Université Mohamed Khider de Biskra
Faculté des Sciences et de la Technologie
Département de génie électrique

MÉMOIRE DE MASTER

Sciences et Technologies
Département de Génie Electrique
Networks and Telecommunications

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Water Quality Monitoring System Based IOT

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Water Quality Monitoring System Based IOT

Le : ………………………………………………………

Présenté par :   **Avis favorable de l'encadreur :**

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Dedication

Ghazali Rayanne:

To my dear mother, Whatever I do or whatever I say, I cannot properly thank you, because you the candle of my life, the energy of my soul, your blood for me is a bond that never misses or tends.

To my dear father, may God have mercy on you and may your soul rest in peace. I wish you were present with me on this important day in my life. If you were alive, you would be proud of me.

To my brothers and sisters, my friends and my companions, may God protect you all for me.

Ammari Mehdi:

To my dear parents, for all their sacrifices, their love, their tenderness, their support and their prayers throughout my studies,

To my dear brothers, for their support and encouragement,

To all my family for their support throughout my university career,

To all my teachers for their support and hard work with us,

May this work be the accomplishment of your so-called wishes, and the result of your unfailing support,

Thank you for always being there for me.

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Acronyms List

TCBM :Technological Condition-based Maintenance

CE :Chip Enable

SCK :Serial Clock

MOSI :Master Out Slave In

MISO :Master In Slave Out

PCF :Packet Control Field

CRC :Cyclic Redundancy Check

OM : Organic Matter

TSM : total suspended solids

BOD :Biochemical Oxygen Demand

COD :Chemical Oxygen Demand

automatic retransmission delay (ARD)

Abstract

In this work, we will create a network of nrf24l01-based sensors for transmitting and receiving data, the purpose of which is to monitor water quality using a network of nrf24l01-based sensors.

The system is powered by an Arduino and the wireless communication between each node is provided by the nrf24l01 module.

Keywords: wireless sensor network, water quality, detection, remote control, nrf24l01.

ملخص

في هذا العمل، سنقوم بإنشاء شبكة من أجهزة الاستشعار المستندة إلى nrf24l01 لارسال واستقبال البيانات، والغرض منها هو مراقبة جودة الماء باستخدام شبكة من أجهزة الاستشعار المستندة إلى nrf24l01.

يتم تشغيل النظام بواسطة Arduino ويتم توفير الاتصال اللاسلكي بين كل عقدة بواسطة وحدة nrf24l01 .

الكلمات المفتاحية : شبكة الاستشعار اللا سلكية , جودة الماء,الكشف , التحكم عن بعد,nrf24l01 .

General Introduction

General Introduction:

With the development of technologies, Wireless Sensor Networks (WSN) has become a mainstay that the world depends on due to its benefits and ease of use. WSN will become the main technology of the Internet of Things, which provides small, inexpensive and easily deployable smart devices.

The Internet of Things (IoT) defines a system of physical objects that can be detected, monitored, and controlled, with which to interact using electronic devices that communicate over various wireless network interfaces. It is used to monitor changes in the areas that people adopt in their daily lives.

These high data rate communication standards require low power consumption and low latency even at low bandwidth. The low cost and low power consumption of available wireless systems and its excellent and outstanding characteristics make this connection most suitable for many embedded applications.

The NRF24L01 is basically a radio transmitter and receiver, used to send and receive data using radio waves. It is commonly used in industrial instrumentation and data transmission projects. It is mostly used in computers, toys, remote controls, toys and other electronic devices. Working as a transceiver is not its only ability, the device deals with Arduino application and covers all types of remote control applications. This wireless module uses the SPI communication protocol to send and receive data between the microcontroller and the module, the SPI bus uses the concept of master and slave, in most common applications, the microcontroller is the master and the nRF24L01 transceiver is the slave.

The objective of this project is to design a sensor wireless network to monitor water quality based on nrf24l01 to send and receive data measurement.

The manuscript is organized as follows:

Chapter 1 is a general overview of wireless sensor networks (WSN); architecture, topologies, types etc.

Chapter 2 presents a detailed study of the communication module used in the wireless sensor network used in this project which is the nRF24l01.

Chapter 3 presents an overview of water quality and the parameters used for describing water quality.

Chapter 4 is a description of the water quality monitoring system developed based on wireless sensor networks.

The conclusion concludes the thesis and identifies some recommendations for the future work.

CHAPTER I : WIRELESS SENSOR NETWORKS

I.1 Introduction

Wireless sensor networks (WSN) are a strong and reliable pillar of global development, with the rapid technological development of sensors, WSN will become the main technology of the Internet of Things, which provides small, inexpensive and easily deployable smart devices. A WSN is a set of specialized devices or sensors that are used to monitor various environmental conditions such as chemical concentrations, levels of pollutants and water quality. A WSN system is designed to monitor and control a phenomenon remotely.

I.2 History of wireless sensor networks:

Though rapid interest and research in WSN fields have taken place only recently but, use of sensors for specialized services is not new. During the Cold War, quiet Soviet submarines were detected by deploying the Sound Surveillance System (SOSUS), which employed acoustic sensors. These systems are now adopted by National Oceanographic and Atmospheric Administration (NOAA) for sensing the events in the oceans. Simultaneously, Air Defense Radar Networks were developed employing aerostats as sensors. The predecessor to the internet, Advanced Research Project Agency Network (ARPANET) formed by US DARPA(Defense Advanced Research Projects Agency) in 1969, served as a test bed for new networking technologies connecting various universities and research centers. A sensor network can be assumed to have many spatially distributed autonomous sensing devices which route the information to a node which can make the best use of the acquired information. The actual WSN may be traced back to the Distributed Sensor Networks (DSN) program which started in 1980 at DARPA [1].

Recent advances in micro fabrication technologies have made possible to produce tiny nodes which can house multiple sensors and have reasonable processing and communication capabilities. In addition to this, development of wireless networking standards having security, stability and minimum end to end delays have led to proliferation of WSN into the field of control and monitoring; the area which was unheard of earlier. The usage of WSN is increasing exponentially due to the features such as: Scalability, Adaptability, Convenience, Mobility, Accessibility, low cost etc [1].
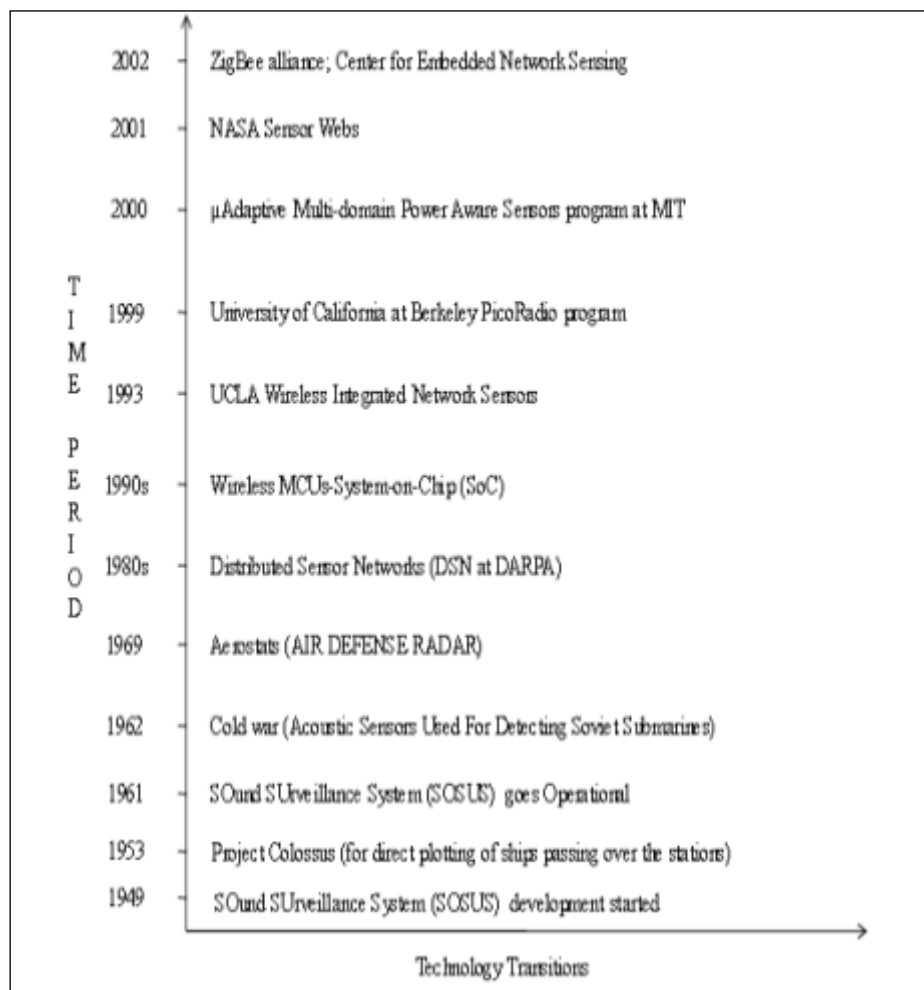
Figure I.1 Technology transmitions in WSN

I.3 Standards and Specifications in Wireless Sensor Networks (WSN) :

I.3.1 Bluetooth:

The current generation of sensor nodes relies on commodity components. The choice of the radio is particularly important as it impacts not only energy consumption but also software design. The Bluetooth wireless radio is a good choice for implementation of wireless sensor network. The Wireless Sensor networks architecture supports different network topologies [2].

Bluetooth is a universal radio interface in the 2.45 GHz ISM(Industrial, Scientific and Medical) frequency band that enables portable electronic devices to connect and communicate wirelessly via short-range, ad hoc networks. Each unit can simultaneously communicate with up to seven other units per piconet. Moreover, each unit can simultaneously belong to several piconets[3].

I.3.2 ZigBee:

ZigBee is the most popular industry wireless mesh networking standard for connecting sensors, instrumentation and control systems. ZigBee, a specification for communication in a wireless personal area network (WPAN), has been called the *"Internet of things"*. ZigBee is an open, global, packet-based protocol designed to provide an easy-to-use architecture for secure, reliable, low power wireless networks. ZigBee and IEEE 802.15.4 are low data rate wireless networking standards that can eliminate the costly and damage prone wiring in industrial control applications. Flow or process control equipment can be placed anywhere and still communicate with the rest of the system. It can also be moved, since the network doesn't care about the physical location of a sensor, pump or valve [4].

The ZigBee RF4CE standard enhances the IEEE 802.15.4 standard by providing a simple networking layer and standard application profiles that can be used to create interoperable multi-vendor consumer electronic solutions [4].

I.3.3 Lora :

LoRa(Long Range) is a new ISM band wireless technology designed for low power, unlicensed, Long Range operation.

LoRaWAN(Long Range Wide Area Network) is a low-power, wide area networking protocol built on top of the LoRa radio modulation technique. It wirelessly connects devices to the internet and manages communication between end-node devices and network gateways. Usage of LoRaWAN in industrial spaces and smart cities is growing because it is an affordable long-range, bi-directional communication protocol with very low power consumption — devices can run for ten years on a small battery. It uses the unlicensed ISM radio bands for network deployments[5].

I.3.4 nRF24L01:

nRF24L01 is a single chip radio transceiver for the world wide 2.4 - 2.5 GHz ISM band. The transceiver consists of a fully integrated frequency synthesizer, a power amplifier, a crystal oscillator, a demodulator, modulator and Enhanced Shock Burst protocol engine. Output power, frequency channels, and protocol setup are easily programmable through a SPI interface [6].

I.4 Types of wireless sensor networks:
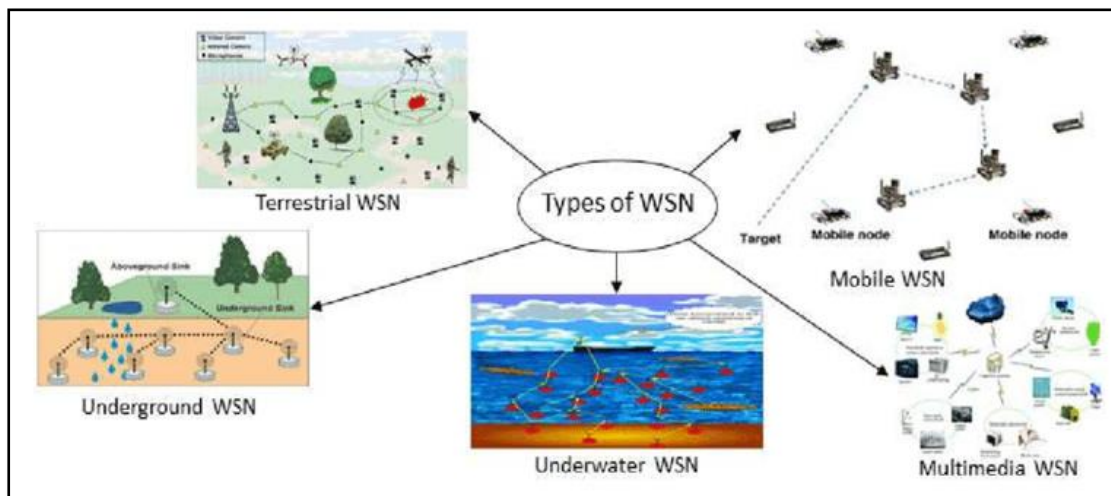
Figure I.2:type of WSNs

- **Terrestrial WSNs:** Terrestrial WSNs are capable of communicating base stations efficiently, and consist of hundreds to thousands of wireless sensor nodes deployed either in an unstructured (ad hoc) or structured (Pre-planned) manner. In an unstructured mode, the sensor nodes are randomly distributed within the target area that is dropped from a fixed plane. The preplanned or structured mode considers optimal placement, grid placement, and 2D, 3D placement models. In this WSN, the battery power is limited; however, the battery is equipped with solar cells as a secondary power source. The Energy conservation of these WSNs is achieved by using low duty cycle operations, minimizing delays, and optimal routing, and so on [7].

- **Underground WSNs:** This type consists of a number of sensor nodes deployed in caves, mines or underground. To enable information retrieval from the underground sensor nodes to the base station, additional sink nodes are located above ground. Wireless communication is a challenge in such environment due to high attenuation and signal loss. Moreover, it is difficult to recharge or replace the batteries buried underground, motivating the design of energy efficient communication protocols for prolonged lifetime. Underground WSNs are used for agriculture monitoring and landscape management [8].
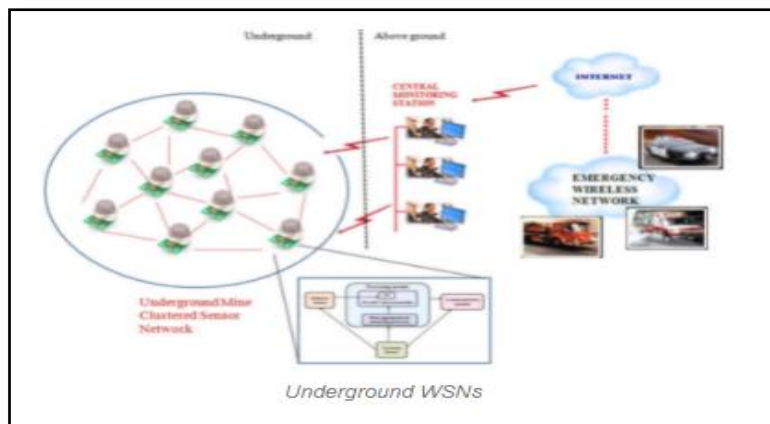
Figure I.3:Underground WSN

- **Under Water WSNs:** More than 70% of the earth is occupied with water. These networks consist of several sensor nodes and vehicles deployed underwater. Autonomous underwater vehicles are used for gathering data from these sensor nodes. A challenge of underwater communication is a long propagation delay, and bandwidth and sensor failures [7].
Underwater, WSNs are equipped with a limited battery that cannot be recharged or replaced. The issue of energy conservation for underwater WSNs involves the development of underwater communication and networking techniques [7].
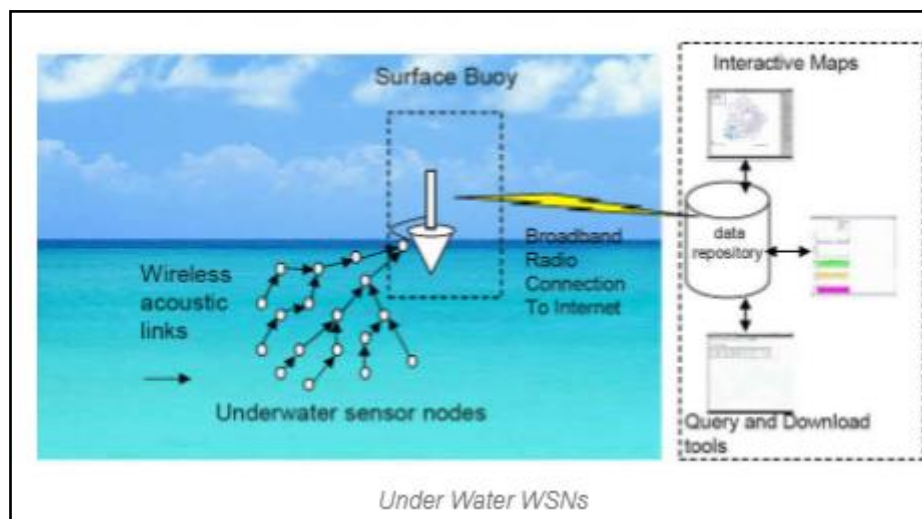
Figure I.4:Under water WSN

- **Multimedia Wireless Sensor Networks:** Multimedia wireless sensor networks are proposed to enable tracking and monitoring of events in the sort of multimedia, like video, imaging, and audio. These networks contain low-cost sensor nodes equipped with cameras and microphones. These sensory nodes of Multimedia WSNs are interconnected together

over a wireless connection for data retrieval, data compression, and correlation [9].

The challenges with the Multimedia WSNs include high bandwidth requirements, high energy consumption, processing, and compressing techniques. Additionally, multimedia contents need high bandwidth for the content to be delivered properly and easily [9].
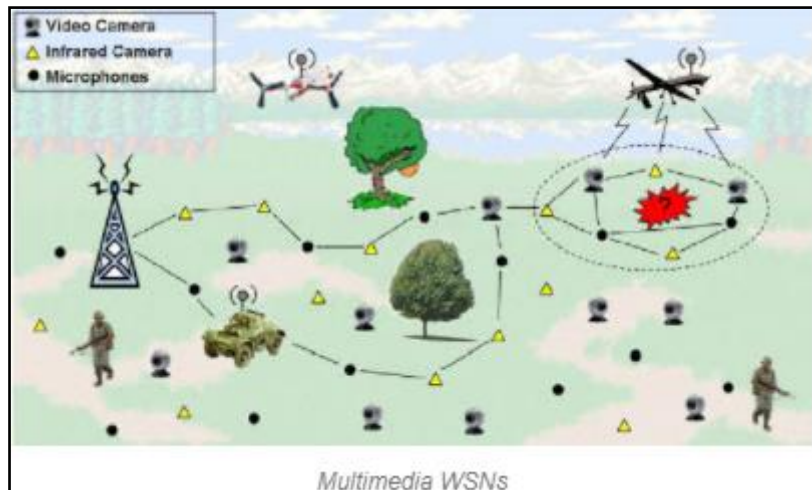
Figure I.5: Multimedia WSN

- **Mobile WSNs:** This type consists of mobile sensor nodes that can move on their own and interact with the physical environment. The mobile nodes have the ability to reposition and organize themselves in the network. A mobile WSN can start off with some initial deployment and nodes can then spread out to gather information. Information gathered by a mobile node can be communicated to another mobile node when they are within range of each other [8].

