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SCADA Monitoring on Radio Relayed Station at Hydro Melioration System Supported in Iot Network

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Abstract: In modern technological development, the commitment to the application of sophisticated electronic systems is noticeable not only in electric power plants but also in industries for healthy and quality food, such as agriculture. We witness daily tribunes and panel discussions sponsored by companies and even governments for the introduction of the terminology of digital agriculture, i.e. the introduction of smart electronic solutions in agriculture. In addition to the commitment to so-called green energy, i.e. obtaining energy from renewable sources, the development of digitization in agriculture is an area in which an enormous application of smart electronic systems is expected in the future. Guided by these reasons, in this paper an electronic system is designed that provides a solution to a problem in hydro melioration system, i.e. the development, design and practical implementation of the Smart electronic system which enables data exchange between the soil irrigation line, MASTER station with screen SCADA and SLAVE stations. The temperature and humidity on the soil and the air are measured in the irrigation line with electronic module SLAVE 1 station. The communication between the irrigation line (SLAVE 1) and the MASTER station is realized with RF network. The MASTER station is installed in one part on industrial plant and here is SCADA screen. The SLAVE 2 station is installed in another part on industrial plant. The SLAVE 2 station is connected by RF (radio frequency connection) to the SLAVE 1station and the same is connected with WIFI in IoT network. In the MASTER, SLAVE 1 and SLAVE 2 stations, microcontroller units as well as appropriate RF modules are installed. The microcontroller in the SLAVE 2 station is connected to the IoT microcontroller for the transfer of measurement data in the Internet network. The solution provides visualization, data log file, and transfer to the IoT network of process data on irrigation line in hydro melioration system.

Keywords: SCADA, Hydro melioration system, Exchange data, RF network, IoT network

Introduction

In modern agricultural production, implementing a monitoring and quality control system is considered essential, as supported by various studies (Fountas, 2020; Narendra, 2019; Narendra, 2019; Rotz, 2019 & Saiz-Rubio, 2020). Such systems should provide timely management of the quantities needed to obtain a quality product. On the other hand, these systems should provide the opportunity to collect and process data on control values in the agricultural plant, (Bennett, 1982; Hor, 2005). In real industrial agricultural processes, there are standalone plants that operate as independent self-contained units. Most often these plants are far from intra and internet network of the agricultural production companies. Therefore, there is a need to automate and connect these agricultural plants in the company intranet and more widely on the Internet (IoT) network. Efforts are made to ensure more reliable and simpler work, especially for operators who are directly exposed to the proper functioning of the entire industrial process. This approach to work is made possible by the so-called SCADA (**S**upervisory **C**ontrol and **D**ata **A**cquisition) system. On the other hand, a modern industrial process control system is truly comperhensive whrn it integrades not only SCADA but also connectivity to an IoT network, (Bhuiyan, 2023; Ariel, 2024 & Stefanov, 2021). Such a concept enables process data to be transferred to any location, real-time visualization, and stored on a personal and cloud computer.

Commonly, some standalone industrial agricultural processes might represent a separate entity. Since these plants are far from the Intra and Internet network of manufacturing companies, the data distribution of analog and digital signals from sensors and actuators of some process quantities (e.g. soil moisture, soil temperature and air temperature and humidity, voltage, current, pressure, flow and level water, etc.) must be made from these remote entities to the master station via wireless communication, most likely a radio frequency (RF) connection (Stefanov, 2021, 2023).

In this paper an electronic system is designed that provides a solution to a problem in hydro melioration system. Specifically, it presents the development, design and practical implementation of a smart electric system that enables data exchange between the soil irrigation line (SLAVE 1), a MASTER station equipped with a SCADA interface, and SLAVE 2 station connected to an IoT network.

Design of SCADA Monitoring for Radio- Relayed Station at Hydro Melioration System

The block diagram of one agriculture hydro melioration system is shown in Figure 1.

