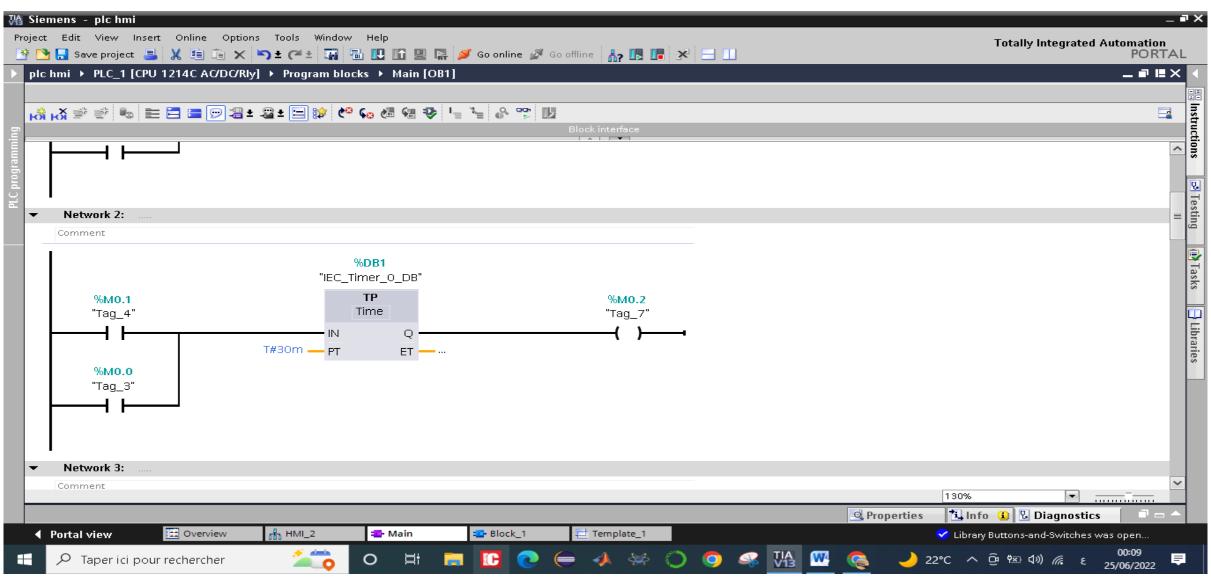


Figure IV.6: second network changing the values format

Network 3: Convert decimal values to real values

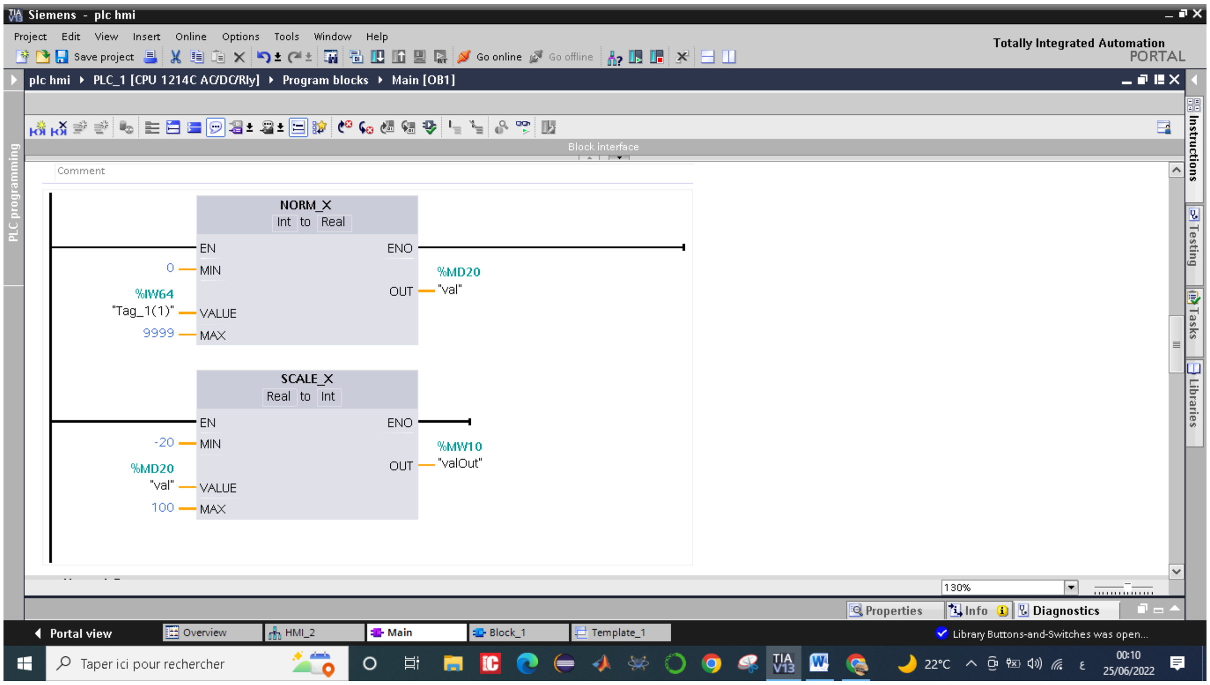


Figure IV.7: network.

Network 5: When the pump is turned