Mobile wireless sensor networks are much more versatile than static sensor networks. The advantages of MWSN over static wireless sensor networks include better and improved coverage, better energy efficiency, superior channel capacity, and so on [7].

I.5 Elements of WSN

A typical wireless sensor network can be divided into two elements:

I.5.1 Sensor Node: A Sensor Node in a WSN consists of four basic components [10]:

- Power Supply,
- Sensor,
- Processing Unit,
- Communication System.

The sensor collects the analog data from the physical world and an ADC converts this data to digital data. The main processing unit, which is usually a microprocessor or a microcontroller, performs an intelligent data processing and manipulation [10].

Communication system consists of radio system, usually a short-range radio, for data transmission and reception. As all the components are low-power devices, a small battery like CR-2032, is used to power the entire system [10].

A Sensor Node consists of not only the sensing component but also other important features like processing, communication and storage units. With all these features, components and enhancements, a Sensor Node is responsible for physical world data collection, network analysis, data correlation and fusion of data from other sensor with its own data [10].
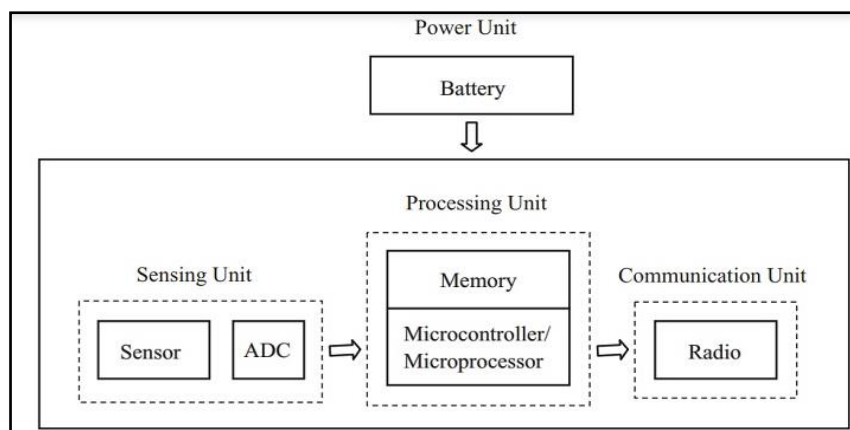
Figure I.6:typical WSN with its fundamental units

I.5.2 Network Architecture:

When a large number of sensor nodes are deployed in a large area to co-operatively 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 (BS) using wireless communication [10].

The base station sends commands to the sensor nodes and the sensor node perform the task by collaborating with each other. After collecting the necessary data, the sensor nodes send the data back to the base station. The base station acts also as a gateway to other networks through the internet. After receiving the data from the sensor nodes, a base station performs simple data processing and sends the updated information to the user using internet [10].
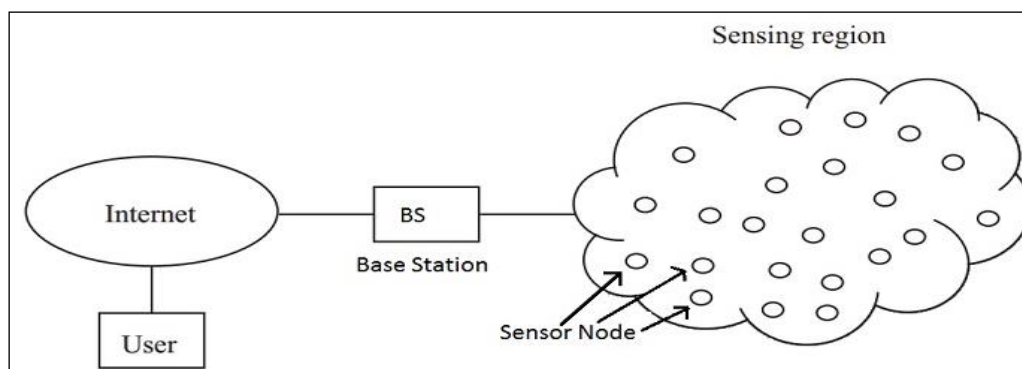
Figure I.7:nrtwork architecture

I.6 Topologies of   wireless sensor networks:

- **Star Topologies**: is a communication topology, where each node connects directly to a gateway. A single gateway can send or receive a message to several remote nodes. In star topologies, the nodes are not permitted to send messages to each other. This allows low-latency communications between the remote node and the gateway (base station) [7].
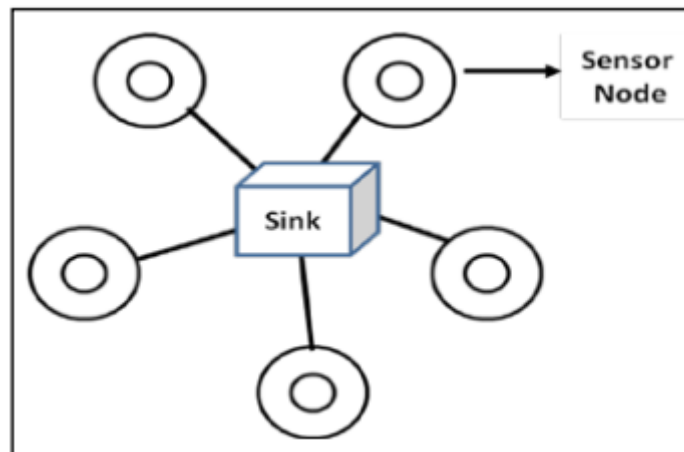
Figure 1.8:star topology

- **Tree topology:** is a sort of structure in which each node is related to the others in a hierarchy. In a topological hierarchy, there are at least three distinct levels. Sometimes it is also called hierarchical topology; all elements are arranged like the branches of a tree. It is a lot like the star and bus topologies. Tree topologies are commonly used to arrange data in databases and workstations in corporate networks. In a tree topology, any two linked nodes can only have one mutual connection, hence there can only be one link between them [11].
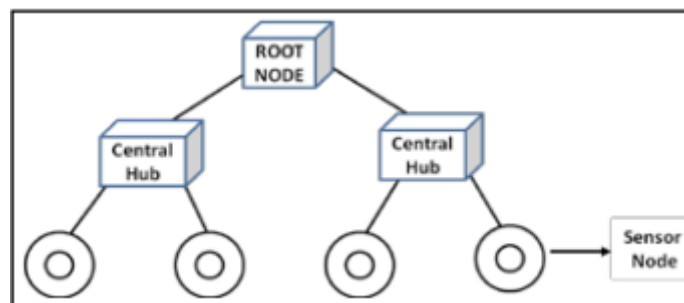
Figure 2.9:tree topology

- **Mesh topology:** is a network setup where each computer and network device is interconnected with one another. This topology setup allows for most transmissions to be distributed even if one of the connections goes down. It is a topology commonly used for wireless networks [12].
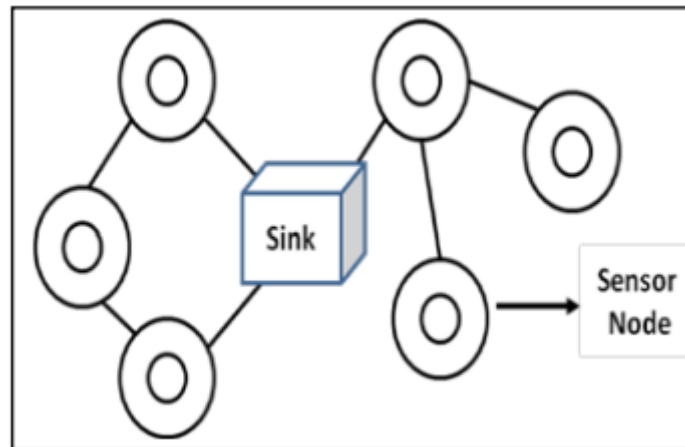
Figure 3.10:Mech topology

Figure I.10**:** Mesh topology

- **Bus Topology**: In this topology, a node wanting to communicate with another device on the network a broadcast message onto the network that all other nodes see, but only the intended recipient actually accepts and processes the message. Bus topology is easy to install but can lead to congestion of traffic because it uses a single path for communication. However, bus networks work is best with a limited number of nodes. If more than a few dozen nodes are added to a network bus, performance problems will likely result [13].
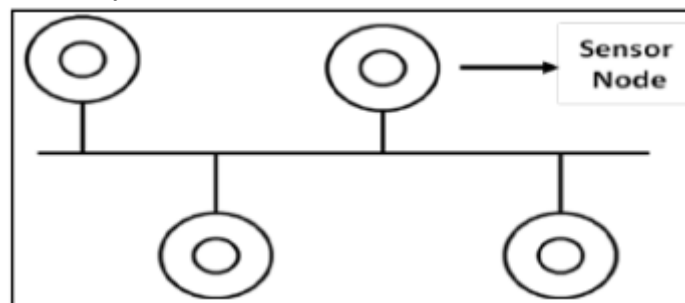
Figure I.11:Bus topology

- **Ring Topology**: generally messages are passed in the ring. Only neighboring nodes are able to communicate with each other. If any node or link is broken during the communication, then it will affect the whole sensor network. Nowadays, ring topology is not preferred much in applications. One advantage of this sensor network topology is that it does not have any leader (central node) [14].
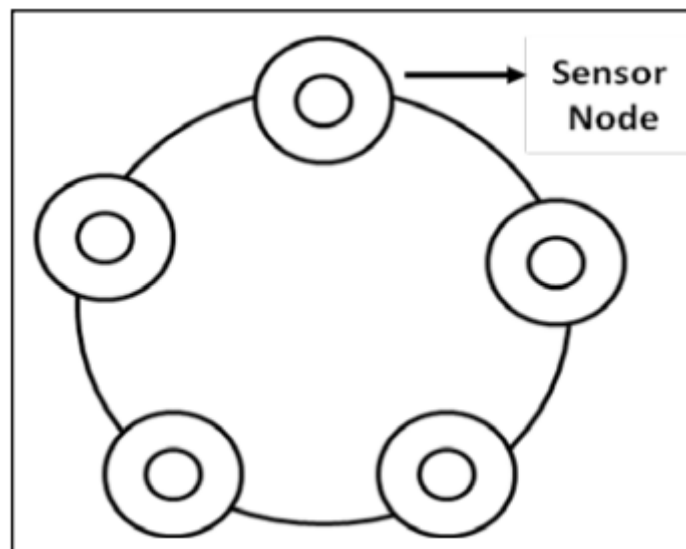
Figure I.12: Ring topology

I.7 Cross layers:

The three cross planes or layers are power management plane, mobility management plane and task management plane, These layers are used to manage the network and make the sensors work together in order to increase the overall efficiency of the network [15].

The difference of architectures between OSI, WLAN and WSN are shown in Table1 [15]:

Wireless sensor network	WLAN	OSI model
WSN application	Application programs	Application layer
WSN middleware	Middlewere	Presentation layer
	Socket API	Session layer
WSN transport protocols	TCP/UDP	Transport layer
WSN roting protocols	IP	Network layer
Error control WSN MAC protocols	WLANadapter&device driver WLAN MAC protocols	Data link layer
Transceiver	Transceiver	Physical layer

Table I.1 : The difference of architectures between OSI

I.7.1 OSI layers :

The layered communication architecture is also known as the Open Systems Interconnection (OSI) model. Most common architecture of WSNs follows the OSI model. In layered communication architecture, both sink and source nodes transmit the data. The communication architecture consists of five layers (i.e. application layer, transport layer, network layer, data link layer, and physical layer) and three cross-planes (i.e. power management plane, mobility management plane, and task management plane). The power management plane deals with the power consumption of the node, the mobility management plane identifies the mobility of node and maintains the information of neighboring nodes, and the task management plane is used to schedule the sensing task in the given area. As per the need of sensing task, different software may be developed and employed in the application layer [16].

1. **Physical layer:** The physical layer provides the interface to transmit the bit stream over the physical channel. The main task is frequency generation, detection, and selection. Pertaining to this layer, the standard of IEEE 802.15.4 is described for WSNs with low power consumption, cost, data rate, complexity, and communication range to increase the battery life. It also deals with designing of mechanical and electrical interfaces [17].

2. **Data Link Layer:** The data link layer establishes and terminates a connection between two physically-connected nodes on a network. It breaks up packets into frames and sends them from source to destination. This layer is composed of two parts—Logical Link Control (LLC), which identifies network protocols, performs error checking and synchronizes frames, and Media Access Control (MAC) which uses MAC addresses to connect devices and define permissions to transmit and receive data [17].

3. **Network Layer:** The Network Layer is where you'll find most of the router functionality that most networking professionals care about and love. In its most basic sense, this layer is responsible for packet forwarding, including routing through different routers. It has two main functions. One is breaking up segments into network packets, and reassembling the packets on the receiving end. The other is routing packets by discovering the best path across a physical network. The network layer uses network addresses (typically Internet Protocol addresses) to route packets to a destination node [17][18].

4. **Transport layer:** The function of this layer is to provide reliability and congestion avoidance. These protocols use different mechanisms for loss detection and loss recovery [19].

5. **The application layer:** is used by end-user software such as web browsers and email clients. It provides protocols that allow software to send and receive information and present meaningful data to users [17].
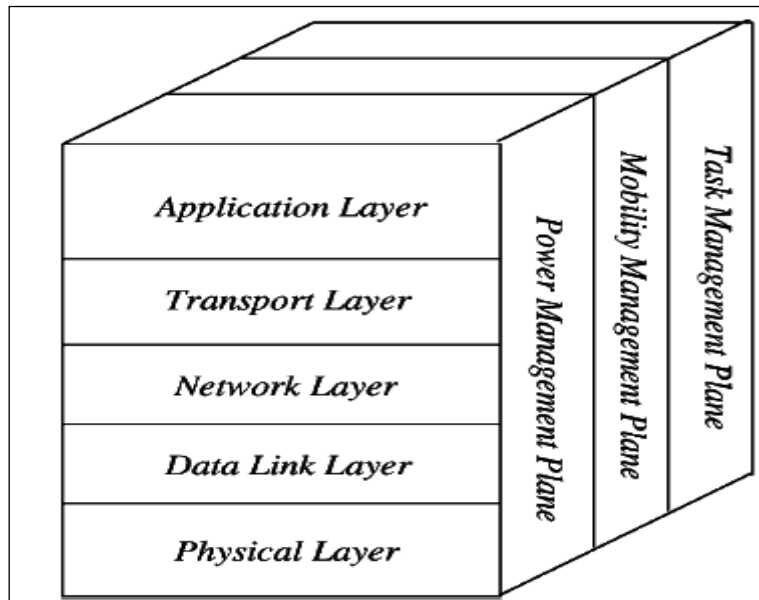
Figure I.13:OSI layers

I.8 Characteristics of wireless sensor network:

The main characteristics of a WSN include [20]:

- Power consumption constraints for nodes using batteries or energy harvesting,
- Ability to cope with node failures,
- Mobility of nodes,
- Communication failures,
- Heterogeneity of nodes,
- Scalability to large scale of deployment,
- Ability to withstand harsh environmental conditions,
- Ease of use,
- Power consumption.

I.9 Classification of Wireless Sensor Networks

Wireless Sensor Networks are extremely application specific and are deployed according to the requirements of the application. Wireless Sensor Networks in general can be classified into the following categories [21].

I.9 .1 Static and Mobile WSN:

In many applications, all the sensor nodes are fixed without movement and these are static networks. Some applications, especially in biological systems, require mobile sensor nodes. These are known as mobile networks. An example of mobile network is animal monitoring [21].

I.9 .2 Deterministic and Nondeterministic WSN:

In a deterministic WSN, the position of a sensor node is calculated and fixed. The pre-planned deployment of sensor nodes is possible in only a limited number of applications. In most application, determining the position of sensor nodes is not possible due to several factors like harsh environment or hostile operating conditions. Such networks are nondeterministic and require a complex control system [21].

I.9 .3 Single Base Station and Multi Base Station WSN:

In a single base station WSN, only a single base station is used which is located close to the sensor node region. All the sensor nodes communicate with this base station, in case of a multi base station WSN, more than base station is used and a sensor node can transfer data to the closest base station [21].

I.9 .4 Static Base Station and Mobile Base Station WSN:

Similar to sensor nodes, even base stations can be either static or mobile. A static base station has a fixed position usually close to the sensing region. A mobile base station moves around the sensing region so that the load of sensor nodes is balanced [21].

I.9.5 Single-hop and Multi-hop WSN:

In a single-hop WSN, the sensor nodes are directly connected to the base station. In case of multi-hop WSN, peer nodes and cluster heads are used to relay the data so that energy consumption is reduced [21].

I.9 . 6 Self – Reconfigurable and Non – Self – Configurable WSN:

In a non – Self – Configurable WSN, the sensor networks cannot organize themselves in a network and rely on a control unit to collect information. In most WSNs, the sensor nodes are capable of organizing and maintaining the connection and work collaboratively with other sensor nodes to accomplish the task [21].

I.9 .7 Homogeneous and Heterogeneous WSN:

In a homogeneous WSN, all the sensor nodes have similar energy consumption, computational power and storage capabilities. In case on heterogeneous WSN, some sensor nodes have higher computational power and energy requirements than other and the processing and communication tasks are divided accordingly [21].

I.10 Applications of WSN:

WSNs have been so admired for their flexibility in solving problems and facilitating solutions that they are now used in many areas, such as:

- **Military Applications:** Possibly, WSNs is an essential fragment of military intelligence, facility, control, communications, computing, frontline surveillance, investigation and targeting systems [22].
- **Animal Tracking:** is another application of wireless sensor networks in which a sensor is attached to the animals' body so that the transportation and position of the animal can be identified [23].
- **Applications in Area Monitoring:** the sensor nodes are positioned over an area where some display is to be observed. When the sensors notice the occurrence being observed (such as temperature, pressure etc), the occurrence is conveyed to one of the base stations (BSs), which then takes action appropriately [22].
- **Environmental Monitoring:** The use of wireless sensor networks in environment extends its application in coal mining, earth quakes, tsunami, flood detection, forest fire prediction, gas leakage, cyclones, rainfall range, water quality, and volcanic eruption and so on. As the network provides an early detection and prediction of all these environmental calamities, it helps in taking a safety measure to certain level. The data is sensed using the sensors and is transmitted to the master station via Internet. This helps in taking precautions and also aids in making people aware of the disaster that is about to come [23].