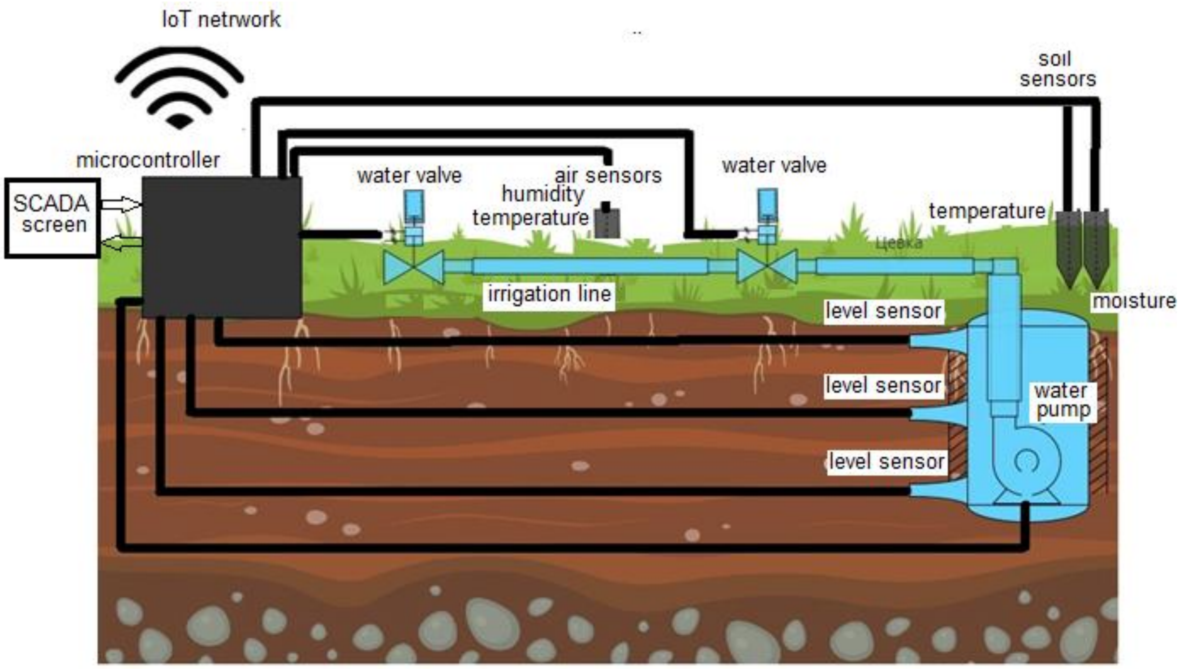


Figure 1. Block diagram of one agriculture hydro melioration system

Elements of this hydro melioration system are water pumps, irrigation lines, water valves, sensors for temperature and humidity of air and soil. These elements are controlled by a microcontroller. Based on the reference values of temperature and moisture, the microcomputer controlled with the water valves and maintains the optimal temperature and soil moisture required for the specific agricultural product. The microcontroller is connected to a SCADA screen for visualization of measured values as well as to IoT network for data distribution on the Internet. A problem or deficiency in such a sophisticated system stems from the need for soil moisture and temperature sensors to be at the end of the irrigation line. Under normal conditions this is solved by a cable connection between the sensors and the microcontroller. But these distances can be several hundred meters and that makes such solutions complex. Therefore, in this paper, a system is designed in which the connection between soil temperature and moisture sensors and the microcontroller is established via RF network.

In Figure 2, a block diagram of an implemented SCADA monitoring system for radio- relayed station within hydro melioration system integrated into an IoT network is shown.