on, this program checks the condition of the pump by waiting for 5 seconds and monitoring the pump sensor. If there is a problem, the system stops and if the necessary valve is not opened.

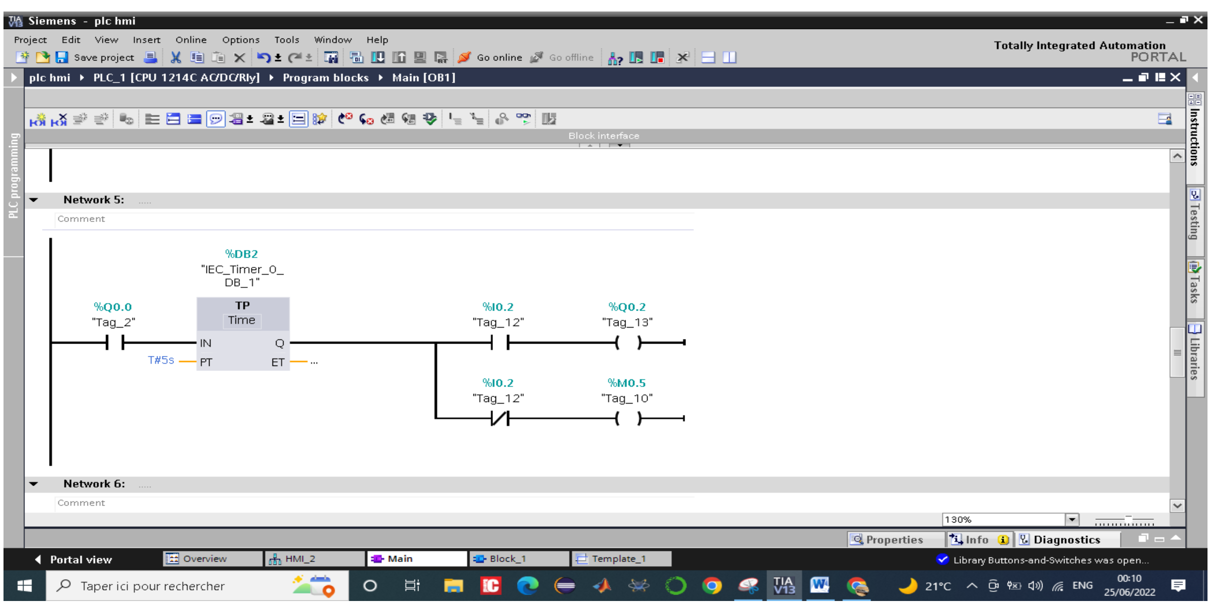


Figure IV.8: Network 5.