- **Transportation Applications:** Instantaneous traffic statistics is being composed by WSNs to later forage transportation models and keep the drivers on alert of possible congestion and traffic difficulties [22].

- **Medical/Health Applications:** Some of the medical/health benefits of WSNs are in the areas of diagnostics, investigation, and drug administration as well as management, supporting interfaces for the incapacitated, integrated patient monitoring and management, tele-monitoring of human physiological information, and tracking and monitoring medical practitioners or patients inside the medical facility [22], nano-informatics and nano-medicine are now beginning to advance in clinical applications via the use of biosensors.

- **Air pollution:** Chemical reactions involving air pollutants create the toxic ozone gas that affects people's health and can also damage plant and animal life. So for the early detection of these air pollutants, wireless sensor networks are used as it focuses on their components that can be selected in air pollution monitoring. This helps in measuring harmful air pollutants. The system takes advantage of the air quality index by comparing the data obtained with the value of the index, and the system detects polluted air [23].

- **Industrial Applications:** WSNs have been advanced for "Technological Condition-based Maintenance (TCBM)" since they could offer momentous cost reductions/investments and allow innovative functionalities. In wired classifications, the installation of adequate sensors is habitually limited by the amount involved in wiring [22].

- **Forest fire detection:** In most of the countries like Australia, the occurrence of forest fire is common because of the dry and hot climate. This will damage the wild lives. In order to prevent the forest fire to some extend wireless sensor networks are used[23]. A network of Sensor Nodes is usually positioned in a forest to detect every time a fire has begun. The nodes with sensors are used to measure temperature, humidity and gases which are produced by fire within the trees or vegetation. The first detection is necessary to get a successful action of the fire fighters; As a result of Wireless as Sensor Networks, the fire brigade are able to know when a fire begins [24].The framework helps in the detection of the forest fire earlier. The energy consumption of the sensor nodes is very less. The system is capable of performing in any kind of environmental conditions [23].

- **Agricultural Applications:** The employment of WSNs has been reported to assist farmers in various aspects such as the maintenance of wiring in a problematic environment, irrigation mechanization which aids more resourceful water use and reduction of wastes [22].
- **Structural Applications:** WSNs can be employed for monitoring the movement of diverse structural projects such as buildings and other infrastructural projects like flyovers, bridges, roads, embankments, tunnels etc., allowing manufacturing/engineering practices to monitor possessions remotely without necessarily visiting the sites, and this would reduce expenses that would have been incurred from physical site visitations [22].
- **Intra car security:** Wired networks and cables are replaced by wireless networks in order to ensure fuel efficiency and reduction in the weight of automotives. But the security issues of such a replacement are highly questionable. But the selection of appropriate security algorithm the execution speed and security issues can be resolved [25].
- **Home applications:** Smart sensor nodes can be entombing in many appliances such as microwave oven, refrigerators, and vacuum cleaners, VCR's etc. These sensor nodes inside the devices can interact with each other and with external network via satellite. The end users can manage the devices more easily and remotely [24].

I.11 Design Issues of Wireless Sensor Network

I.11.1 Energy Consumption:

In WSN, power consumption is one of the main issues. As an energy source, the battery is used by equipping sensor nodes. The sensor network is arranged within dangerous situations so it turns complicated for changing otherwise recharging batteries. The energy consumption mainly depends on the sensor nodes' operations like communication, sensing & data processing. Throughout communication, the energy consumption is very high. So, energy consumption can be avoided at every layer by using efficient routing protocols [25].

I.11.2 Localization:

Sensor localization is a fundamental and critical issue for network operations and management. The sensor nodes are deployed in ad-hoc manner so they do not have any information about their position. The problem of determining the physical location of the sensors after they have been deployed is called localization. This problem can be solved by beacon nodes, GPS and proximity based localization [24].

I.11.3 Coverage:

The sensor nodes in the wireless sensor network utilize a coverage algorithm for detecting data as well as transmit them to sink through the routing algorithm. To cover the whole network, the sensor nodes should be chosen. There efficient methods path algorithms as well as coverage design protocol are recommended [24].

I.11.4 Clocks:

Clock synchronization is a critical service in WSN. The goal of time synchronization is to provide a common timescale for local clocks of nodes in sensor networks. Clocks ought to be synchronized in some applications such as tracking and monitoring [24].

I.11.5 Computation

The computation can be defined as the sum of data that continues through each node. The main issue within computation is that it must reduce the utilization of resources. If the life span of the base station is more dangerous, then data processing will be completed at each node before data transmitting toward the base station. At every node, if we have some resources then the whole computation should be done at the sink [25].

I.11.6 Production Cost:

Large numbers of nodes are deployed in the sensor networks, so if the cost of a single node will be very high then we can assume the overall cost of the network will also be very high. Eventually, the cost of every sensor node has to be kept low. So cost of each sensor node in the network is a challenging issue [24].

I.11.7 Hardware Design

When designing any sensor network's hardware such as power control, micro-controller, and communication unit. Micro-controller & communication unit must be energy-efficient. Its design can be done in such a way that it uses low-energy hardware design [24] [25].

I.11.8 Quality of Service:

The quality of service or QoS is nothing but, the data must be distributed in time because some of the real-time sensor-based applications mainly depend on time. So if the data is not distributed on time toward the receiver then the data will turn useless. In WSNs, there are different types of QoS issues like network topology that may modify frequently as well as the accessible state of information used for routing can be imprecise [25].

I.12 Advantages of WSN:

The advantages of WSN are [26] [27]:

1. Network setups can be carried out without fixed infrastructure.

2. Suitable for the non-reachable places such as over the sea, mountains, rural areas or deep forests.

3. Flexible if there is random situation when additional workstation is needed.

4. Implementation pricing is cheap.

5. It avoids plenty of wiring.

6. It might accommodate new devices at any time.

7. It is flexible to undergo physical partitions.

8. It can be accessed by using a centralized monitor.

I.13 Disadvantages Of WSN:

The disadvantages of WSN are [26][27] :

1. Less secure because hackers can enter the access point and obtain all the information.

2. Lower speed as compared to a wired network.

3. More complicated to configure compared to a wired network.

4. Easily troubled by surroundings (walls, microwave, large distances due to signal attenuation, etc).

5. Gets distracted by various elements like Bluetooth.

6. Still Costly (most importantly).

7. Affected by long distance and obstacles such as Walls.

Conclusion:

WSN are a widely applicable, major emerging technology. WSN are getting smaller and faster, increasing their potential applications in commercial, industrial, and residential environments. However, the limit of applications depends only upon the sensors.

CHAPTER II: STUDY AND DEVELOPMENT OF TECHNOLOGY NRF24L01

II.1 introduction :

In this present communication world there are numerous high data rate communication standards that are available, but none of these meet the sensors' and control devices' communication standards. These high-data rate communication standards require low-latency and low-energy consumption even at lower bandwidths. The available proprietary wireless systems' nrf24l01 is low cost and low-power consumption and its excellent and superb characteristics makes this communication best suited for several embedded applications [1]. NRF24L01 is normally used in industrial devices and projects for data transmission. It is mostly used in computer, toys, remote control, games, and other electronic devices [2].

NRF24L01 is a single chip transceiver working under general ISM(Industriel, Scientific and Medical) frequency band 2.4-2.5GHz. The wireless transceiver includes frequency generator, enhanced Schock Burst TM mode controller, power amplifier, crystal amplifier, modulator and demodulator. The output power channel selection and protocol can be set by SPI (serial peripheral interface) interface [3].

nRF24L01 is the least expensive RF module and it comes with great features. A single module communicates at 2.4 GHz frequency which makes it legal. It can transmit and receive data by a single module. Acting as a transceiver is not its only ability,The device interfaces with the Arduino application and covers all kinds of remote-control applications. This wireless module uses SPI communication protocol and offers a 10MBs data rate with a 125 address range which makes it reliable the most reliable RF module. The RF module uses the GFSK module to transceiver the data[4].
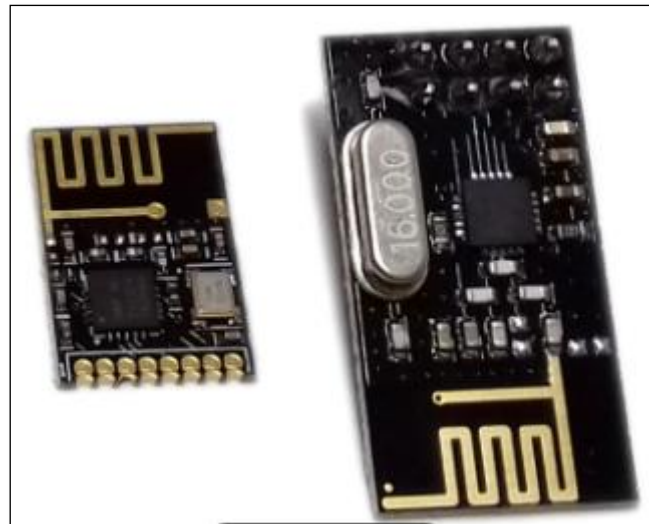
Figure II.1:NRF24L01

II .2 NRF24L01 PINOUT and Description:

The NRF24L01 contains eight main pins, but it also has some additional pins.

Let's discuss all of its pins with detail: [2]

	Pin Name	Description
1	CE	This pin is chip enable; it is used to activate RX or TX mode.
2	CSN	This pin is used for SPI protocol interfacing
3	SCK	This pin is used for serial clock provider.
4	MOSI	This pin is used to get data from a master microcontroller device and to send data to a slave device.
5	MISO	This pin is used to get data from a slave device and to send data to master device.
6	IRQ	This pin is used for interrupt data.
7	VDD	At this pin, we apply 3.3V DC supply.
8	VSS	This pin is for ground
9	XC2	This pin is used for analogue output crystal providing pin.
10	XC1	This pin is used for analogue input crystal pin.
11	VDD-PA	This is pin is used to a power amplifier.
12	ANT1	This pin is used for antenna interfacing.

13	ANT2	This pin is also used for antenna interfacing.
14	Vss	There are two grounds in NRF24L01, this is the second one.
15	IREF	This pin is used for reference current.
16	DVDD	This pin is used for Positive Digital Supply output for de coupling purposes.
17	GROUND	This is used for ground.

Table II.1 : NRF24L01 PINOUT and Description
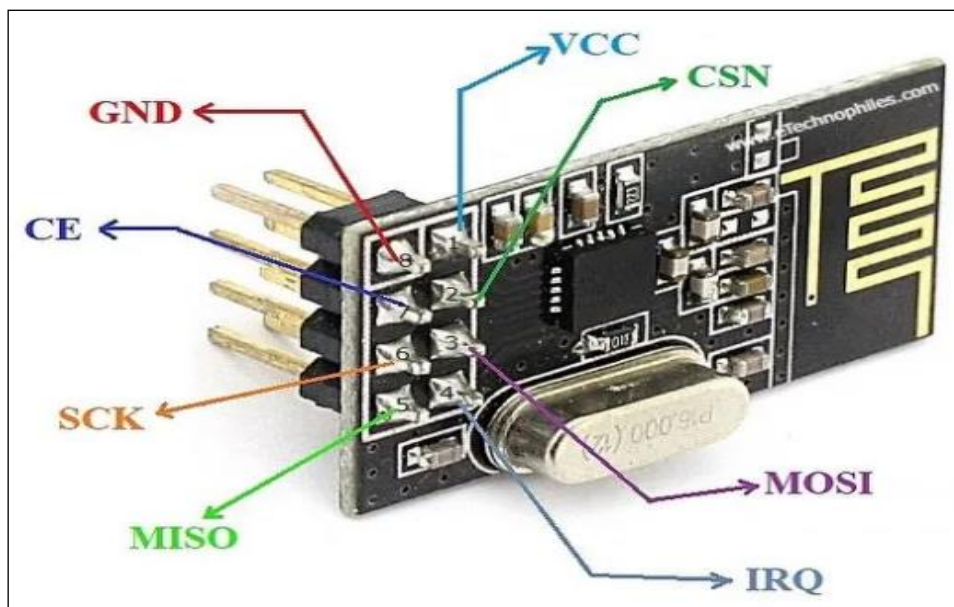
Figure II.2:NRF24L01 pinout

II .3 nRF24L01 block diagram :
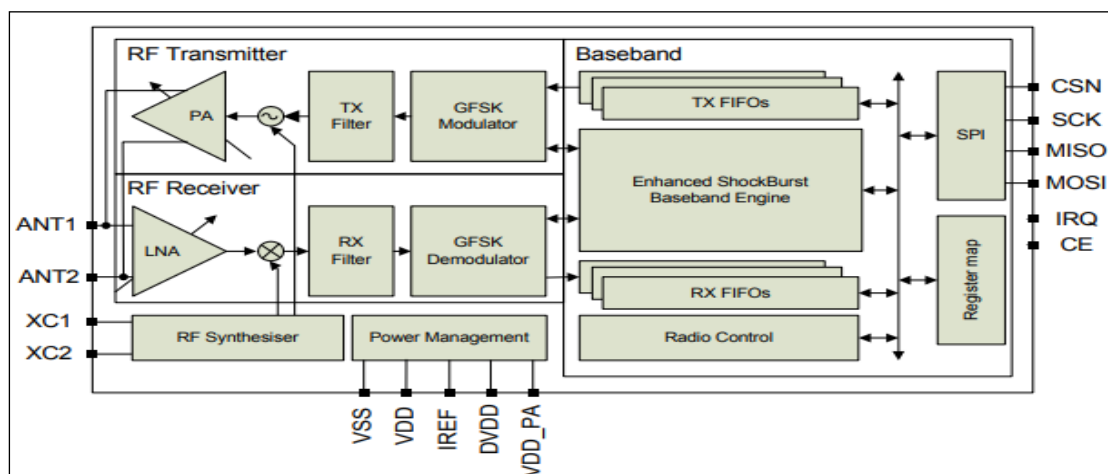
Figure II.3:NRF24L01 block diagram

II .4 NRF24L01 Technical Specifications:

The nrf24l01 technical are [3] [5] :

- Supporting 6-channel receiving
- **Low operation voltage:** 1.9～3.6V
- High speed: 2Mbps. Since the time spent on the transmisson in the air is short, it greatly reduces collision in wireless transmission.
- **Multi-frequency point:** With 125 frequency points, it can meet multipoint communication and frequency hopping communication requirements.
- **Ultra-Small:** With a built-in 2.4 GHz antenna, it's small size – 15x29mm (including the antenna).
- Low power consumption: When working under answer mode, it greatly reduces current consumption with fast transmission in air and startup time.
- **Low application cost:** NRF24L01 integrates all high speed signal processing related with RF protocol. For example, it automatically resends packets lost and generates answer signal. The SPI interface of NRF24L01 can be connected by the hardware SPI port of MCU or simulated with the I/O ports of SCM. With the built-in FIFO, it can connect with all kinds of high and low speed microprocessor, thus it is easy to use low cost SCM.
- **Easy to develop:** It is easy to develop because the link layer is fully integrated on the module
- True single chip GFSK transceiver
- Complete OSI Link Layer in hardware
- Short switching time enable frequency hopping

II .5 How nrf24l01 works :

The nRF24L01 wireless module, it's working, and interfacing with Arduino. nF24L01 is one of the legal RF communicators for modern applications. Its compact design and reliable nature make it a great option to be used in various projects that involve the wireless transmission of data over a distance[4].

The module can use 125 different channels which gives a possibility to have a network of 125 independently working modems in one place. Each channel can have up to 6 addresses, or each unit can communicate with up to 6 other units at the same time[4].

nRf24l01 operates on radio frequencies. In addition, these modules are designed using the 2.4 GHz frequency and use the SPI communication protocol to transmit and receive data between the microcontroller unit and the module [6] .

The SPI bus uses a master and slave concept, in most common applications microcontroller unit is the master and the nRF24L01 transceiver module is the slave [6] .

The nRF24L01 transceiver module communicates via a 4-pin SPI with a maximum data rate of 10 Mbps. All parameters such as frequency channel (125 selectable channels), output power (0 dBm, -6 dBm, -12 dBm or -18 dBm) and data rate (250 kbps, 1 Mbps or 2 Mbps) can be configured via the SPI interface [6].

II .6 The NRF24L01 transceiver module:

The NRF24L01 transceiver uses the 2.4GHz band and can operate at baud rates from 250Kbps to 2Mbps. If it is used in an open place and at a lower baud speed, its range can be up to 100m [8].

Figure II.4 : NRF24l01

II .6.1 RF channel frequency:

The nRF24L01 transceiver module transmits and receives data on a certain frequency called Channel. Also, for two or more transceiver modules to communicate with each other, they must be on the same channel. This channel could be any frequency within the 2.4 GHz ISM band or to be more specific, Each channel occupies less than 1 MHz bandwidth. This gives us 125 possible channels with 1 MHz spacing [6] .

The following formula shows the relationship between the RF channel frequency and the RF channel[4]:

RF Channel Frequency = 2400 + Selected Channel
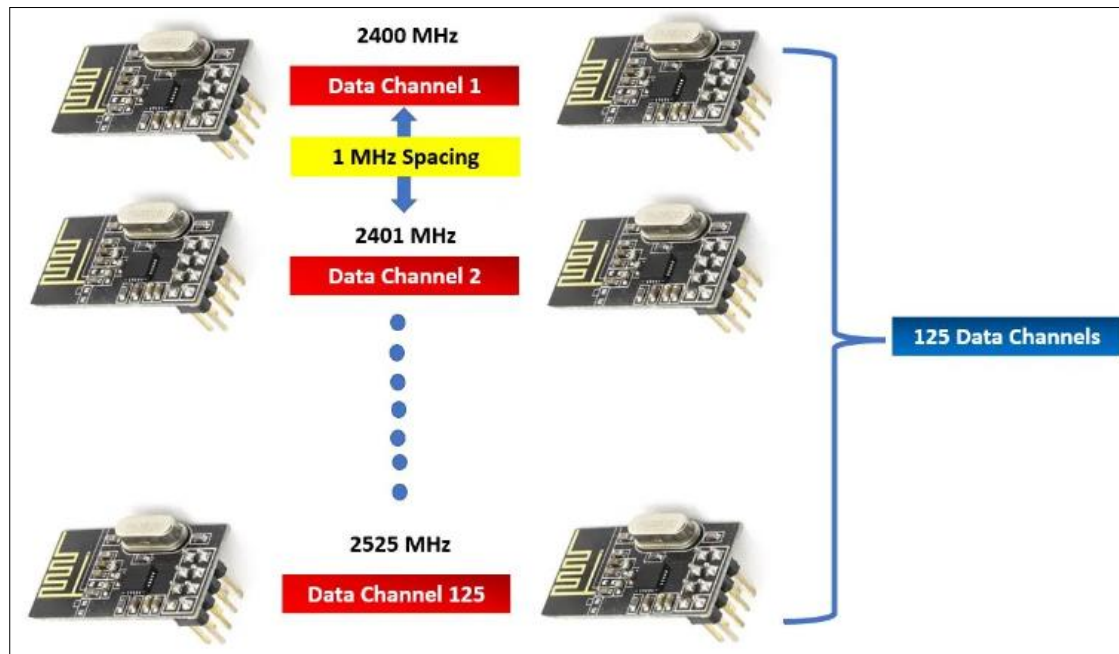
Figure II.4:RF channel frequancy

II .6.2 nRF24L01 multi-receiver network :

There are a bunch of applications nRF24L01 is useable but making a mesh is one of the best abilities of nRF24L01 which makes it different from another module[4].