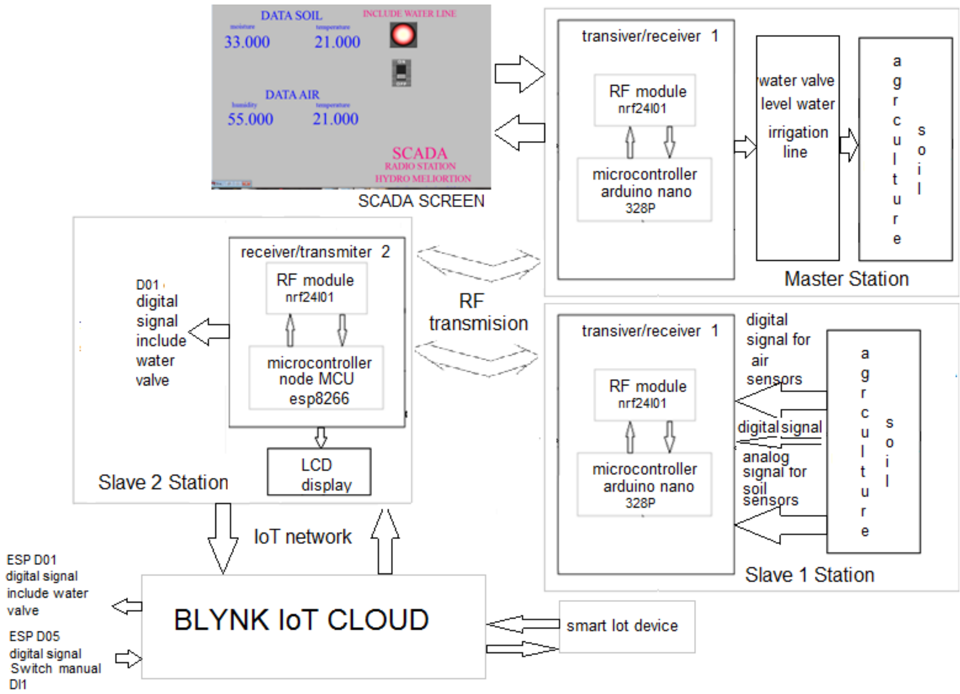


Figure 2. Block diagram of SCADA monitoring system for radio- relayed station at hydro melioration system in IoT network

This is block diagram illustrates the design and practical implementation of a smart electronic system that enables data exchange between the SLAVE 1 station, MASTER station equiped with a SCADA interface and the SLAVE 2 stations. The SLAVE 1 station is installed within the agriculture plant, where it collects real- time data from soil sensors and transmits it to the MASTER station. The temperature and humidity of the soil and the air are measured in SLAVE 1 station. The communication between SLAVE 1 and the MASTER station is via RF network. The MASTER station is installed in one part on agriculture industrial plant and is equipped with a SCADA screen for real- time monitoring and control of the system. The SLAVE 2 station is installed in another part on industrial plant. The SLAVE 2 station is connected via RF (radio frequency connection) to the SLAVE 1station but also it is connected to IoT network via Wi-Fi. In the MASTER, SLAVE 1 and SLAVE 2 stations, microcontroller units as well as appropriate RF modules are installed. The microcontroller in the SLAVE 2 station is connected to an IoT microcontroller in order to transfer the measurement data over the Internet network. The solution provides visualization, data log file, and transfer to the IoT network of process data on irrigation line in hydro melioration system. With this design concept, reliable transmission of soil moisture and temperature signals is obtained regardless of the distance between the sensor (SLAVE 1) and MASTER and SLAVE 2 stations.

In the designed SCADA system prototype, switches and LEDs were used as sensors and actuators to validate the correct operation of the solution. The microcontrollers in both the MASTER and SLAVE 1 stations are ATmega328P units mounted on Arduino Nano board (ATmega328P, 2015), (ESP8266, 2020). The microcomputer that enables the system’s connection to the IoT network is a NodeMCU ESP8266-12E (ESP8266, 2020) which is embedded in the SLAVE 2 station. The RF connection between the stations is established using the nRF24L01 module, (nRF24L01, 2020). The prototype system design includes the development of the SLAVE 1, MASTER and SLAVRE 2 stations as well as the design of the SCADA and IoT control system.

Design of the SLAVE 1 Station

In real industrial agricultured plants there are parts that are remote from intra and internet network. In such standalone plants there is often a challenge with timely collection, visualization, and analysis of signals from sensors that are critical for the proper functioning of industrial equipment. The designed RF SLAVE 1 - MASTER - SLAVE 2 network in this paper solves this issue by enabling the integration of sensor signals from standalone plants into the company's intra network. Figure 3 represents the block diagram of SLAVE 1 station which is a component of the system shown in Figure 2.