Network 6: Convert decimal values to real values

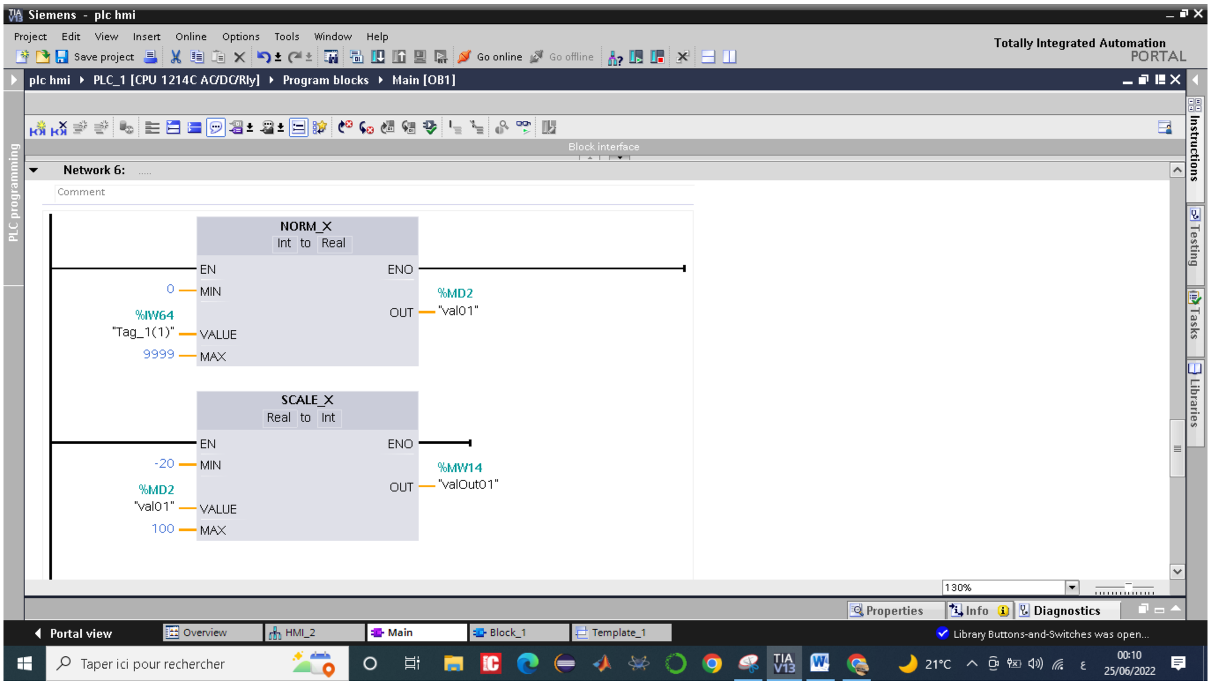


Figure IV.9: network6

IV.4 Conclusion

In this chapter we have proposed a solution to irrigate farms in an intelligent and automatic way, our experimental output, briefly described in the detailed architecture, that shows the automated working of water pump and data updating and stored in the Gateway has been done by the proposed system. Program run on PLC fetches the data from the Gateway from the sensor and check the sensor data is greater than or less than the given threshold value to start the water pump. If the data is less than the given threshold value the pump will automatically start, and stop automatically if the sensor data is found higher than the threshold value.

General Conclusion and Further Work

General Conclusion and Further Work

As it is known the population growth and increased demand for food production, the need for automation of the agricultural filed has become very necessary. Therefore our solution comes from the question of automated irrigation and proposed a new intelligent irrigation system using wireless sensor networks. The installed system presented in this chapter achieves the objective of gathering data from various sensors and calculating irrigation needs for a given type of crop. Communication between the Gateway and the PLC fulfilled the requirements. However, improvements can be done in order to reduce the amount of water that is wasted. This solution is scalable, which means that it can be used for different types of cloud services and can be used with many other sensors with other purposes.

So that in the future, we will seek for the best solutions to minimize energy consumption. Also, we will approach the security side where the measured data should be secure and we will be in need for data encryption technologies. And also the pain point that we face to link the Gateway with the PLC should be optimize.

And other types of sensors could be integrated to monitor plant growth, sensors like PH and EC to correct the value of the treated water (fertigation station), amount of fertilizer used, etc. The system is expected to be integrated with other types of irrigation and multiple electronic valves, and is necessary to know more information of the crop to the irrigation system works efficiently. And also other kinds of valves could be used to accurately regulate the pressure and amount of water that is sent to the crop. Warning systems can be combined into the project in case of floods, natural disaster, fires or the poor condition of the crop. In addition, disaster response scenarios can be created by incorporating systems that drain water, fire systems, etc. It is also expected that the system can have several applications and can be used in smart parking, gardens, greenhouses etc.

References

[1] K. A.-J. A. Kell, "smart irrigation system," *Iraqi Forum for Elites and Competencies.*

[2] T. A. Hassan, Palm - fig - persimmon - pomegranate, Dar Aladdin for publishing, distribution and translation, 01 Jan 2005.

[3] "Milesight IoT," [Online]. Available: https://www.milesight-iot.com/. [Accessed 13 05 2022].

[4] L. a. N. B. Hamami, "Towards a Smart Irrigation System based on Wireless Sensor Networks (WSNs)," *International Conference of Computer Science and Renewable Energies,* 2018.