The nRF24L01 provides a feature called Multi-receiver. It is the abbreviation of Multiple Transmitters Single Receiver. In which each RF channel is logically divided into 6 parallel data channels called data channels. In other words, a data channel is a logical channel in the physical RF channel. Each data channel has its own physical address (data channel address) and can be configured [6].
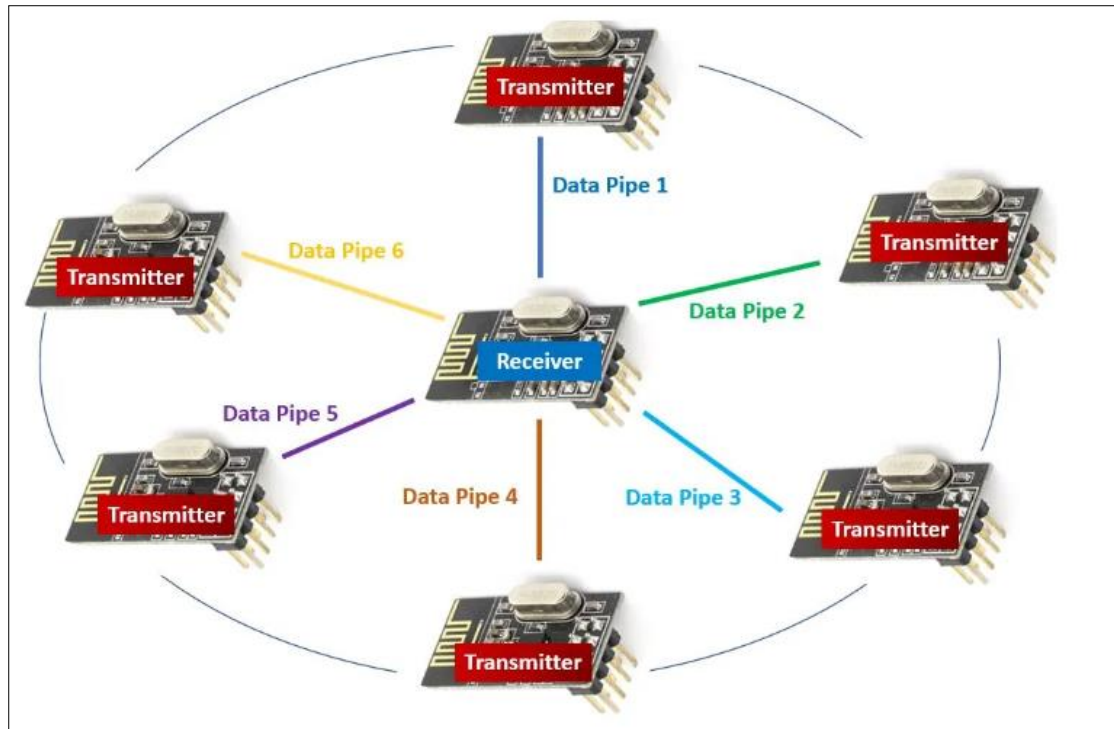
Figure II.5:nrf24l01 multi-receiver

II .6.3 Improved :

The nRF24L01 transceiver module uses a packet structure called Enhanced ShockBurst. This simple packet structure is broken down into 5 different fields, which is shown below [6]:
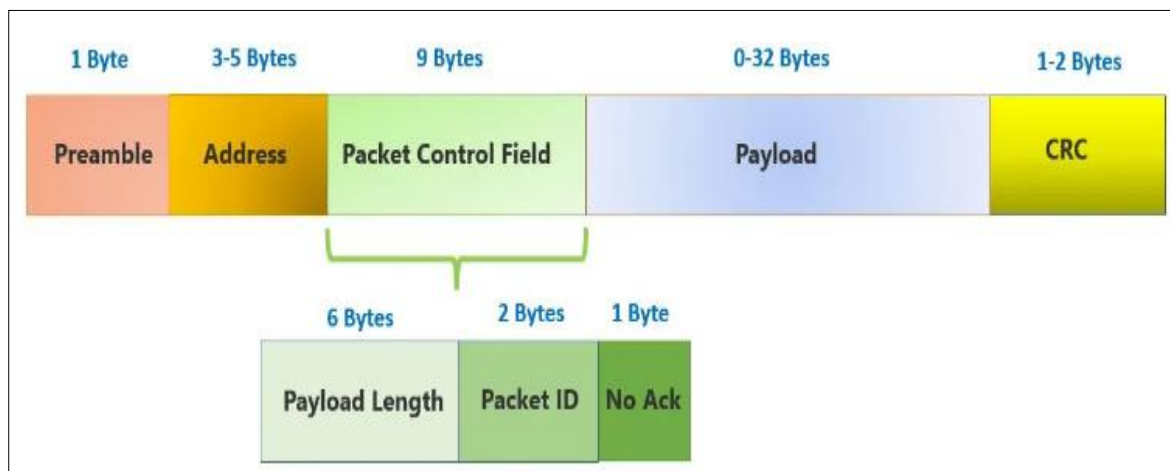
Figure II.6:Enchanced ShockBrust protocol packet structure

The original ShockBurst structure consisted only of the Preamble, Address, Payload, and Cyclic Redundancy Check (CRC) fields. Improved ShockBurst brought greater functionality for more enhanced communications using a newly

introduced Packet Control Field (PCF). It provides each packet sent with a packet ID, which allows the receiving device to determine if a message is new

or has been retransmitted, each message can request an acknowledgment be sent when received by another device [6].

II .6.4 nRF24L01 Automatic packet management :

II .6.4 .1 Data Transfer with acknowledgement and interrupt:

This is the simplest case where data is sent from the transmitter to the receiver and gets received by the receiver. Then we wait for 130us for the acknowledgment packet to receive. After the receiver successfully obtains the message, it sends an acknowledgment message to the transmitter which is then received by it. When the receiver receives the packet, it sends an ACK packet to the transmitter. The transmitter then generates an interrupt signal to denote the availability of new data packet [4] [6].
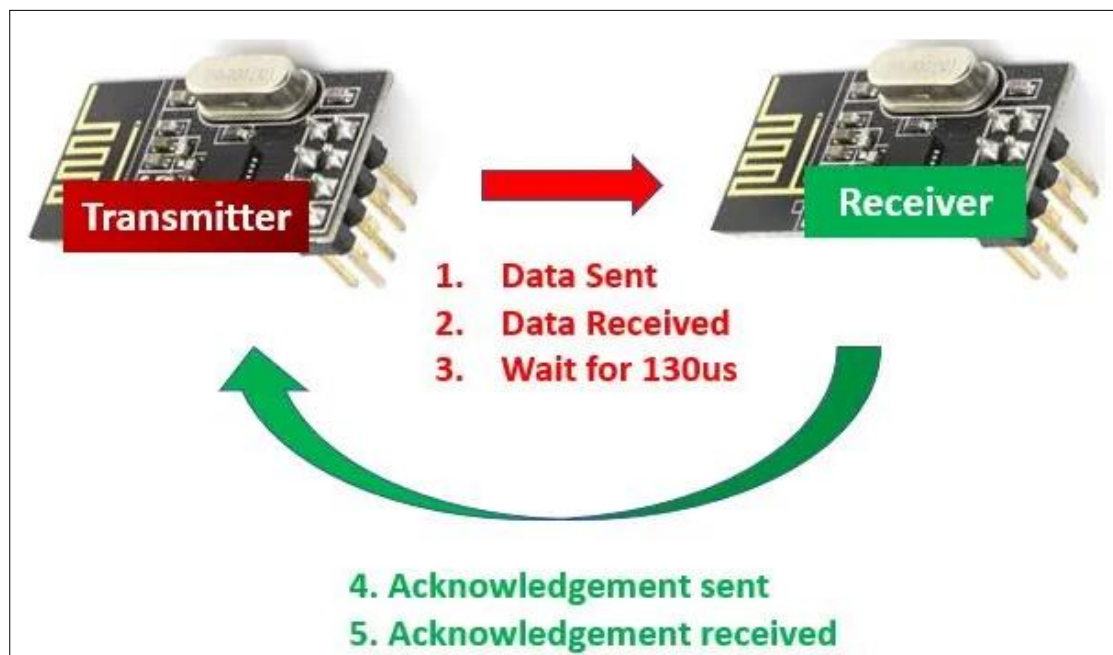
Figure II.7:Data Transfer with acknowledgement

II .6.4 .2 Data Transfer with data packet lost :when the transmitter sends the data packet to the receiver, it gets lost before gets transmitted. In the meanwhile, the transmitter waits for the automatic retransmission delay (ARD) time to finish until it receives the acknowledgment message. If the acknowledgment message does not arrive within this time then the data pack is retransmitted to the receiver. After that, the retransmitted data gets received by the receiver which in turn sends the acknowledgment message after a wait of 130us. After the

acknowledgment message is received by the transmitter, it creates the interrupt signal [4].
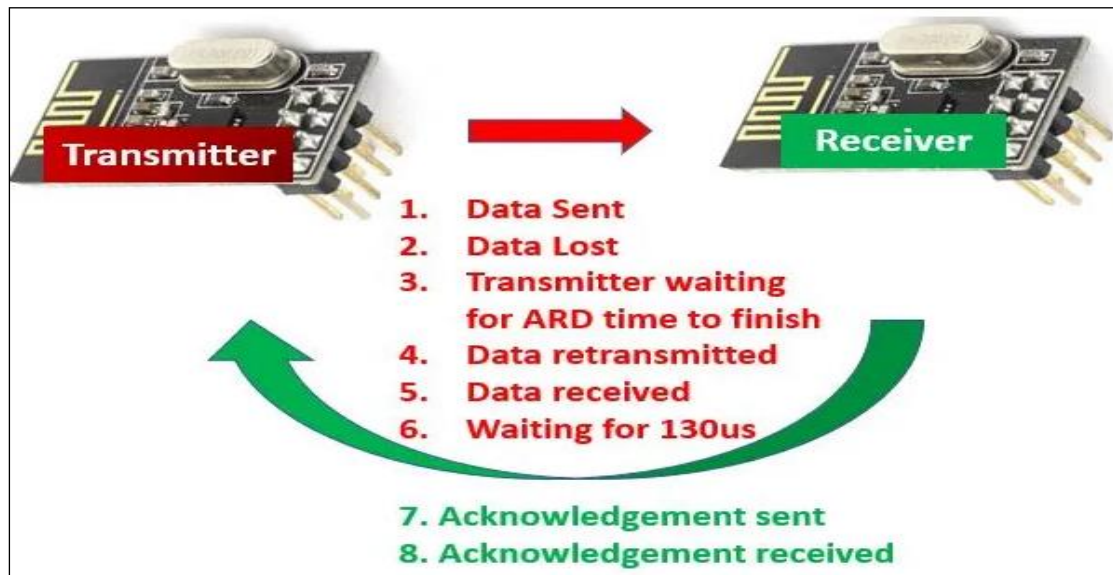
Figure II.8:Data Transfer with data packet lost

II .6.4 .3 Data Transfer with acknowledgement lost:

the data is successfully received by the receiver but the acknowledgment packet gest lost. the transmitter believes that the receiver does not contain the packet at all.Therefore, the data packet is retransmitted as the transmitter did not receive an acknowledgment message. After the ARD time finishes, the data packet gets retransmitted. The receiver now receives the same data packet again, checks the packet ID, and abandons it. It then sends the acknowledgment message to the transmitter which then receives it and generates an interrupt signal for the next data packet transmission. [6].

The packet processing is done completely automatically by the nRF24L01 chip without external interference.

Figure II.9: Data Transfer with acknowledgement lost

II .7 Radio Control :

This chapter describes the nRF24L01 radio transceiver's operating modes and the parameters used to control the radio[7].

The nRF24L01 has a built-in state machine that controls the transitions between the chip's operating modes. The state machine takes input from user defined register values and internal signals[7].

II .8 Operational Modes :

You can configure the nRF24L01 in power down, standby, RX or TX mode. This section describes these modes in detail [7].

II. 8.1 State diagram:

The state diagram in Figure 11. shows the operating modes and how they function. There are three types of distinct states highlighted in the state diagram [7]:

• Recommended operating mode: is a recommended state used during normal operation.

• Possible operating mode: is a possible operating state, but is not used during normal operation.

• Transition state: is a time limited state used during start up of the oscillator and settling of the PLL.

When the VDD reaches 1.9V or higher nRF24L01 enters the Power on reset state where it remains in reset until entering the Power Down mode[7].
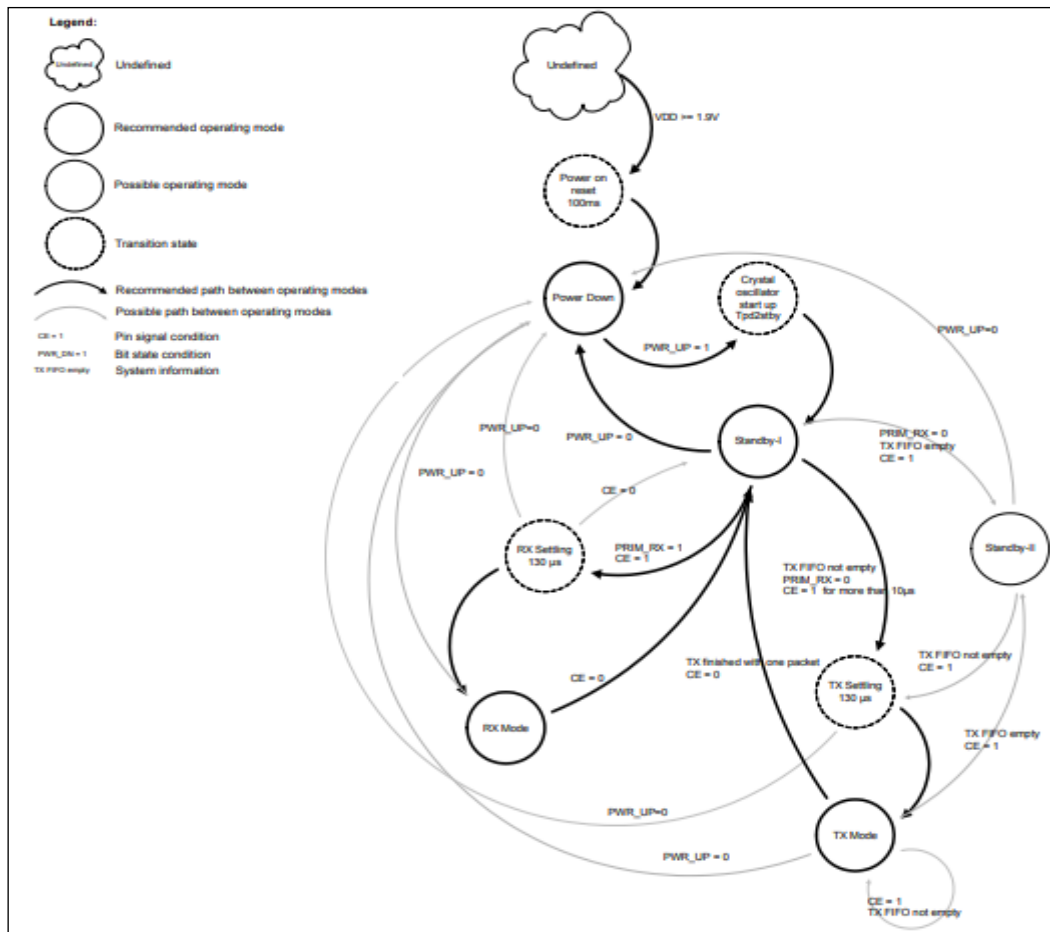

Figure II.10:Radio control state diagram

II. 8.2 Power Down Mode :

In power down mode nRF24L01 is disabled using minimal current consumption. All register values available are maintained and the SPI is kept active, enabling change of configuration and the uploading/downloading of data registers [7].

II. 8.3 Standby Modes:

II. 8.3.1 Standby-I mode:

By setting the PWR_UP bit in the CONFIG register to 1, the device enters standby-I mode. Standby-I mode is used to minimize average current consumption while maintaining short start up times. In this mode only part of the crystal oscillator is active. Change to active modes only happens if CE is set high and when CE is set low, the nRF24L01 returns to standby-I mode from both the TX and RX modes[7].

II. 8.3.2 Standby-II mode:

In standby-II mode extra clock buffers are active and more current is used compared to standby-I mode. nRF24L01 enters standby-II mode if CE is held high on a PTX device with an empty TX FIFO. If a new packet is uploaded to the TX FIFO, the PLL immediately starts and the packet is transmitted after the normal PLL settling delay (130µs) [7].

II. 8.4 RX mode:

The RX mode is an active mode where the nRF24L01 radio is used as a receiver. To enter this mode, the nRF24L01 must have the PWR_UP bit, PRIM_RX bit and the CE pin set high.In RX mode the receiver demodulates the signals from the RF channel, constantly presenting the demodulated data to the baseband protocol engine. The baseband protocol engine constantly searches for a valid packet. If a valid packet is found (by a matching address and a valid CRC) the payload of the packet is presented in a vacant slot in the RX FIFOs. If the RX FIFOs are full, the received packet is discarded. The nRF24L01 remains in RX mode until the MCU configures it to standby-I mode or power down mode [7].

However, if the automatic protocol features (Enhanced ShockBurst™) in the baseband protocol engine are enabled, the nRF24L01+ can enter other modes in order to execute the protocol [7].

II. 8.5 TX mode:

The TX mode is an active mode for transmitting packets. To enter this mode, the nRF24L01 must have the PWR_UP bit set high, PRIM_RX bit set low, a payload in the TX FIFO and a high pulse on the CE for more than 10µs[7].

The nRF24L01 stays in TX mode until it finishes transmitting a packet. If CE = 0, nRF24L01 returns to standby-I mode. If CE = 1, the status of the TX FIFO determines the next action. If the TX FIFO is not empty the nRF24L01 remains

in TX mode and transmits the next packet. If the TX FIFO is empty the nRF24L01 goes into standby-II mode. The nRF24L01 transmitter PLL operates in open loop when in TX mode. It is important never to keep the nRF24L01 in TX mode for more than 4ms at a time. If the Enhanced ShockBurst™ features are enabled, nRF24L01 is never in TX mode longer than 4ms [7] .