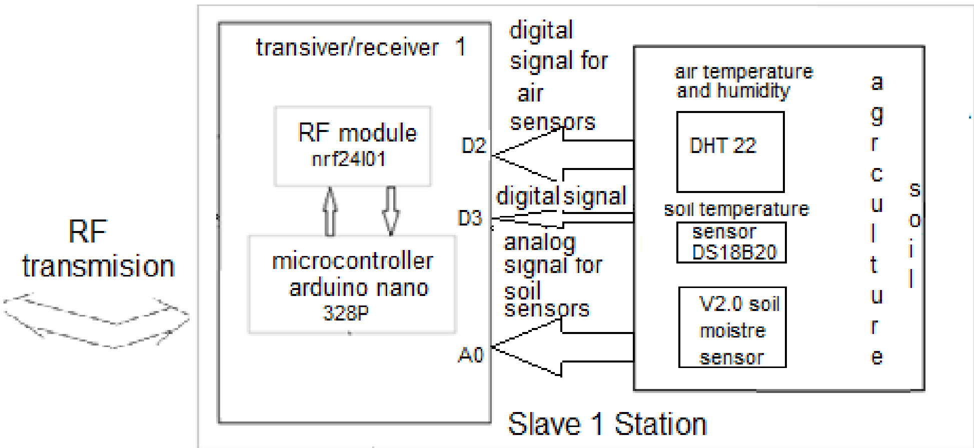


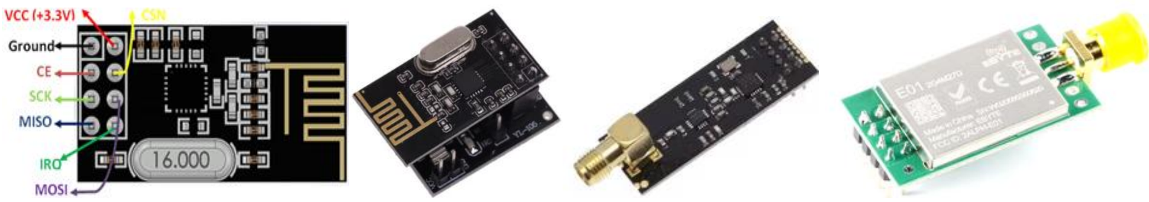
Figure 3. Block diagram of SLAVE 1 station

The SLAVE 1 station consists of a sensors network, RF module and microcontroller. The sensors network in SLAVE 1 station includes a soil moisture sensor V2.0, sensor a soil temperature sensor DS18B20, and air temperature sensor DHT 22. These sensors transmit their signals to Atmega328P microcontroller mounted on Arduino nano board. Specificaly, DHT 22 sends a digital signal to pin D2 for air temperature and humidity, DS18B20 sends a digital signalo to pin D3 for soil temperature and V2.0 soil moisture sensor sends an analog signal to pin A0. The microcontroller communicates serially with nRF24L01 RF module which transmits radio signals corresponging to the sensor data to the MASTER and SLAVE 2 stations.

Features of the Used Hardware

a.) nRF24L01 Module

The nRF24L01 is a single-chip radio transceiver module that operates in 2.4 - 2.5 GHz ISM band. It integrates a frequency synthesizer, a power amplifier, crystal oscillator, demodulator, modulator and Enhanced ShockBurs ™ protocol engine. Output power, frequency channels, and protocol setup are easily programmable through an SPI interface. Additionally, its built-in Power Down and Standby modes enables efficient power saving. Figure 4 shows several types of electronic boards based on nRF24L01 module.



a.) b.) c.) d.)
Figure 4. Electronic board of nRF24L01 module and his pinout

Figure 4(a) shows the basic nRF24L01 module along its pinout capable for communication up to distance to 100 m in open air conditions. Figure 4(b) shows the same module mounted on a socket for easier integration. Figure 4(c) shows an extended range version of the nRF24L01 module for distance up to 1.1km. Figure 4(d) includes wtho high- power modules E01-ML01DP5 with communication range up to 2500m and E01-2G4M27D (nRF24L01P+PA+LNA) for distance up to 5000m. Table 1 provides the pinout configuration of the nRF24L01 module.