[5] I. B. Mustafa Kocakulak, "An Overview of Wireless Sensor Networks Towards Internet of Things," IEEE, 2017.

[6] D. M. T. Z. k. Sohrabi, WIRELESS SENSOR NETWORKS, Techology , Protocol, and Application, Canada: The Willy interscience, 2007.

[7] A. H. S. R. ,. R. P. S. R. S. Mohd Javaid, "Intrusion Detection for Wireless Sensor Networks by Game Theory," *Sensors International,* pp. 1-10, 2021.

[8] E. Dr.S.Omkumar, "course Material for wireless sensor network," DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING.

[9] "Basics of Wireless Sensor Networks (WSN) | Classification, Topologies, Applications," Electronics Hub., 2019. [Online]. Available: https://www.electronicshub.org/wireless-sensor-networks-wsn/.

[10] E. d. a. m. i. WSN, "Miloud BAGAA," Sciences and technology Houari Boumediene, Algeria, 2014.

[11] Culler-Mayeno,E., "A Technical Report: Wireless Sensor Networks and How They Work," University of California Santa Barbara, 2006.

[12] P. K. M. Al-Aubidy, Microcontroller-Based Wireless Sensor Networks Lecture 14, Philadelphia : Philadelphia University.

[13] Yinbiao, D., & Lee, D., "EC White Paper Internet of Things:," *International Electrotechnical*

Commission, (2014).

[14] Y. Sankarasubramaniam I. F. Akyildiz, W. Su and E. Cayirci, "Wireless sensor networks: a survey. Computer networks,," pp. Pages 393-422.8,10,14, 2002.

[15] M, O, Farooq and T, Kunz, "Operating Systems for Wireless Sensor Networks: A Survey," *sensors*, p. 5900–5930., 2011.

[16] L. J. V. Carolina Del-Valle-Soto, "Smart Campus: An Experimental Performance Comparison of Collaborative and Cooperative Schemes for Wireless Sensor Network," *www.mdpi.com/journal/energies,* vol. 12, p. 3135, August 2019.

[17] M.A.E. Villegas, S.Y. Tang, Y. Qian, , Wireless Sensor Network Communication, Architecture for Wide-Area Large Scale Soil Moisture Estimation and Wetlands Monitoring, Department of Electrical and, 2007.

[18] M,Yaqoob, "An Analytical Survey on Routing Protocols for Wireless Sensor Network (WSN)," *International Journal of Computer Applications,* December 2014.

[19] Ahmed A. Abouelfadl1 , M. A. M. El-Bendary2 and F. Shawki1, "Enhancing Transmission over Wireless Image Sensor Networks Based on ZigBee Network," *Life Science Journal,* January 2014.

[20] M. I. M.A. Matin, "Overview of Wireless Sensor Network," North South University, Dhaka, Bangladesh, 2012.

[21] M. Matin, Wireless sensor networks technology and protocols., Janeeza Tradine 9.51000 Rijeka, Croatia, 2012.

[22] M.Kocakulak ,I. Butun, "An Overview of Wireless Sensor Networks Towards Internet of Things".

[23] Ramesh, S., "A Protocol Architecture for Wireless Sensor Networks,," School of Computing, University of Utah, 2008, pp. 1-10.

[24] K,Pothuganti . A, Chitneni, "A comparative study of wireless protocols: Bluetooth, UWB, ZigBee, and Wi-Fi," pp. 655-662, September 2014.

[25] [Online]. Available: https://cs.wmich.edu/~alfuqaha/Fall09/cs6030/lectures/WPAN.pdf. [Accessed 17

05 2022].

[26] J. Oller C. Gomez and J. Paradells., "Overview and evaluation of bluetooth low energy: An emerging low-power wireless technology. Sensors,," pp. 12(9), 11734-11753, 2012.

[27] Ata Elahi, Adam Gschwender, ZigBee Wireless Sensor and Control Network, Pearson, Oct 29, 2009 .

[28] C. C. William, "ZigBee Technology: Wireless Control that Simply," in *Communications Design Conference*, 2 March 2013.

[29] L, Chhaya . P, Sharma . G, Bhagwatikar and A, Kumar, "Wireless sensor network based smart grid communications: Cyber attacks, intrusion detection system and topology control.," pp. 6-5, 2017.

[30] [Online]. Available: https://www.electronics-notes.com/articles/connectivity/wifi-ieee-802-11/what-is-wifi.php. [Accessed 08 05 2022].