II .9 compact, highly integrated low cost solution:

The nRF24L01 integrates a complete 2.4GHz RF transceiver, an RF synthesizer, and full baseband logic including the unique Enhanced Shock Burst™ hardware link layer, advanced power management and a high-speed SPI for the host controller interface. No external loop filters, resonators or VCO varactor diodes are required, only a low cost ±60ppm 16MHz crystal, matching circuitry and the antenna[8] .

II .10 NRF24L01 with Arduino circuit diagram:
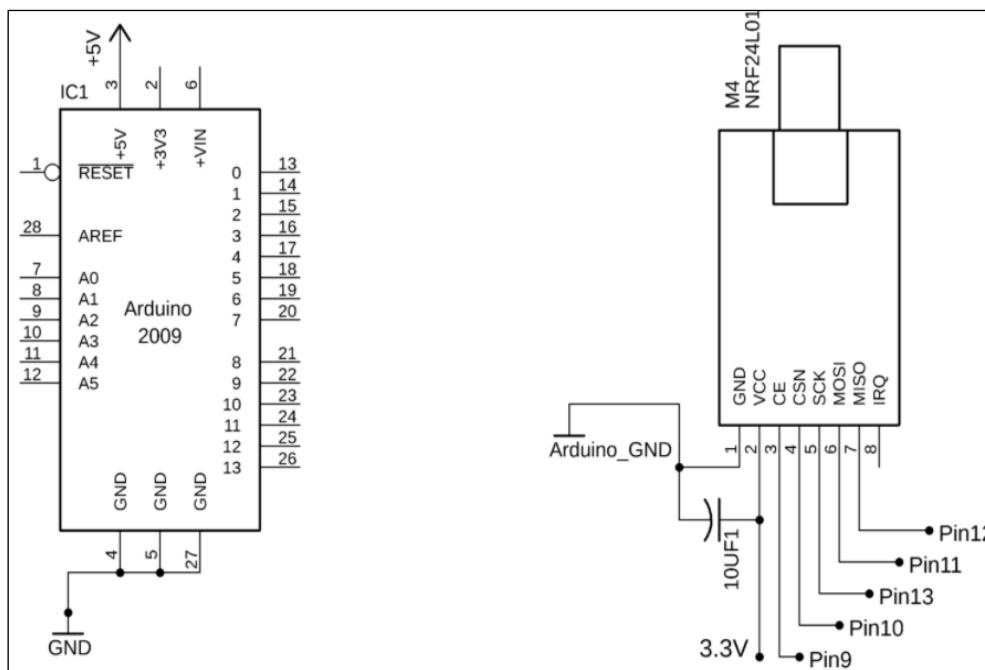
Figure II.12 :Block Diagram

II .11 Ultra low power consumption :

A unique combination of high air data rate and advanced power management[8]

The nRF24L01 has a unique combination of four features that enable the implementation of ultra-low power wireless connectivity [8]:

• Sub 14mA TX and RX active currents that permit coin-cell battery operation

• Advanced power management with power saving idle modes combined with rapid active mode start-up from idle

• High 2 Mbps on-air data rate that allows the transceiver to minimize the time it spends in the relatively more power consuming active mode for a given effective data rate

• Enhanced ShockBurst™ link layer minimizes processing load on the host microcontroller reducing average current consumption.

II .12 NRF24L01 module scope :

One of the most important components of IoT projects is communication. nrf24l01 can be successfully applied in the following areas:[9][10]

- Wireless PC Peripherals,
- It is used in mesh networks,
- Mice, keyboards and remotes,
- Advanced Media Center Remotes,
- VoIP Headsets,
- Sports watches and sensors,
- RF remote controls for consumer electronics,
- Active RFID,
- Asset Tracking Systems,
- Mobile electronics,
- Computers,
- Automated systems,
- Various smart home elements,
- Alarms,
- Temperature control and other functions,
- Games,
- Consumer electronics.

The nRF24L01 board includes a frequency synthesizer, demodulator, amplifiers and other components. The channel number determines the operating frequency of the module.[9]

The module has 4 working modes : Power off, standby, RX mode, TX mode. Current consumption in RX mode is higher than in TX mode [9].

II .13 application example :

Nrf24l01 with single ended matching network crystal,bias resistor,and decoupling and capacitor [7]:
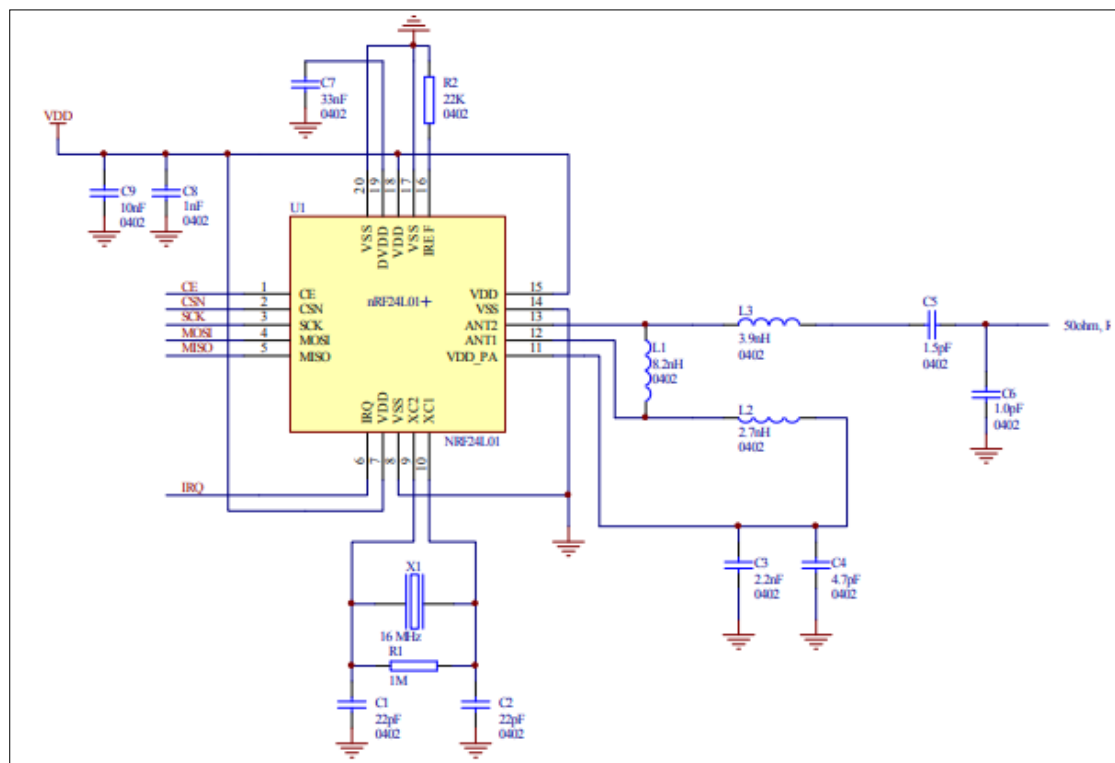
Figure II.13:nrf24l01 schematic for RF layouts with single ended

II .14 Advantages of NRF24L01 :

- **Low Cost the NRF24L01 :**is one of the cheapest wireless transceiver modules on the market [10].
- **Ease of pairing with a microcontroller / Arduino board** : The nRF24L01 can be easily paired with a variety of microcontroller systems; MCU/ARM/PIC/AVR/STM32 using SPI protocol or RF24 library when pairing with Arduino [10].

- **2.4 GHz for wireless communication flexibility:** The 2.4 GHz operating frequency allows for higher bit rate uses rather than other lower operating frequencies. It also uses GFSK modulation for data transmission, which means the data transfer rate can be 250 kbps, 1 Mbps or 2 Mbps [10].
- **High Transmission Range :** The nRF24L01, when used with the correct configuration, is capable of transmitting wavelengths over many miles [10].
- **Endless Applications:** Ranging from wireless PC peripherals to controllers and toys, the nRF24L01 can be used in many scenarios[10].

II-15 Conclusion:

The nRF24L01 is a reliable solution to building a low-cost transceiver RF module for project. Due to its low price, small size and availability it is recommended to those who are involved in IoT projects or who need simple tools for communication. For these reasons, we have chosen it as the communication module in our water quality monitoring system.

CHAPTER III: QUALITY OF WATER

III.1 Introduction :

Since the industrial revolution at the end of the 18th century, the world has discovered new sources of pollution almost every day. Thus, the air and water can potentially be polluted everywhere. Little is known about the evolution of pollution levels. The increase in water-related diseases allows a true assessment of the degree of environmental pollution. This chapter summarizes water quality parameters from an ecological point of view not only for humans, but also for other living things. According to its quality, water can be classified into four types. These four types of water quality are discussed through an in-depth review of their important common attributes, including physical, chemical and biological parameters. These water quality parameters are examined in terms of definition, sources, impacts, effects and measurement methods [1].

Water is the second most important need for life to exist after air. As a result, water quality has been widely described in the scientific literature [1].

Water quality standards are established to protect the specific different uses of an aquifer. The water bodies are then monitored by countries to ensure that these standards are met and that the water body supports its specific uses, involving strict guidelines [2][3].

When a water quality assessment reveals that a body of water does not support its designated uses, it is considered disabled by the Algerian Environmental Protection Agency (EPA). The vulnerability results from two main categories of water pollution: point source or non-point source pollution. Point source pollution arises from effluents discharged regularly (such as daily) from industrial experiments and municipal wastewater treatment plants through permanent channels such as pipes or ditches. As a result, local and federal governments are constantly working to ensure everyone in the community has safe drinking water [2][3].
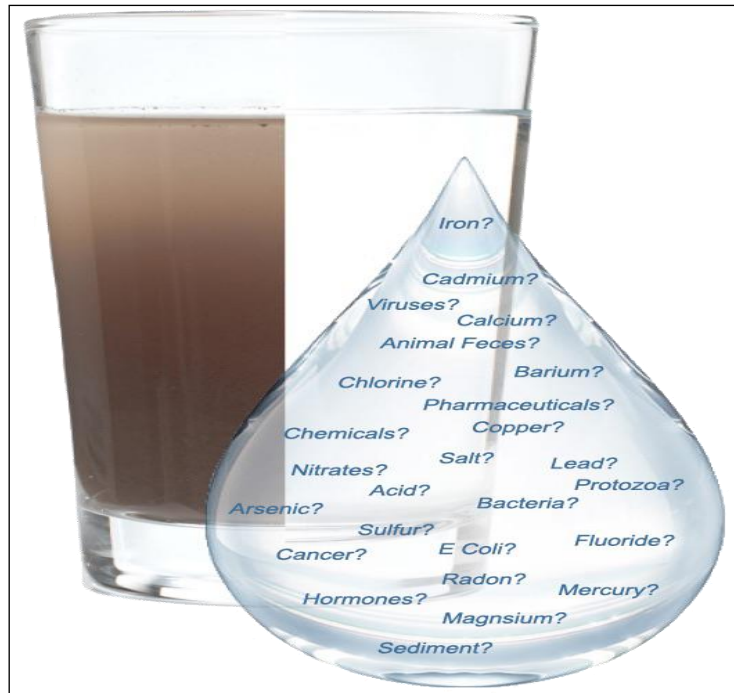
Figure III .1:water quality

III.2 Classification of waters:

Water can be divided into groundwater and surface water [4]. Both types of water can be exposed to contamination risks from agricultural, industrial and domestic activities, which can include many types of pollutants such as heavy metals, pesticides, fertilizers, hazardous chemicals and oils [5][6].

Water quality can be classified into four types: potable water, appetizing water, contaminated (polluted) water and infected water [7]. The most common scientific definitions of these types of water quality are [6]:

Drinking water: It is safe to drink, palatable and usable for domestic purposes [8].

Appetizing water: It is aesthetically pleasing; it takes into account the presence of chemicals that do not pose a threat to human health.

Contaminated (polluted) water: It is that water containing undesirable physical, chemical, biological or radiological substances, and it is unsuitable for consumption or domestic use [8].

Infected water: It is contaminated with a pathogenic organism [8].

III.3 Water Resources in Algeria :

Renewable water resources in Algeria are estimated at approximately 19 billion cubic meters per year (BCM/yr) (Table 1), approximately 450 cubic meters (m3) per capita per year. This is below the recommended 500 m3 per capita per year recognized as the scarcity threshold indicating a water crisis. Water resources are characterized by high variability[9]

Water resource	Volume(BCM)	Region
Renewable surface water	11	North and south
Renewable groundwater	2.5	North
Non-renewable groundwater	6.1	South

Table III.1 : Water resource availability.

III.3.1Surface water:

Algeria is divided into five major river basins comprising a total of 17 catchments and concentrated mainly in the north. The renewable surface water resources are estimated to total 11 BCM [10]. Surface water inflows are low in the Saharan basin. In contrast, the north relies mainly on surface water, since almost 7 BCM is captured by a number of medium and large dams. Runoff occurs as rapid and powerful floods that replenish the dams during the short rainy season [9].

III.3 .2 Groundwater:

Groundwater resources are estimated to total 7.6 BCM, but demand is much higher in the north of the country. Important aquifers in the Sahara meet 96% of water demand in the south [9] [11].

In the mountainous region in the north, the aquifers are shallow and exploited using wells and springs. While these aquifers are naturally recharged with 1.9 BCM/yr, The deficit is mainly due to a lack of effective groundwater management, linked to poor knowledge of the resource, an increase in the number of illegal wells and a lack of coordination between the water authorities [9] [12][13].

Groundwater in the south is mainly fossil with very low renewability. The water resources are contained within two major overlapping aquifers, the Complex Terminal and the Continental Interlayer, which form the transboundary North-

Western Sahara Aquifer System (NWSAS). The deep aquifers are exploited mainly using deep boreholes, whereas the shallow ones are exploited using the traditional foggara system [9][14].
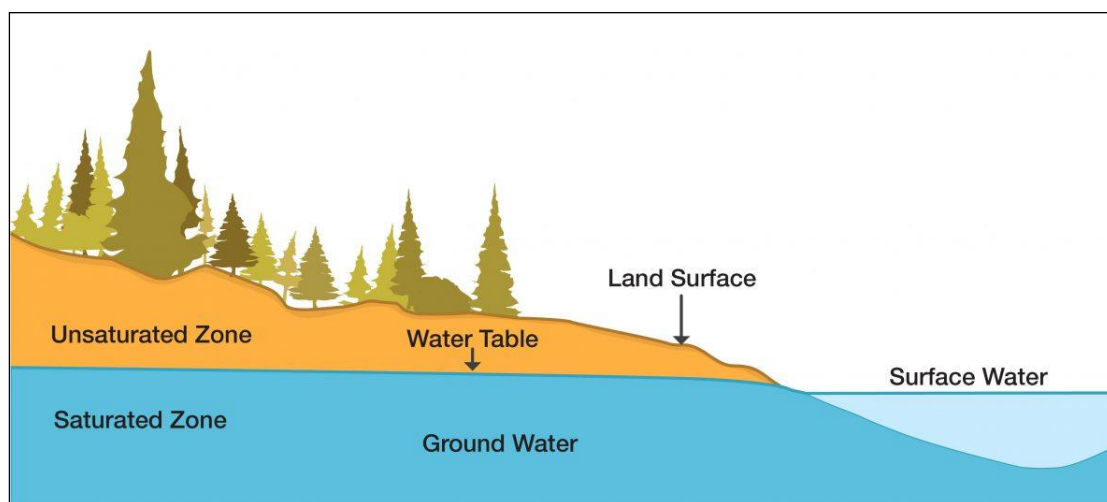

Figure III.2: Water Resources

III.3.3 Non-conventional sources (Desalination, wastewater reuse , rainwater harvesting) :

Comparing supply and demand shows a current water deficit of 1.3 BCM. The projected population growth almost certainly means this deficit will grow, necessitating a new strategy for seawater desalination and wastewater reuse [9].

III.3.4 Wastewater reuse

The reuse of treated wastewater has become a priority in the new water policy, resulting in the rehabilitation of old stations and the construction of new ones. The aim is to build 239 wastewater treatment plants with a total capacity of 1.2 BCM/yr of purified water mainly intended for irrigation, thereby preserving traditional water resources while increasing agricultural production [9][15].

III.4 Types of pure water:

Deciding on the type of pure water you need for your application can be challenging. Knowing this tells you which filtration technology you use and the systems you need to produce the right quality water.[16]

There are several types of water, and we will mention three types in particular: the first type, the second type and the third type :[16]
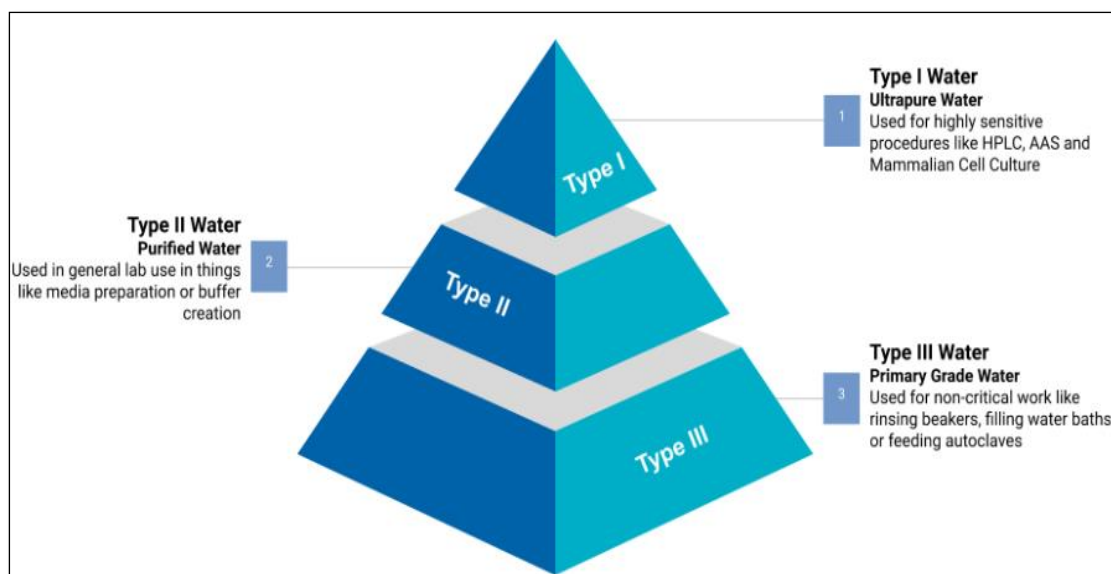
Figure III.3: Types of pure water

III.4 .1 Type 1 water (ultrapure water) :

Grade I water, also known as ultrapure water, is the purest form of water to produce. It is used for the most critical applications and advanced analytical procedures [16].

This includes:

- Cell and tissue cultures
- Liquid chromatography, including high performance liquid chromatography (HPLC)
- gas phase
- Inductively Coupled Plasma Mass Spectrometry (ICP-MS)
- Biology

Molecular Type I can also be used in applications requiring Type II water. This is a fairly common practice that can help avoid the generation of by-products during applications [16].

III.4.2 Type 2 water :

Type II water quality does not have the same purity as Type I, but still maintains high levels of purity. It is a good feed water for clinical analyzers because calcium buildup is reduced with this type of water [16].