Table 1. Pinout configuration of nRF2Ll01 module

Pin Number	**Pin Name**	**Abbreviation**	**Function**
1	Ground	Ground	Connected to the Ground of the system
2	Vcc	Power	Powers the module using 3.3V
3	CE	Chip Enable	Used to enable SPI communication
4	CSN	Ship Select Not	This pin has to be kept high always, else it will disable the SPI
5	SCK	Serial Clock	Provides the clock pulse using which the SPI communication works
6	MOSI	Master Out Slave In	Connected to MOSI pin of MCU, for the module to receive data from the MCU
7	MISO	Master In Slave Out	Connected to MISO pin of MCU, for the module to send data from the MCU
8	IRQ	Interrupt	It is an active low pin and is used only if interrupt is required

NRF24L01 Features:

- 2.4GHz RF transceiver Module
- Operating Voltage: 3.3V
- Nominal current: 50mA
- Range : 50 – 100 m
- Operating current: 250mA (maximum)
- Communication Protocol: SPI
- Baud Rate: 250 kbps - 2 Mbps.
- Channel Range: 125
- Maximum Pipelines/node : 6
- Low cost wireless solution

The nRF24L01 is a wireless transceiver module, meaning it can both transmit and receive data. The module's operating frequency is 2.4 GHz, which falls under the ISM band and hence making it legally usable in almost in all countries for engineering applications. When operating under optimal contiditions the module can cover a distances up to 100m (approximately 200 feet) making it an excellent choice for various wireless and remote-controlled projects.

The module operates at 3.3V making it compatible with both 3.2V and 5V systems. Each module has an address range up to 125 addresses and each module can communicate with 6 other modules simultaneously. Thic capability allows the formation of complex wireless comunications structures such as mesh networks or star networks making the nRF24L01 an ideal choice for practical and scalable wireless applications.

The communication with nRF24L01 module is achieved via SPI protocol. These modules can either be interfaced with 3.3V microcontroller or a 5V microcontrollers equipped with SPI port. Detailed instruction on interfacing and configuration is provided in the module's datasheet Figure 5 shows a typical circuit diagram for interfacing the nRF24L01 module with the microcontroller. Although the example demonstrates 3.3V microcontroller the same connection principle applies to 5V microcontroller. The SPI Pins (MISO, MOSI and SCK) are connected to the corresponding SPI pins on the microcontroller while the signal pins (CE and CSN) are connected to the GPIO pins of the MCU. Additionally, several ready-to-use libraries, such as R24 Library, are available for interfacing this module with Arduino.

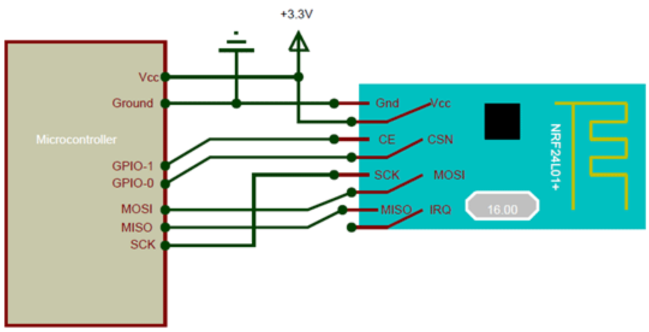
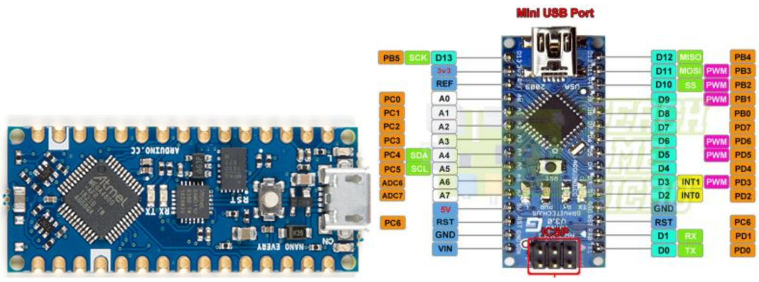