[31] "LoRa alliance," [Online]. Available: https://lora-alliance.org/about-lorawan/. [Accessed 02 06 2022].

[32] "the network thing," [Online]. Available: https://www.thethingsnetwork.org/country/algeria/. [Accessed 02 05 2022].

[33] "seeedstudio," [Online]. Available: https://www.seeedstudio.com/blog/2021/04/27/a-gentle-introduction-to-lorawan-gateways-nodes/. [Accessed 13 05 2022].

[34] C. J. M. B. .. P. R. K. s. J. B. H, "Wireless sensor networks: recent developments and potential synergies," *The Journal of Supercomputing*, 2013.

[35] D, Ampeliotis, "Signal Processing & Communication Challenges in Sensor Networks," 2009.

[36] E. Stuntebeck I. Akyildiz, " Wireless underground sensor networks: Research challenges. Ad Hoc Networks," p. (4(6)):669–686, 2006.

[37] N, Hariharan. S, Sreelekshmi, "A Survey on Wireless Sensor Networks," vol. 1, no. 11, pp. 75-81, 2017.

[38] A,H, Farooqi and F, Aslam Khan, "Intrusion Detection Systems for Wireless Sensor networks:A survey," FAST National University of Computer and Emerging Sciences,, pp. 234-235.

[39] A. k. .. S. I, "Military Applications using Wireless Sensor Networks: A survey," *International Journal of Engineering Science and Computing,* vol. 6, no. 6, pp. 7039-7043, 2016.

[40] B. W. H. .. S. S. K. .. B. R. T, "Wireless Sensor Networks for Battlefield Surveillance," 2006.

[41] R,Tahir, M,Younas Javed, A, Raza Cheema, "Rabbit-MAC: Lightweight Authenticated Encryption in Wireless Sensor Networks," pp. 573-577, July 2008.

[42] "auto connected car news," [Online]. Available: https://www.autoconnectedcar.com/. [Accessed 18 05 2022].

[43] "acko," [Online]. Available: https://www.acko.com/car-guide/connected-cars-features-benefits/. [Accessed 18 05 2022].

[44] "CISO MAG," [Online]. Available: https://cisomag.eccouncil.org/internet-connected-cars-are-vulnerable-to-attacks-report/. [Accessed 18 05 2022].

[45] D. K. R. D. .. S. D. A. S. G. A. S. J, "Modern Agriculture Using Wireless Sensor Network (WSN)," pp. 515-519, 2019.

[46] "Gouvernement des Territoires du Nord-Ouest," [Online]. Available: https://www.enr.gov.nt.ca/en/services/wildfire-operations/detecting-wildfire. [Accessed 18 05 2022].

[47] K,Haseeb , Ikram, Ud Din , Ahmad A, and Naveed I., "An Energy Efficient and Secure IoT-Based WSN Framework: An Application to Smart Agriculture," *sensors,* 2020.

[48] V. D. &. P. R. D. S, "RECENT TRENDS IN USING WIRELESS SENSOR NETWORKS IN INDUSTRIAL ENVIRONMENT," *International Journal of Computer Networking, ,* vol. 3, no. 3, pp. 11-20, Aug 2013,.

[49] "adafruit," [Online]. Available: https://www.adafruit.com/product/1733. [Accessed 02 06 2022].

[50] Bodunrin Isa Bakare, "Design and Implementation of an Improved Wind Speed Meter (Anemometer)," 2019.

[51] "Renke," [Online]. Available: https://www.renkeer.com/. [Accessed 17 05 2022].

[52] "nibblewave," [Online]. Available: http://nibblewave.com/. [Accessed 12 05 2022].

[53] "comptus," [Online]. Available: https://www.comptus.com/. [Accessed 13 05 2022].

[54] M.A. Martínez , José M. Andújar and J. M. Enrique, "A New and Inexpensive Pyranometer for the Visible Spectral Range," *sensors,* pp. 4615-4634, 2009.

[55] "diribo," [Online]. Available: https://www.diribo.com/en. [Accessed 08 05 2022].

[56] Y.Cheng , C.Fang , J. Yuan , and L, Zhu , "Design and Application of a Smart Lighting System Based on Distributed Wireless Sensor Networks," 29 November 2020.

[57] "meanwell," [Online]. Available: https://www.meanwell.com/. [Accessed 18 05 2022].