It can also be used in applications such as:

- General practices
- Laboratory
- Analysis and preparation
- Microbiological
- Electrochemistry
- Spectrophotometry

In general It can also be used as feed water for the production of type I water [16].

III .4. 3 Type 3 water (OSM WATER)

TYPE III quality water, also known as reverse osmosis water, is water produced by reverse osmosis purification technology. Of all the types of pure water, it has the lowest level of purity, but it is usually the starting point for basic laboratory applications, such as cleaning glassware, heating baths, or preparing supports. It can also be used as feed water for the production of Type I water [16].

III .5 Water Quality:

Socio-economic development and rapid urbanization have had a negative impact on the quality of water resources, and industrial and urban pollution has been observed in dams, groundwater and rivers. Although Algeria recognizes the polluted state of its water resources, no clear measures have yet been taken at the national level [17].

The quality of water corresponds to a set of physico-chemical and bacteriological criteria which define its degree of purity and, consequently, its suitability for various food, domestic, agricultural or industrial uses [18].

To find out the quality of the water, we examine the Standards for measuring water quality which is represented in :

III.5.1 Organoleptic parameters :

The organoleptic parameters are:

- The so-called apparent coloring when the substances in suspension add their own coloring to it. Actual and apparent colors are approximately the same in clear water and low turbidity water [18][19].

- Smell can be defined as:

All the sensations perceived by the olfactory organ when smelling certain substances

The quality of this particular feeling is brought about by each of these substances.

– Taste can be defined as the set of taste, olfactory and chemical sensitivity sensations perceived when the food or drink is in the mouth [18][19].

III.5.2 Physical Parameters :

III.5.2 .1 Turbidity :

Though less used than some of the other water quality parameters on this list, turbidity refers to how cloudy water is. When you use Turbidity sensors, these devices are designed to measure the ability that light has to pass through water. High levels of turbidity can occur as a result of higher concentrations of silt, clay, and organic materials. The main issue with turbidity in water is that the water will look bad. No one wants to drink cloudy water. Several additional problems that are caused by high turbidity include [20]:

-Water treatment costs will be higher

-High levels of particulates can act as a shield for harmful microorganisms, which makes it more difficult to get rid of these contaminants

-Suspended materials may damage fish gills, reduce growth rates, and decrease resistance to diseases

-Various suspended particles can act as adsorption media for mercury, cadmium, lead, and other heavy metals

-Dissolved oxygen concentration will likely decrease

With a device (turbidimeter) we measure the resistance it opposes by the water to the passage of light to give it a value. We measure the turbidity by the NTU standardized method by spectrometry, i.e. measurement of the absorption of light by water [21].

- NTU < 5 => clear water

- NTU < 30 => slightly cloudy water

- NTU > 50 => Cloudy water.

A significant turbidity of the water leads to a reduction in its transparency which reduces the penetration of solar radiation useful to aquatic life (photosynthesis) [21].

S M (suspended matter) is the term used for very fine particles in suspension (sand, clay, organic products, particles of polluting products, micro-organisms, etc.) which give the water a cloudy appearance (turbidity) and oppose light penetration necessary for aquatic life. In too large quantities, they therefore constitute a solid pollution of water [21].

The quantity of total suspended solids (TSM) is measured by filtering a liter of water and weighing the dried residues. The result is expressed in mg/l. (It is estimated that an inhabitant releases around 90 grams per day of suspended solids in their wastewater) [21].

turbidity is caused by the presence of suspended solids, metal oxides and hydroxides, planktonic organisms and colored dissolved substances. The most important effect of turbidity is its ability to protect bacteria and viruses against disinfection [18][19].

III.5.2 .2 Density :

It is the specific mass of a body and the mass of the unit volume of this body. By definition, that of pure water at 4°C is 1 gram per milliliter[18][19].

III.5.2 .3 Temperature :

Water temperature influences many other parameters. This is primarily the case for dissolved oxygen essential for aquatic life: the higher the temperature of the water, the more the quantity of dissolved oxygen decreases. Too high a temperature of the waters of a river can therefore lead to dramatic situations of lack of dissolved oxygen which can lead to: the disappearance of certain species, the reduction of self-purification, the accumulation of nauseous deposits (odors), the accelerated growth of plants (including algae) [21] .

Thermal pollution can originate from urban or industrial hot water discharges into the watercourse. The thermal pollution of small rivers can also originate from the overflows of ponds installed on their banks and which by their large surface play a role of "heat pump" [21].

In summer, in high atmospheric temperatures, the sudden heating by the sun of the waters in poor condition of a low-oxygen river can lead to a thermal shock resulting in spectacular fish mortality. The wooded edges of watercourses (riparian forests) limit the heating of water [21].

Due to the variations of certain water parameters with temperature (dissolved oxygen, conductivity, etc.) standardized analyzes are carried out on water samples at 20° C. For field analyses, it is therefore necessary to take into account water temperature, and then make the conversion (tables). Some field measuring devices automatically make this conversion according to the water temperature [21].

The temperature of drinking water must be lower in summer and higher in winter than the temperature of the thirst-quenching air. It must be between 8°C and 15°C; between 20°C and 25°C it quenches thirst badly[18][19].

III.5.2 .4 Electrical conductivity :

Another core physical parameter that we should be aware of involves electrical conductivity, which measures how well a sample of water or similar solution can carry or conduct electrical currents. Conductivity levels will increase as the amount of ions in the water increases [20].

This is one of the main parameters when measuring water quality because of how easy it is to detect water contamination levels when measuring the conductivity of water. High conductivity means that the water contains a high amount of contaminants [20].

The measurement in micromhos/cm (µS/cm) or milliSiemens/m (mS/cm) of the electrical conductivity of water is carried out using a conductivity meter. This measures the passage of electricity between two electrodes immersed in water. The measurement is carried out at 20° C or with a conductivity meter with automatic temperature compensator [18][19]. .

If very pure water is an insulator which opposes a great resistance to the passage of electricity, it is no longer the same when it is loaded with mineral salts of natural origin (calcium, magnesium, sodium, potassium). In addition to this natural mineralization linked to the nature of the soil, there are also pollutants. Conductivity makes it possible to globally appreciate all the products in solution in the water, Rainwater only offers a conductivity varying between 60 and 100 µS/cm [21].

The conductivity measurement is a fairly simple means of detecting an anomaly indicating the probable presence of pollution, by comparing the value measured with that which one was entitled to expect.. [18][21].

MVS(Volatile materials suspension)This parameter is sometimes used. Volatile materials in suspension are those which are likely to be volatilized by laboratory test at a temperature of 550°C. MVS are generally assimilated to organic materials in suspension. MVS are measured in mg/l[20].

It is the inverse of electrical resistivity. According to Rodier, (2005), the relationship between resistivity and conductivity is:[18]

$$\text{Resistivity } (\Omega.Cm) = 106/\text{conductivity } (\mu s/cm)$$

III.5.2 .5 pH :

pH This parameter, which is measured with test strips or a device (pH meter), gives the degree of acidity or alkalinity of water[20]. The pH value in natural water depends on the origin of this water and the geological nature of its course. Most natural waters have a pH between 6.5 and 8.3. It may happen that some polluted waters, by industrial discharges, contain strong acids such as HCl and H_2SO_4, and therefore their pH is then much lower than 4.5 [18][19]. . pH measurement has an interest in determining the aggressiveness and disinfection of water by chlorine. . The pH (potential hydrogen) reflects the concentration of H+ ions in water: $pH = - \log [H+]$[21].

Water in rivers generally approaches neutrality, represented by a pH of 7[21].

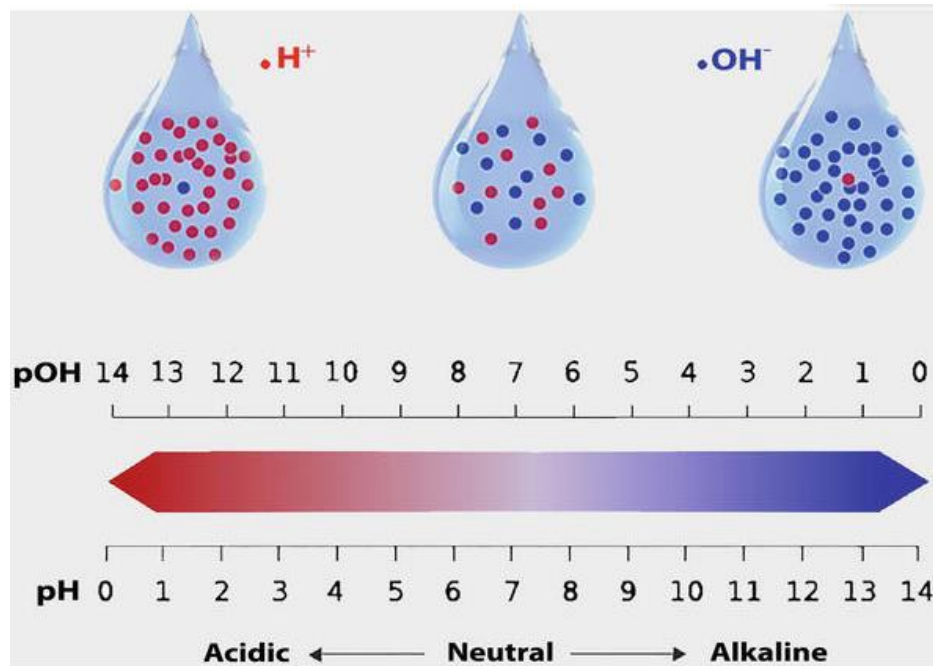The pH must be between 6 and 8 to support aquatic life [21].

Figure III .4: ph

In each natural environment, the waters have their own pH value depending on the subsoil of their catchment area[21]:

> 7 in limestone regions where the waters are basic because they are highly mineralized, < 7 in primary subsoil regions (Vosges, etc.) where the waters are acidic [19].

A pH measurement, different from the usual value of the watercourse, can be the index of an arrival of pollution, generally industrial, upstream of the point of measurement [21].

Its value, most often measured using a pH meter or "pH paper", indicates whether the water is acidic (from 1 to <7), neutral (7), or basic (from > 7 to 14) , Also called alkaline [21].

The pH varies slightly with temperature. The analysis must therefore be carried out at 25° C or with a pH meter with automatic temperature compensator [21].

HARDNESS Water is to be soft when it is low in calcium and magnesium. The sum of the two constitutes the Hydrotimetric Title. Conversely, water will be said to be hard. (> at 10Th) [21].

Ph < 5	- strong acidity - presence of mineral or organic acid in natural waters
Ph =7	pH neutral
7<ph<8	near neutrality, majority of surface waters
5.5< ph <8	underground waters
Ph >8	Alkalinity

Table III.2: PH

III.5.2 .6 Hardness :

Mainly due to the presence of calcium and magnesium salts, it is practically manifested by the difficulty of foaming with the soap[18].

III.5.3 Chemical parameters :

III.5.3.1 Organic material :

Non-humic substances are formed by basic products, proteins and amino acids, polysaccharides and simple sugars, fats and fatty acids, hydrocarbons, pigments, vitamins and various toxins [18][19].

They are generally of little importance because they are well degraded and used as soon as they appear in the water by micro-organisms, their renewal is very rapid [19].

Humic substances make up most of the organic matter in natural waters, produced by micro-organisms (fungi, bacteria), from plant and animal products [18][19].

III.5.3.2 Alkalinity :

The alkalinity of water corresponds to the presence of hydrogen carbonates, carbonates and hydroxides [18][19].

III.5.3.3 Chlorides :

Chlorides (salts). They are not harmful, but are an important indicator of the arrival of pollution. They are not eliminated by treatment plants. In nature, they are often indicators of the arrival of urban effluents. As an indication, in tap water the maximum allowed is 250 mg/l. of chlorides [20]. Chlorideions are present in

all waters at different concentrations and in the form of salts: sodium chloride, potassium chloride or calcium chloride, introduced by natural or human sources. The waters must not be aggressive [18][19].

III.5.3.4 Dissolved oxygen :

The presence of oxygen in water is essential for the respiration of aerobic living beings [21], The dissolved oxygen level is the most sensitive parameter. The input of organic pollution in a watercourse, the solubility of oxygen in water decreases when the temperature increases [18][19].

Below a certain oxygen concentration threshold, fish are asphyxiated. (7 mg/l for salmonids; 3 mg/l for carp) The oxygen in the water also enables the process of oxidation of organic matter, but this decomposition depletes the aquatic environment in oxygen [21].

The oxygenation of water comes first from the contact of its surface with the atmosphere. It is favored by the eddies, the waterfalls and especially the temperature of the water. Because the hotter the water, the less oxygen is soluble in it [21].

Oxygen saturation value of water under ordinary conditions (atmospheric pressure 760 mm Hg):[21]

- at 5°C, maximum dissolved oxygen: 12.3mg/l.
- at 10°C: 10.9 mg/l,
- at 15°C: 9.7 mg/l,
- at 20°C: 8.8 mg/l,
- at 25°C: 8.1 mg/l,

Dissolved oxygen decreases when its measured concentration is below the saturation value, since supplemental oxygenation is provided [21].

The oxygen content of the waters of a river can therefore vary during the day by several mg/l depending on the temperature and the presence or otherwise of aquatic plants (up to around 20mg/l in the event of eutrophication) [21].

The oxygen content of the waters of a river also varies according to the depth: very low in deep water, which can approach the saturation rate near the surface.

To measure the dissolved oxygen of a watercourse, it is possible to use an oximeter, equipment with a special probe. There are also colorimetric kits using chemical reagents. It is a very important parameter for life in the river [21].

III.5.3. 5 Organic Matter(OM):

Contained in water is the part of organic pollution that has not yet decomposed (dead living matter or excreta from living organisms). They are therefore naturally present in water, but in low concentrations. If there is more, there is pollution from discharges of poorly treated domestic wastewater, agricultural effluents [21].

OM can be found in water either dissolved or in visible particulate form. The presence of visible deposits of organic matter in the bed of a river is unacceptable and very often indicates the proximity of a raw discharge or a very poor state of the river. (In addition, the degradation of organic matter consumes and reduces the dissolved oxygen in the water necessary for aquatic life). The organic pollution load can be quantified using standardized techniques: COD, BOD5 [21].

III.5.3. 6 BOD, COD and oxidizability:

The BOD (Biochemical Oxygen Demand) expresses the quantity of oxygen necessary for the degradation of the biodegradable organic matter of water by the development of micro-organisms, under given conditions. The conditions commonly used are 5 days (we can therefore have a partial degradation) at 20°C, away from light and air: we then speak of BOD5 [22].

The COD (Chemical Oxygen Demand) expresses the quantity of oxygen necessary to oxidize the organic matter (biodegradable or not) of water using an oxidant: potassium dichromate [22] .

This method therefore gives a more or less complete picture of the oxidizable materials present in the sample (some hydrocarbons are not oxidized under these conditions). The objective of COD is therefore different from that of BOD, COD can be carried out more quickly than BOD ("forced oxidation"), and gives a picture of the organic matter present even if the development of microorganisms is impossible. The result is expressed in mg/l of O_2[22].

Situation	BOD5, in mg/l of O2
pure and living natural water	< 1
slightly polluted river	$1 < c < 3$

sewer	$100 < c < 400$
wastewater treatment plant rejection	$20 < c < 40$

Table III.3: BOD, COD and oxidizability

Generally, the COD = 2 to 1.5 x BOD5. The following empirical relationship relates the BOD5, COD and organic matter of the sample (OM) [22]:

$$MO = (2BOD5 + COD)/3$$

III.6 Major ions :

III.6 .1 Calcium and Magnesium :

Calcium Ca_2^+ and magnesium Mg_2^+ are present in crystalline rocks and sedimentary rocks. They are very soluble and therefore are widely represented in most waters[22].

III.6 .2 Sodium and potassium :

The sodium cation (Na^+) is very abundant on earth. It is found in crystalline rocks and sedimentary rocks (sands, clays, evaporites). Halite rock (NaCl evaporite) and potassium (K^+) is quite abundant on land, but not common in waters. Potassium is in crystalline rocks (but in minerals less weatherable than those containing sodium), evapotites (sylvinite Kcl) and clays[22].

III.6 . 3 Sulphate :

The origins of sulphates in water are varied. The natural sources are rainwater[22].

III.6 . 4 Chlorides :

The Cl^- ion is present in small quantities on earth. The main source of chloride in the waters is due to the dissolution of sedimentary rocks

III.7 Areas where smart water quality management systems can be employed :

Smart water quality systems would be most useful and effective in healthcare facilities, water utilities, agriculture, wastewater management, manufacturing and aquaculture [23].

III.7.1 Healthcare facilities and laboratories: Healthcare facilities require 100% pure water to keep patients safe and free from infection. Laboratories and research centers also require water entirely free from any toxic elements to conduct error-free experiments and generate genuine outcomes [23].

III.7.2 Water utilities: Water monopolies that supply water to household areas for drinking and other domestic purposes must ensure that the water is not contaminated and is plentiful in nutrients. For making the water free from any toxicants, they can implement IoT-based smart water quality management [23] .

 Preserving water quality and saving water in agriculture is exceptionally crucial for absolute quality crop production. Water suspended with toxic elements can impact crop growth and health. These unhealthy crops then affect people's health negatively [23].

III.7.3 Agriculture: Preserving water quality and saving water in agriculture is exceptionally crucial for absolute quality crop production. Water suspended with toxic elements can impact crop growth and health. These unhealthy crops then affect people's health negatively [23].

III.7.4 Wastewater management: IoT solutions can be used for treating wastewater before it is transferred to freshwater bodies. All the vital parameters such as temperature, Ph, turbidity, and TDS level of wastewater must be monitored and free from toxicants and dirt[23].

III.7.5 Manufacturing: Various factories and manufacturing units discharge chemical substances in water bodies even if there are strict regulations against this act. This discharge impacts the health of organism that consumes water from those bodies. Thus, industries must implement IoT-based real-time water monitoring solutions to maintain water bodies' water quality and be compliant to government regulations [23].

III.7.6 Aquaculture: Safe living conditions for aquatic plants and animals become obstinate when the concentration of harmful gases and other toxic elements rise too much. Smart water monitoring products help to monitor and maintain water parameters such as temperature, Ph level, and dissolved oxygen level and analyze the presence of destructive elements [23].

III.8 Environmental and health risks:

The lack of integrated water management exacerbates environmental and health risks across the country [17].

The decline in water quality is taking on worrying proportions, particularly in the north. Uncontrolled agricultural practices lead to degradation of water quality through return flows. In urban areas, water supply is at risk of biological and physico-chemical pollution due to illegal and uncontrolled discharges into streams and water bodies. This risk is amplified by outdated treatment plants that are not equipped to treat water polluted with heavy metals and pesticides [17].