Figure 5. nRF24L01module interfaced with a microcomputer

With help of these available libraries nRF24L01can be easily interfaced with Arduino using jus a few lines of code. However, for other microcontrollers it is necessart to consult the module's datasheet to properly configure SPI communication. The nRF24L01module is a bit tricky to use especially since there are many cloned versions in the market. In case of troubleshoot, 10μF and 0.1μF capacitors should be added in parallel to source Vcc and GND pins. Also, the 3.3V power source must be clean and free of any noise as voltage fluctuation can cause module malfunction.

b.) Microcontroller ATmega 328P

The Arduino nano is an open- source microcontroller board based on the Microchip ATmega328P microcontroller developed by Arduino.cc. The board is equipped with sets of digital and analog input/output (I/O) pins that can be interfaced with various expansion boards (shields) and other external circuits. The board includes 14 digital I/O pins of which six capable to support PWM output, 8 analog I/O pins. Programming is done using Arduino IDE (Integrated Development Environment) via a type B USB cable. The Arduino nano can be powered by either through USB connection or an external 9V battery. The onboard ATmega328P microcontroller comes preprogrammed with a bootloader enabling code uploads without requiring an external hardware programmer, (Saiz-Rubio, 2020). In Figure 6(a) is shown Arduino nano board with build-in Atmega328P microcontroller, while in Figure 6(b) are shown its pinouts configuration.



a.) b.)

Figure 6. a.) Arduino Nano and b.) pinout

c.) DHT22 Temperature and Humidity Sensor

The DHT22 is a commonly used temperature and humidity sensors. The sensor comes with a dedicated NTC to measure temperature and an 8-bit microcontroller to output the values of temperature and humidity as serial data, (DHT22, n.d.). The connection diagram for this sensor is shown in Figure 7.

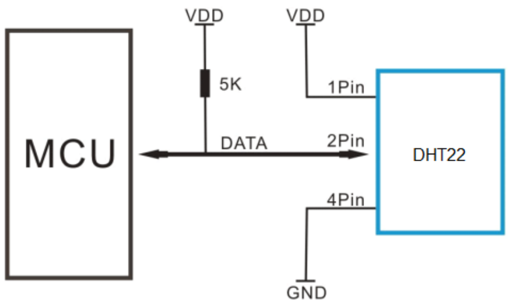


Figure 7. Connection diagram for DHT22 sensor

The DHT22 sensor is factory calibrated, making it easy ton interface with wide range of microcontrollers. The sensor can measure temperatures in range from 0°C to 50°C and relative humidity from 20% to 90% with an accuracy of ±1°C for temperature and ±1% for humidity. Since the DHT22 sensor outputs data in a serial digital format the setup is simple and requires minimal hardware. As shown in Figure 8 the data pin is connected to a I/O pin of the MCU through 5kΩ pull-up resistor. This single data line carries both temperature and humidity values in the following 40-bit format: 8-bit humidity integer + 8-bit humidity decimal +8-bit temperature integer + 8-bit temperature decimal and +8-bit parity bit (checksum). This sensor can be used for temperature and humidity measurement, local weather station, automatic climate control and environment monitoring. Figure 8 shows the actual size of the DHT22 sensor along with its pinout configuration.

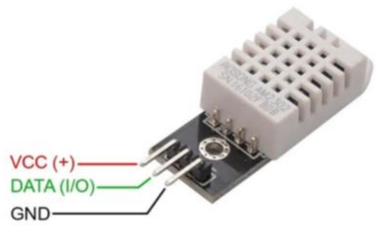


Figure 8. DHT22 sensor and its pinouts

DHT22 Specifications:

- Operating Voltage: 3.5V to 5.5V
- Operating current: 0.3mA (measuring) 60uA (standby)
- Output: Serial data
- Temperature Range: 0°C to 100°C
- Humidity Range: 20% to 100%
- Resolution: Temperature and Humidity both are 16-bit
- Accuracy: ±1°C and ±1%