[58] "meanwell," [Online]. Available: https://www.meanwell-web.com/en-gb/. [Accessed 12 05 2022].

[59] "advanticsys," [Online]. Available: https://www.advanticsys.com/. [Accessed 03 06 2022].

[60] "Kepware," [Online]. Available: https://www.kepware.com/en-us/products/kepserverex/. [Accessed 18 06 2022].

Appendix A

Programmable Logic Controller Overview:

Automation it's one of the main reasons that led to the rapid and remarkable development of the industry, as it has solved many complex problems in this field, due to its reservation of specialized applications that require large processing volumes. Its first appearance in the United States of America in the automotive industry.

Programmable logic controller is the basis of industrial automation. PLC is important in the field of industry and other control systems due to its strength of structure and exceptional functional characteristics such as sequential control, timers, ease of programming, reliable control capabilities and other features that made it important in the industry and others fields.

➢ Areas of use PLC

- One of the most prominent areas that used PLC is the industry where it controls production lines and alarm systems, and sometimes it plays the role of the human element in the factory, such as robots, and others.
- In the field of games, especially of large size, controlling game modes with ease
- In the field of construction and architecture, such as topography devices, construction machines, and others
- It is also used in some huge machines such as excavators and cranes, and it is also used in the medical field and many other fields.
- It is also used in the field of agriculture, such as controlling irrigation systems, controlling climate factors for protected agriculture, fertilization systems, pumping pesticides, and others.

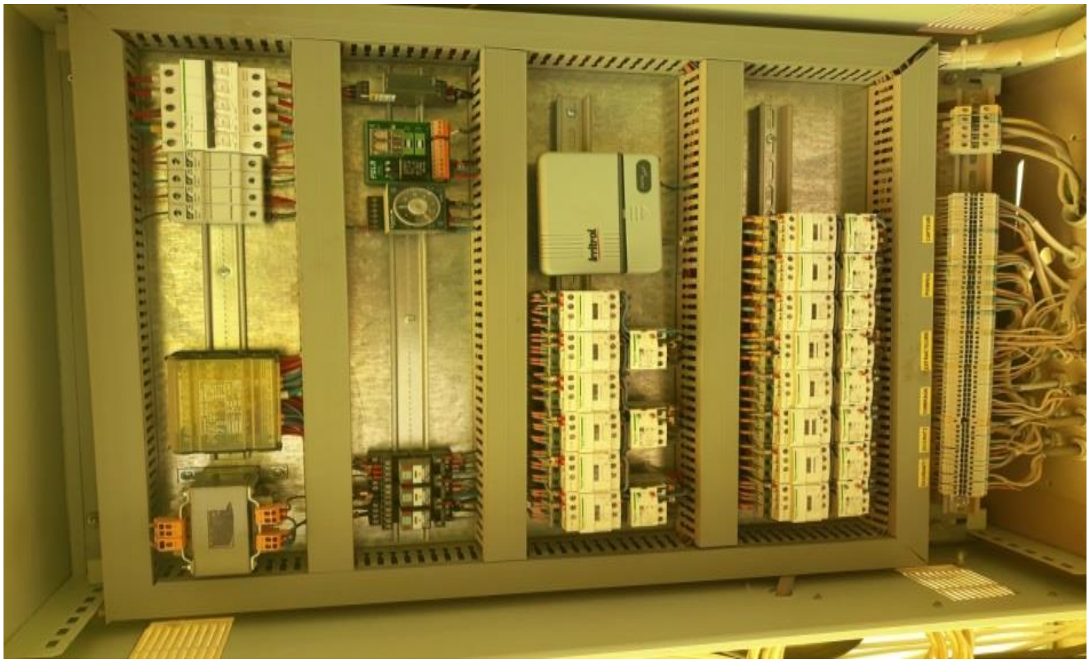


Figure Appendix A. 1: Control unit for a protected farm at the University of Biskra.

- ## The new SIMATIC S7-1200

SIMATIC S7-1200 Basic Controllers are the ideal choice for simple and autonomous tasks in the low to mid performance ranges. These compact devices are characterized by minimal space requirements, telecontrol capability and integrated technology modules for measuring, weighing and counting, so that no other special modules are required.

New compact CPU SIMATIC S7-1200 with more functionality and 125 KB of internal memory. Covers more motion applications with the addition of the Line Driver inputs/ outputs. Free assignment of the PTO/PWM outputs and the HSC inputs can be freely assigned as well for greater flexibility. An integrated trace function has been added to give users a troubleshooting tool for determining how signals are interacting.