Salinization is also a recurring problem that poses challenges for water supply management. Certain regions in the west of the country are mainly affected by high salinization rates, which have irreversibly degraded the irrigated agricultural plains. In the south, excessive pumping and uncontrolled irrigation are further salinizing the naturally saline soils and aquifers of the terminal complex. In coastal areas such as Oran, Algiers and Jijel, overexploitation of coastal aquifers leads to irreversible salt intrusion [17].

Water-borne illnesses have occasionally been reported, which pose a health risk that authorities cannot always control. In 2018, 76 cases of cholera were reported in six coastal provinces. Such outbreaks are usually a consequence of old, leaky sanitation infrastructure contaminating water used for irrigation [17].

III.9 Benefits of using IoT based water quality management solutions :

Smart water quality management solutions contribute to increased productivity by improving processes and workflows. Industries' overall revenue can be increased, and water costs can be reduced by real-time monitoring of water. Safety and reliability of workplaces and other network operations can also be improved significantly with predictive maintenance, one of the most prominent IoT features [23].

All IoT Agenda network contributors are responsible for the content and accuracy of their posts. Opinions are of the writers and do not necessarily convey the thoughts of IoT Agenda [23].

Conclusion :

Overall, the activities undertaken under the Water Quality and Aquatic Ecosystem Health Program continue to be relevant, given the ongoing need to assess water quality for various uses, determine threats and trends in water quality over time, as well as define the effectiveness of environmental programs. The program aligns with federal laws, such as the Department of the Environment Act, the Water Resources Act, and supports priority programs. program administrators maintain consistency with federal responsibilities by developing and implementing intergovernmental agreements on water quality monitoring.

CHAPTER IV : PRACTICAL REALIZATION

IV.1. Introduction

Safe water is becoming a scarce resource, due to the combined effects of increased population, pollution, and climate changes. Water quality monitoring is thus paramount, especially for domestic water. Traditionally used laboratory-based testing approaches are manual, costly, time consuming, and lack real-time feedback. Recently developed systems utilizing wireless sensor network (WSN) technology have reported weaknesses in energy management, data security, and communication coverage.

The WSN in IoT projects enables the information and communication systems invisibly embedded in the environment since the sensor network enables people to interact with the real world remotely. Recently, environmental monitoring system based on WSN system using different wireless communication standards has attracted intensive interest.

The main of this project is to develop a system for continuous monitoring of water quality at remote places using wireless sensor networks with low power consumption, low-cost and high measurement accuracy. Water parameters such as turbidity, pH and temperature are measured at a remote place using available sensors and the collected data from various sensor nodes are sent to the base station by the wireless channel for further processing and may be sent by internet to distant processing centers.

IV.2. System Architecture

The general architecture of the proposed system is shown in figure IV.1

The system contains two main parts several end –nodes, and a base station for data processing. The sensor nodes are placed at the bank of the water. The measured data of water parameter are collected by the sensor nodes and sent to data processing system.
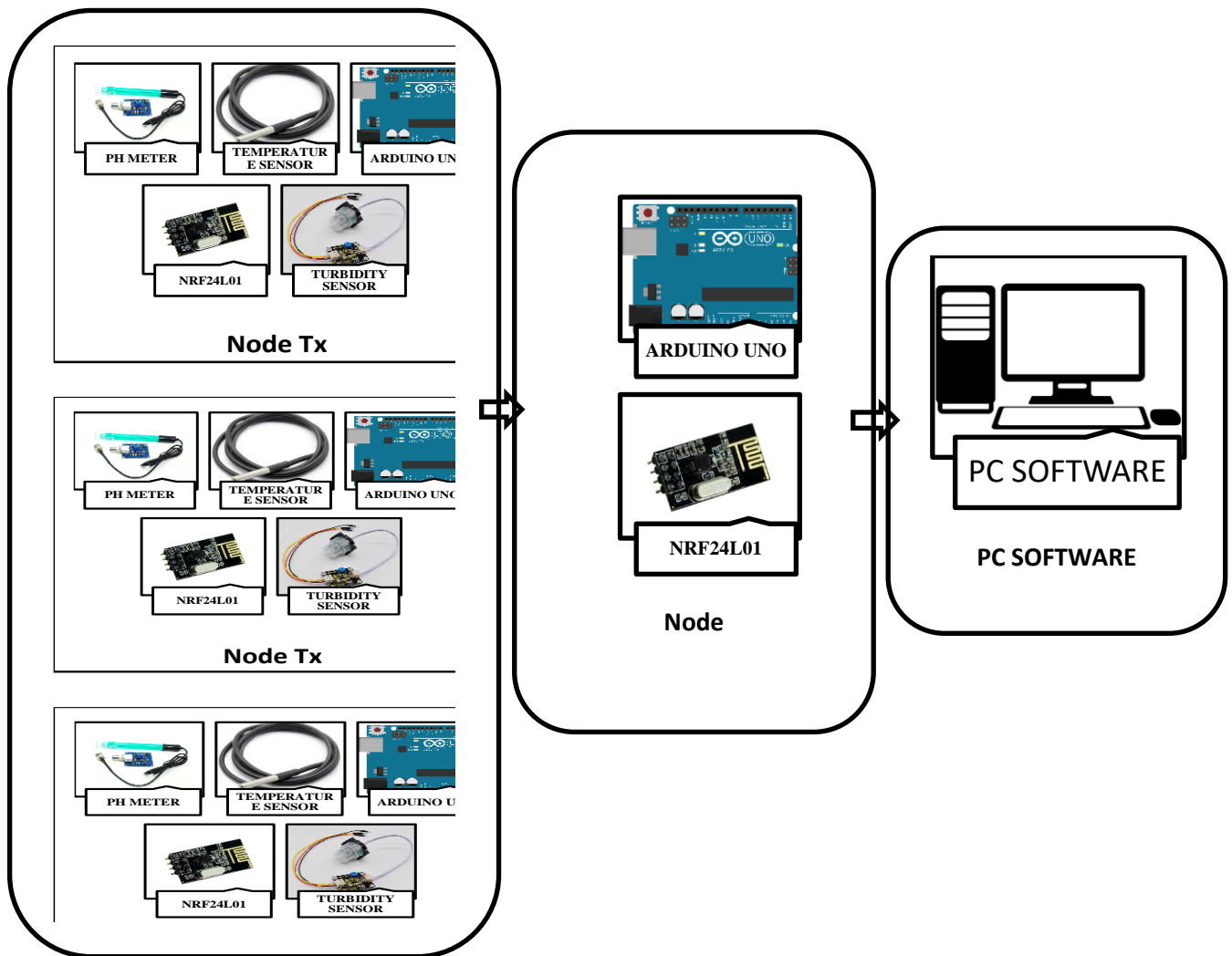
Fig IV.1 System architecture

IV. 3. System Components

Each sensor node, as shown in figure IV.2, contains an Arduino board, a turbidity sensor, temperature sensor, Ph sensor and a nRF24l01 communication module. The base station node contains an Arduino and nRF24l01 communication module and it is connected to the PC through serial communication.
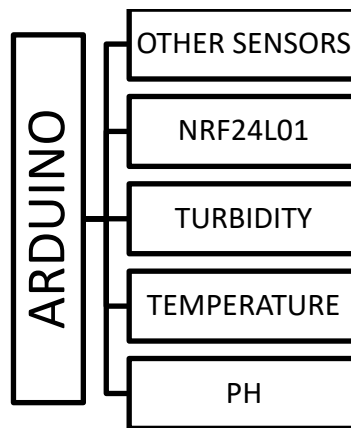
Fig IV.2 Node structure

IV. 3.1. Sensing Module :

This module consists of three most influencing water quality measuring sensors i.e pH sensor, turbidity sensor and temperature sensor. These sensors are connected to an Arduino board, for collecting data which is further sent to the base station at any request. nRf24l01 has been used for the communication purposes.

IV. 3.1.1 Ph Meter Sensor:

The unit that we use to measure the acidity of a substance is called ph. The term "H" is defined as the negative log of the hydrogen ion concentration. The range of pH can have values from 0 to 14. A pH value of 7 is neutral, as pure water has a pH value of exactly 7. Values lower than 7 are acidic and values greater than 7 are basic or alkaline.
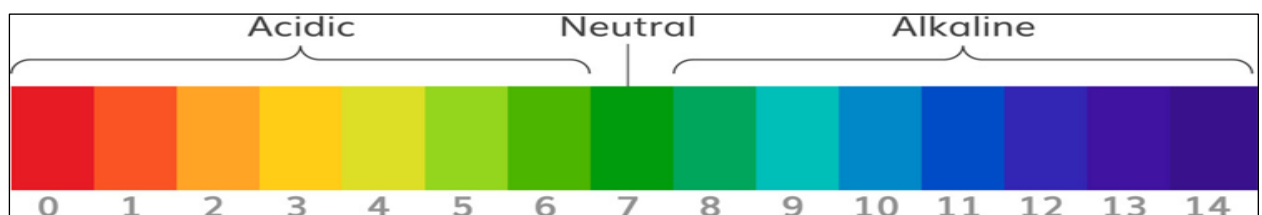
Fig IV.3 pH levels

Fig IV.4 pH meter electrodes
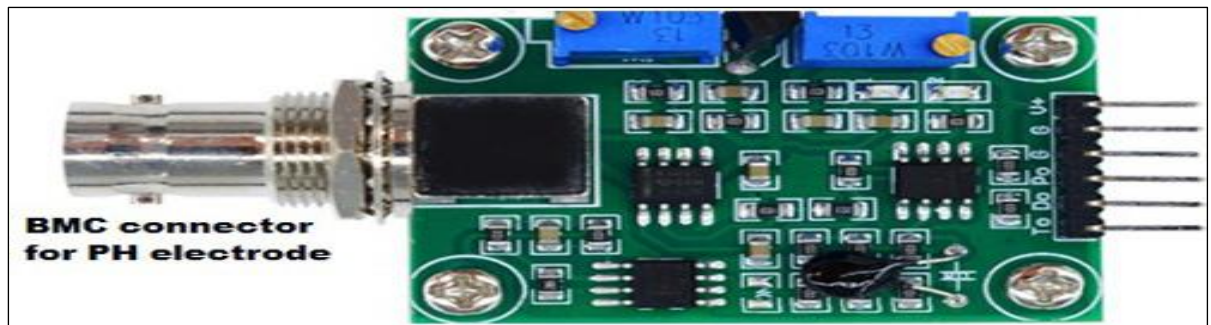
Fig IV.5 pH Signal Conversion Board

Pin Description:

V+: 5V DC input

G: Ground pin

Po: pH analog output

Do: 3.3V DC output

To: Temperature output

pH Electrode Structure:
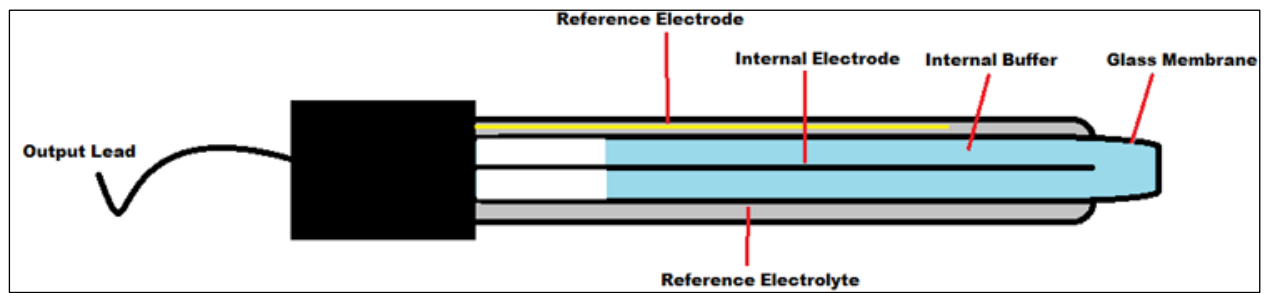
Fig IV.6 pH electrodes structure

The structure of a pH sensor is shown in figure IV.5. The pH Sensor looks like a rod usually made of a glass material having a tip called "Glass membrane". This membrane is filled with a buffer solution of known pH (typically pH = 7). This electrode design ensures an environment with the constant binding of H+ ions on the inside of the glass membrane. When the probe is dipped into the solution to be tested, hydrogen ions in the test solution start exchanging with other positively charged ions on the glass membrane, which creates an electrochemical potential across the membrane which is fed to the electronic amplifier module which measures the potential between both electrodes and converts it to pH units. The difference between these potentials determines the pH value based on the Nernst equation.

pH Sensor with Arduino, Circuit Diagram:
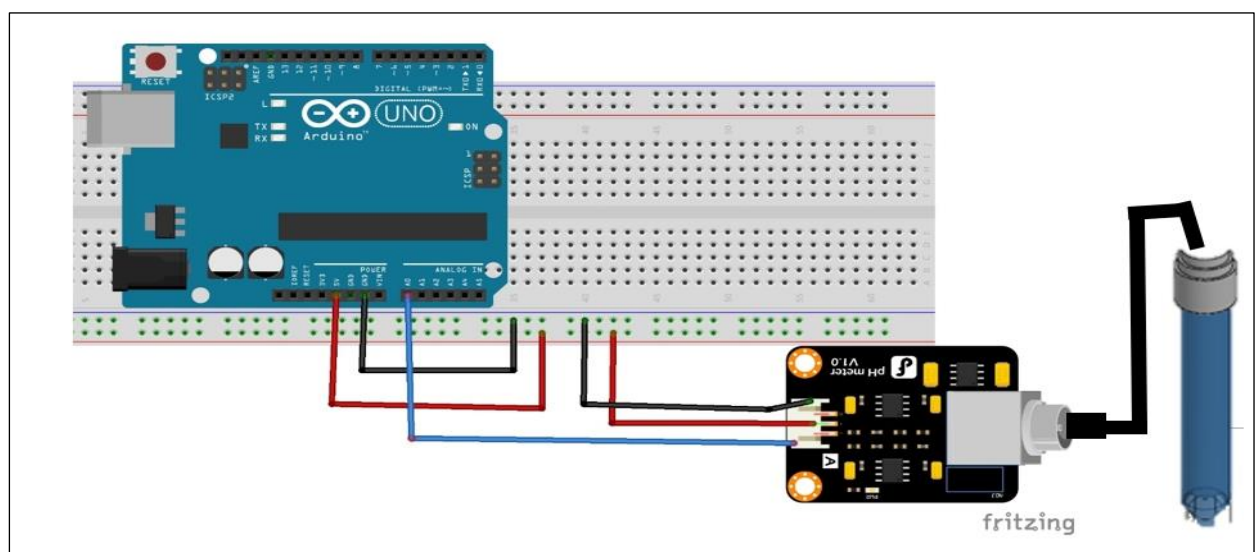
Fig IV.7 pH sensor Arduino

This Arduino code will read pH value from the pH Meter sensor.

```
#include <Wire.h>

float calibration_value = 21.34 - 0.7;
int phval = 0;
unsigned long int avgval;
int buffer_arr[10],temp;
float ph_act;

void setup()
{
  Wire.begin();
 Serial.begin(9600);
}
void loop() {
for(int i=0;i<10;i++)
 {
 buffer_arr[i]=analogRead(A0);
 delay(30);
 }
 for(int i=0;i<9;i++){
 for(int j=i+1;j<10;j++){
 if(buffer_arr[i]>buffer_arr[j]){
 temp=buffer_arr[i];
 buffer_arr[i]=buffer_arr[j];
 buffer_arr[j]=temp;
 }}}
 avgval=0;
 for(int i=2;i<8;i++)
 avgval+=buffer_arr[i];
 float volt=(float)avgval*5.0/1024/6;
 ph_act = -5.70 * volt + calibration_value;

}
```

IV. 3.1.2 Turbidity Sensor:

Water turbidity is an important measuring unit to determine water quality and describes the degree of water cloudiness.

Turbidity is caused by a huge number of small particles that are suspended in water and invisible to the human eye. While bigger particles are settling down rapidly, small particles – also known as colloids – are settling down very slowly or not at all
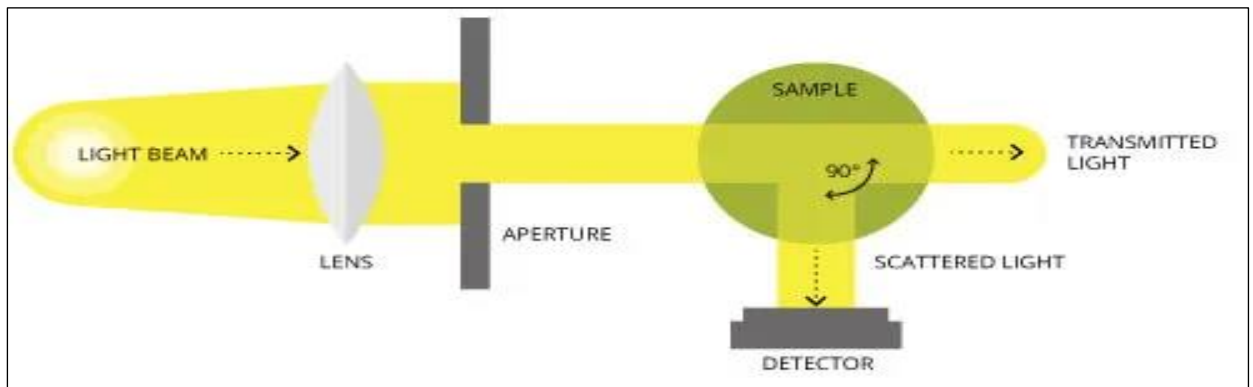
Fig IV.8 Operating principle of turbidity sensor

The turbidity sensor operates on the principle that when the light is passed through a sample of water, the amount of light transmitted through the sample is dependent on the amount of particles in the water. As the particle level increases, the amount of transmitted light decreases. The turbidity sensor measures the amount of transmitted light to determine the turbidity of the wash water.