The DHT22 sensor is available in two forms as a sensor or as a module. In both cases, the performance remains the same. The sensor comes in a 4-pin package, although only three pins are typically used in applications, whereas the module comes with 3- pin configuration. The key difference between the sensor and module is that the module version includes filtering capacitor and built-in resister making it easier to use directly with microcontrollers. In contrast, when using the sensor, these components must be added externally if are required.

d.) DS18B20 Temperature Sensor

The DS18B20 (Figure 9) is a digital temperature sensor manufactured by Maxim Integrated (formerly Dallas Semiconductor). It is widely used due to its reliability and ease of integration, offering a relatively high accuracy of ±0.5 °C across a broad temperature range from -55°C to + 125°C, (DS18B20, 2019).


Figure 9. DS18B20 temperature sensor

The DS18B20 sensor operates with a voltage range of 3.0 to 5.5V, making it compatible with both 5V systems like Arduino and 3.3V systems such as the ESP32 and Raspberry Pi. One of the key advantages is that it requires only a single digital I/O pin for communication, regardless of how many sensors are connected. The sensor communicates using the Dallas Semiconductor 1-wire protocol which is similar to I2C but offers lower data rates and longer communication range. Another advantage is that each DS18B20 sensor has a unique 64-bit serial code, which enables multiple sensors to be connected on the same 1-Wire bus without address conflicts. The the sensor's resolution can be set programmatically configured to 9, 10, 11, or 12 bits, correspoding This corresponds to temperature increments of 0.5°C, 0.25°C, 0.125°C, and 0.0635°C, respectively. By default, the sensor operates at 12-bit resolution upon power-up.

e.) V2.0 Soil Moisture Sensor

There are two main types of soil moisture sensors: capacitive and resistive soil moisture sensors. The reason for prefering capacitive sensor over resistive ones are explained below. In the Figure 10(a) is shown resistive soil moisture sensor, while in Figure 10(b) is shown capacitive soil moisture sensor.

a.) b.)

Figure 10. Soil moisture sensor: a.) resistive soil moisture sensor and b.) capacitive soil moisture sensor

Resistive Soil Moisture Sensor

The resistive soil moisture sensor consists of two metal probes that are inserted into soil to measure its volumetric water content. These probes allow a small electric current to pass through the soil and then the sensor measured the resulting resistance. When the soil contains a higher amount of water, the soil will conduct more electricity which results in lower resistance. This indicates a higher moisture level. Dry soil conducts electricity poorly, so when there will be less water, then the soil will conduct less electricity which leads to higher resistace and indicates a lower moisture level. This simple principle of conductivity makes resistive sensors easy to use, but their exposed metal components are prone to corrosion over time, reducing accuacy and durability of the sensor.

Capacitive Soil Moisture Sensor

The soil moisture sensor uses capacitive sensing to measure soil moisture levels unlike many other sensors on on the market that relay on resistive sensing. It is constructed from corrosion-resistant material which significantry enhances its durability and service life. By instaling the sensor into the soil around plants real-time soil moisture data is obtained. This module features an onboard voltage regulator giving it a wide operating voltage range of 3.3 to 5.5V.

While both types of sensor measure moisture-related properties, capacitive sensors offer clear addvantages. The major drawback of resistive sensors is the corrosion of metal probes, which occures not only to soil expouser but also because a constant DC current causes electrolysis. This drastically shortens the lifetime of the sensor. Capacitive sensors provide more reliable and consistent readings, as the measure the dielectric permittivity of the surrounding medium rather that just electrical resistace. Moisture changes the dielectric constant of the soil which the sensor detects. Water itself is not a good conductor; it's the dissolved ions (e.g. from fertilizer) that affect resistance. Therefore, resistive sensors can give false readings due to changes in ion concentration even if water content hasn't change. Capacitive sensing avoids this issue by measuring the overall dielectic which is more directly affected by actual water content. Thus, capacitive soil moisture sensors offer greater accuracy, stability, and longevity, making them the preferred choice for modern precision agriculture and gardening applications. Specifications of the capacitive sensor used in this application are:

- Operating Voltage: 3.3 ~ 5.5 VDC.
- Operating Current: 5mA.
- Interface: PH2.54-3P.
- Dimensions mm(LxWxH): 98 x 23 x 4.
- Supports 3-Pin Gravity Sensor interface
- Analog output.
- Weight (gm): 15.