Figure Appendix A. 2: SIMATIC S7-1200.

➢ The new Basic Panels

New SIMATIC HMI Basic Panels feature high-resolution touch display with 16:9 ratio for intuitive operation, innovative graphical user interface, integrated system diagnostics, PROFINET and PROFIBUS interfaces and USB interface for connecting to devices. Seamless integration of controller and HMI engineering software ensures maximum efficiency during development.

Figure Appendix A. 3**:** Basic Panels.

Appendix B

The TIA Portal

Efficient automation begins with efficient engineering. The TIA Portal Basic provides logic, visualization and network programming using proven navigation, icons and menus; these are for all screens. The automatic identification and upload concepts enable fast hardware configuration and documentation storage on the CPU. Tags are easily combined between editors, resulting in significant cost savings for development tasks. The symbols can be directly assigned to the hardware.

Figure Appendix B. 1: TIA PORTAL screen.

➢ Design and handling

Integrated PROFINET/Ethernet port eliminates the need for additional proprietary programming cables and no expansion module is required. Modular signal boards can be connected directly to the front of the CPU without increasing the footprint of the CPU. This gives flexibility to help solve your application-specific requirements. Removable connectors for the entire product range make CPU and signal module replacement fast and efficient.

➢ OPC Overview

OPC stand for Open Platform Communications. OPC is the most prominent protocol used in industrial automation systems because it is a link between the main server and various devices, so it is considered an important element in the mechanism of communication between various automation systems and OPC consists of two basic elements:

- The first is software, which is the main server and usually connects to a device, such as HMI, which converts data into the form of the OPC protocol.
- The second is the client, which exchanges data and commands with the server.

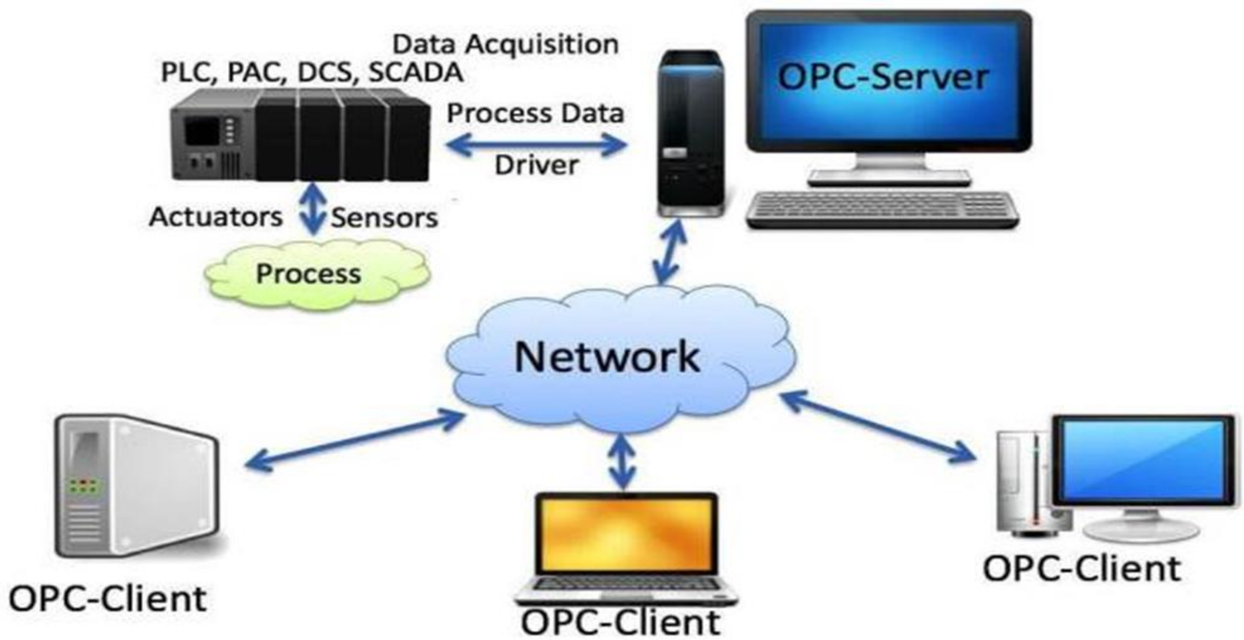


Figure Appendix B. 2: OPC working mechanism.