Turbidity Sensor with Arduino, Circuit Diagram:
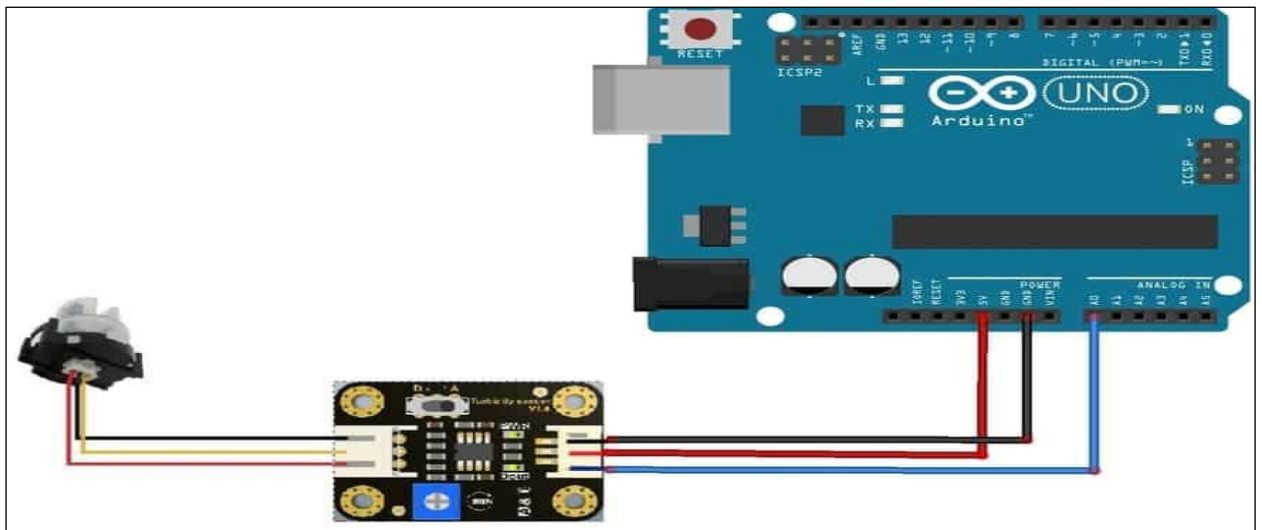
Fig IV.9 Turbidity sensor Arduino

S.N	Turbidity Sensor	Arduino UNO
1	VCC	5V
2	GND	GND
3	Data	A0

This Arduino code will read turbidity value from the Turbidity sensor.

```
#include <Wire.h>

int Turbidity_Sensor_Pin = A0;
float Turbidity_Sensor_Voltage;
int samples = 600;
float ntu; // Nephelometric Turbidity Units

void setup(){
  Serial.begin(9600); // for debugging purposes
  pinMode(Turbidity_Sensor_Pin, INPUT);
}

void loop()
{

   Turbidity_Sensor_Voltage = 0;

   for(int i=0; i<samples; i++)
   {
      Turbidity_Sensor_Voltage += ((float)analogRead(Turbidity_Sensor_Pin)/1023)*5;
   }

  Turbidity_Sensor_Voltage = Turbidity_Sensor_Voltage/samples;
  Turbidity_Sensor_Voltage=round_to_dp(Turbidity_Sensor_Voltage,2);

   if(Turbidity_Sensor_Voltage < 2.5){
     ntu = 3000;
    }else{
     ntu = -1120.4*square(Turbidity_Sensor_Voltage)+5742.3
*Turbidity_Sensor_Voltage - 4352.9;
    }
}
float round_to_dp( float in_value, int decimal_place )
{
 float multiplier = powf( 10.0f, decimal_place );
 in_value = roundf( in_value * multiplier ) / multiplier;
 return in_value;
}
```

IV. 3.1.3 Temperature Sensor:

Here we are using the pre-wired and waterproofed version of the DS18B20 sensor. This sensor is handy when you need to measure temperature in wet conditions. DS18B20 can measure the temperature between -55 to 125°C (-67°F to +257°F).

Fig IV.10 Circuit Diagram for DS18B20

S.N	DS18B20 Sensor	Arduino UNO
1	VCC	5V
2	GND	GND
3	Data	D2
4	4.7k ohm resistor	Between Data and VCC

DS18B20 Pins connection with Arduino

This Arduino code will read temperature value from the DS18B20 sensor.

```
#include <OneWire.h>
#include <DallasTemperature.h>

// Data wire is plugged into digital pin 2 on the Arduino
#define ONE_WIRE_BUS 2

// Setup a oneWire instance to communicate with any OneWire device
OneWire oneWire(ONE_WIRE_BUS);

// Pass oneWire reference to DallasTemperature library
DallasTemperature sensors(&oneWire);

void setup(void)
{
  sensors.begin();  // Start up the library
  Serial.begin(9600);
}

void loop(void)
{
  // Send the command to get temperatures
  sensors.requestTemperatures();
```

```
//print the temperature in Celsius
Serial.print("Temperature: ");
Serial.print(sensors.getTempCByIndex(0));
Serial.print((char)176);//shows degrees character
Serial.print("C | ");


delay(500);

}
```

IV. 3.2. Communication Module

The nRF24l01 module is used to transmit data from nodes to base station. The sensor node transmits data to the base station through the nRF24L01 wireless communication module, and the nRF24L01 wireless communication module of the base station is configured to receive data from the sensor node.
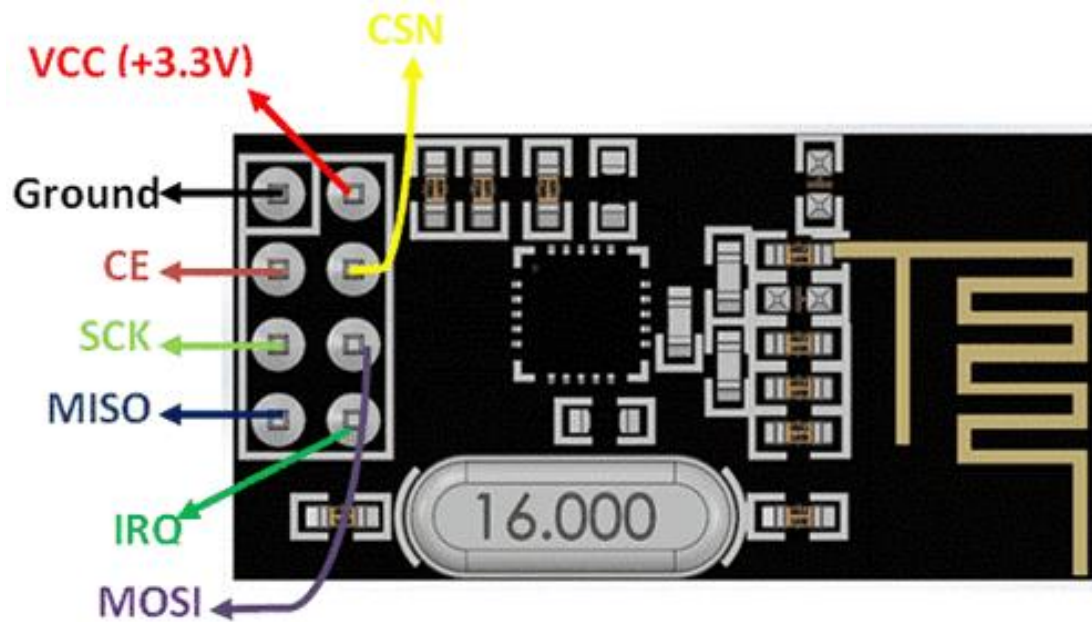
Fig IV.11 nRF24L01 wireless communication module

S.N	NRF24L01 Module	Arduino UNO
1	VCC	3.3V
2	GND	GND
3	CE	Pin 9
4	SCN/CSN	Pin 10
5	SCK	Pin 13
6	MOSI	Pin 11
7	MISO	Pin 12

Arduino Code to Transfer Data Using nRF24L01 to another nRF24L01.

```
#include <SPI.h> // Call SPI Library
#include <nRF24L01.h> // Call NRE Version Library
#include <RF24.h> // RF24 Header File
#include <RF24Network.h>

/*-----( Declare Constants and Pin Numbers )-----*/
#define CE_PIN   9
#define CSN_PIN 10


RF24 radio(CE_PIN, CSN_PIN); // Create a Radio
RF24Network network(radio);

const uint16_t this_node = 001;
const uint16_t other_node = 000;


void setup(){

  Wire.begin();
  Serial.begin(9600);
  radio.begin();//Intializing NRF24L01 Module
  network.begin(/*channel*/ 90, /*node address*/ this_node);

}

void loop(){

network.update();
  byte senderID = 1;
  noed noedt = {senderID, TempC, Ntu, Ph};

  RF24NetworkHeader header(/*to node*/ other_node);
  bool ok = network.write(header, &noedt, sizeof(noedt));

  Serial.println(ok);

```

Arduino Code to Receive Data Using nRF24L01.

```
#include <SPI.h>
#include <nRF24L01.h>
#include <RF24.h>
#include <RF24Network.h>

/*-----( Declare Constants and Pin Numbers )-----*/
#define CE_PIN   9
#define CSN_PIN 10

RF24 radio(CE_PIN, CSN_PIN); // Create a Radio
RF24Network network(radio);

const uint16_t this_node = 000;


void setup()
{
  Serial.begin(9600);
  SPI.begin();
  radio.begin();
  network.begin(/*channel*/ 90, /*node address*/ this_node);
}

void loop(){

network.update();

  while ( network.available()) {

    RF24NetworkHeader header;


    noed noedt;
    network.read(header, &noedt, sizeof(noedt));


  }

  delay(1000);

  }
```

IV. 3.2. Water Quality Monitor Software:

The base station is responsible for collecting data from the various sensor nodes, processing the data and transmitting it to a remote system or to cloud through the internet further processing or for simple storage.

In this project, we have designed software for data collection and data storage in the base station storage system. The software is designed using visual c#.

IV. 3.2.1. Software Description:

After Installing the Software, Application Interface will be like that:
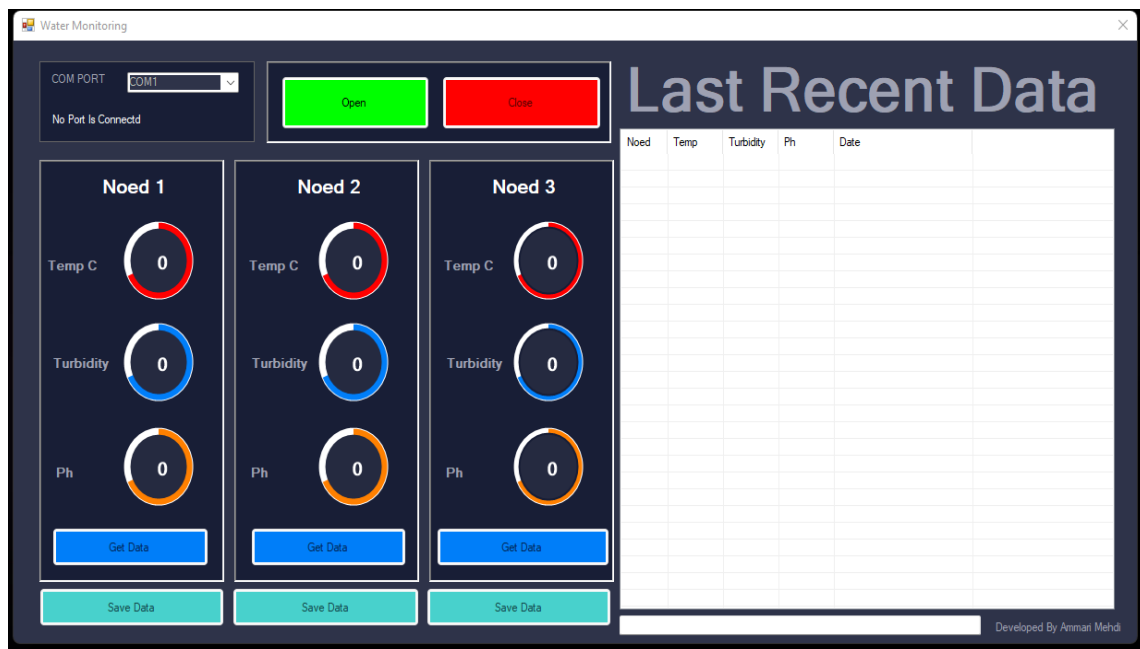
Fig IV.12. Water quality monitoring Software Interface
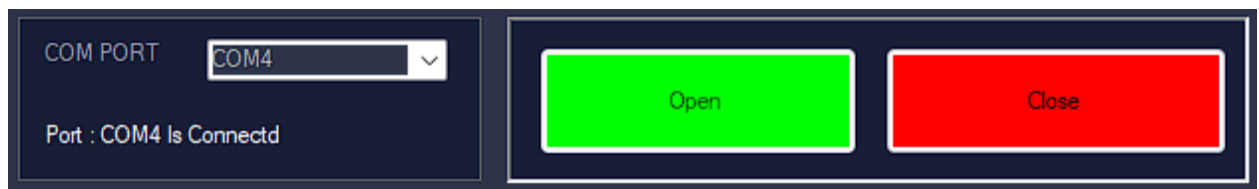
This Section Contain:

- ✓ Combo box with available COM Ports Connected with Software.
- ✓ Two buttons to connect or disconnect from selected Port.
- ✓ Text contains name of selected port and is connected or No.

This Section contains:

- ✓ Nodes available in software and in our case we have only 3 nodes.

Each node section contains:

Node Number

- ✓ Text and Progress bar contain Temperature value.
- ✓ Text and Progress bar contain Turbidity value.
- ✓ Text and Progress bar contain Ph meter value.
- ✓ Button to get data from serial.
- ✓ Button to save node sensors values to database.

This Section contains:

- ✓ Table for stored sensors values.
- ✓ Table values for each node like that form: (node number, temperature value, turbidity value, PH values, Date).

IV. 3.2.2. Software User's Guide :

The steps for using the software are described in the following steps:
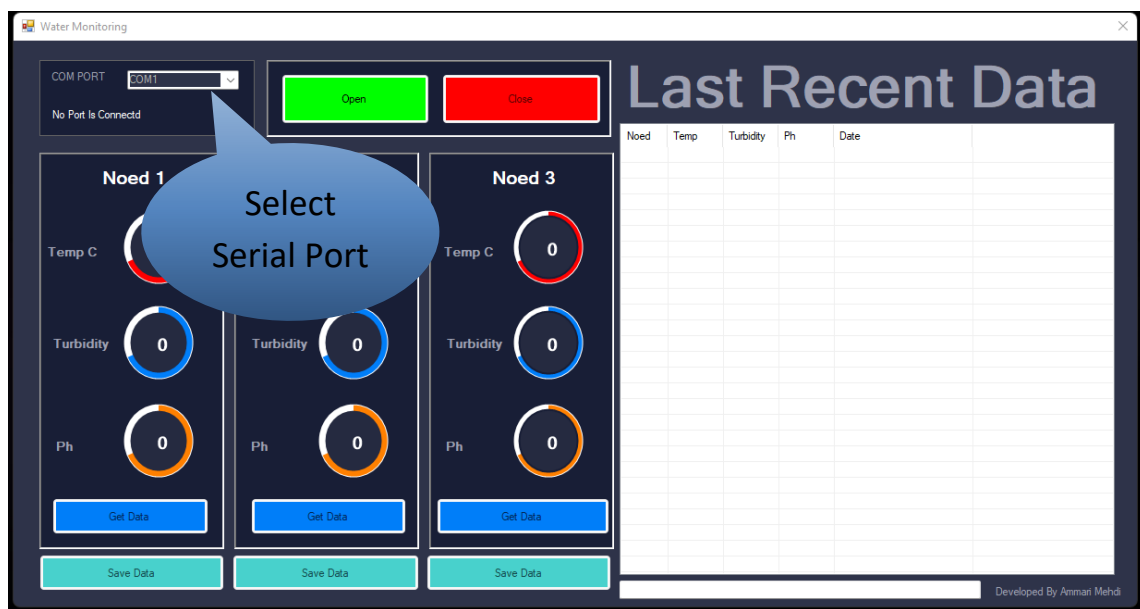
- ✓ Chose Serial Port from Combo Box

Software will store available Com Ports in Combo Box
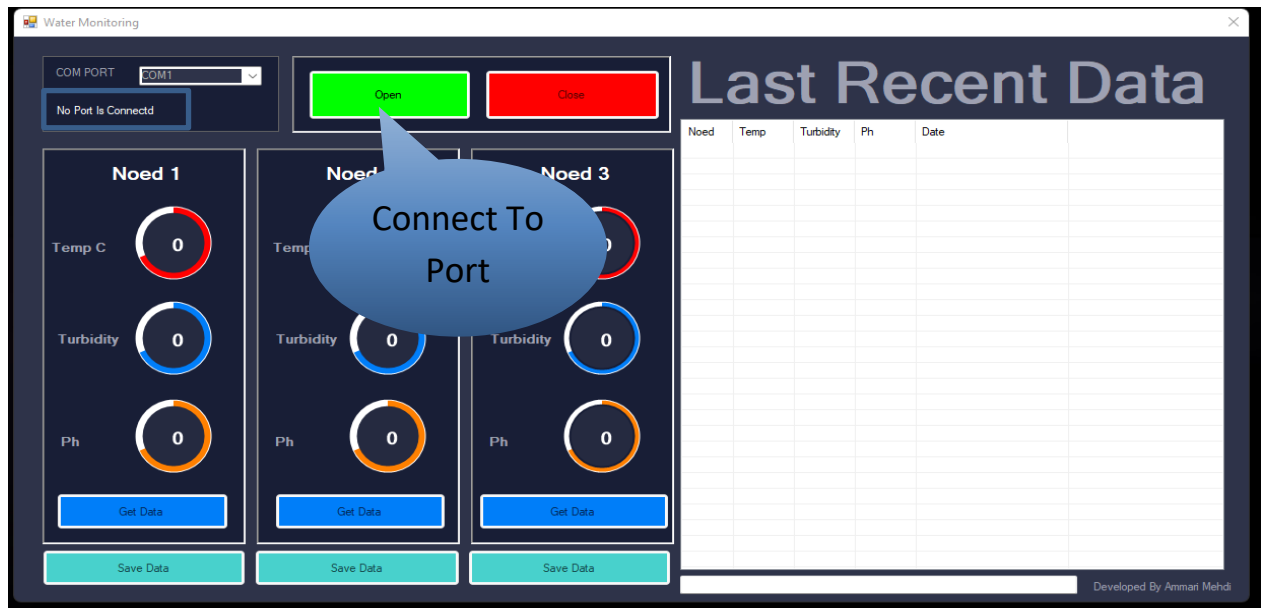
✓ Connect To Selected Port by Clicking Open Button.

Software will connect to Port, if connection is successfully the name of connected port will be shown as connected.

✓ Get Data from Serial by Clicking Get Data Button.

Software will get sensors values and show each value on progress bar, then save button will be enabled to save data to table.

✓ Save Data To Database by Clicking Save Data Button.

IV. 4. Conclusion

The water quality monitoring system is an important element of drinking water management and safety and a major factor affecting human health and safety. In an important social environment where material needs are progressively being met, more and more people are seeking to lead a healthy life, and the demands on water quality are increasingly high. We have designed this water quality monitoring system based on the Arduino board and the low power nRF24L01 wireless communication module. The system requires minimal wiring and has the advantages of good versatility, high practicality and stable performance. It can also realize wireless communication, and in the case of an external antenna, wireless communication within a range of 1000 meters can be realized.

General Conclusion

General conclusion

Water quality control is one of the basic operations that must be carried out at the present time. In this project, we have conducted a study that allowed us to discover and enhance our knowledge of communications and microcontrollers. To achieve this, we have implemented and designed a wireless sensor network based on NRF24L01 to send and receive data, which is designed for water quality monitoring.

In this project we have used only three parameters; turbidity, pH and turbidity since they are the only sensors available. Adding other sensors is simple and does not require much modification.

In this work, we were only interested in collecting data, the processing and analysis of the data to determine the presence of anomalies would be of great importance.

Furthermore, this WSN platform can be also expanded to the supervision and monitoring of other physical quantities in different fields.

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