Design of the MASTER Station

The block diagram of the MASTER station is shown in Figure 11.

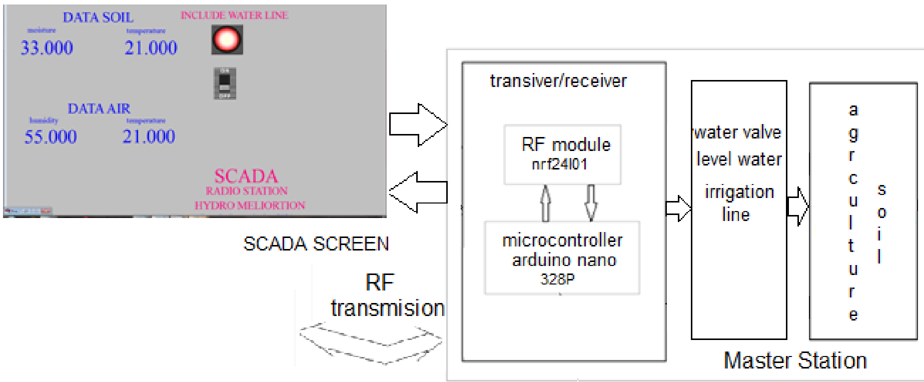


Figure 11. Block diagram of MASTER station

The design of the MASTER station includes ATmega328P microcontroller mounted on an Arduino nano board, nRF24L01 RF module and SCADA interface developed using CX-Supervisor and other necessary hardware components. The functionality of the MASTER station is defined by the following signal logic:

- D01: a digital output signal that is activated by user interaction with a virtual switch Dl1on the SCADA screen
- D02: a digital output signal which is activated automatically when the soil moisture level drops below a preferred threshold. An LED indicator is used to indicate this signal.

An essential component of the designed prototype SCADA system is CX-Supervisor, a powerful SCADA software package developed by Omron.

Design of the SCADA

SCADA is developed using Omron CX-Supervisor software, a platform specifically designed for PC- based visualization and machine control. CX- Supervision is suitable for both simple and highly complex supervisory control tasks. It offers powerful functions for a wide range of PC-based HMI requirements. For rapid development of basic applications, it provides numerous predefined functions and libraries. CX-Supervisor has extremely simple, intuitive handling and high user friendliness. CX-Supervisor runs standard PC desktop computers running Microsoft Windows. CX-Supervisor is intuitive and easy to use, and allows the developer to rapidly configure, test and debug a project. CX-Supervisor comprises two separate executable Windows programs, CX-Supervisor Development environment and CX-Supervisor Runtime environment. Applications are created and tested using the development environment and then delivered as a final customer application with the runtime environment. The runtime-only environment may only be used for executing an application previously generated using the development environment. It is not possible to generate a new runtime application using the runtime environment. In Figure 12, there is shown connection between sensor hardware, microcontroller and CX-Supervisor SCADA.

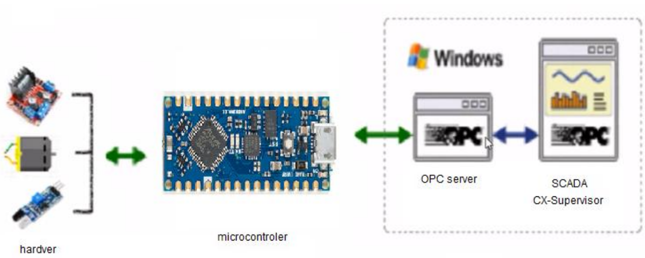


Figure 12. Connection between sensor hardware, microcontroller and CX-Supervisor SCADA

Setting up Graphic Symbols

The intial step in building the SCADA interface involves configuring the graphical symbols. After the project is created and its associated interface page is prepared, various graphical elements, such as indicators, buttons and control panels, can be designed and integrated into the page layout as illustrated in Figure 13.

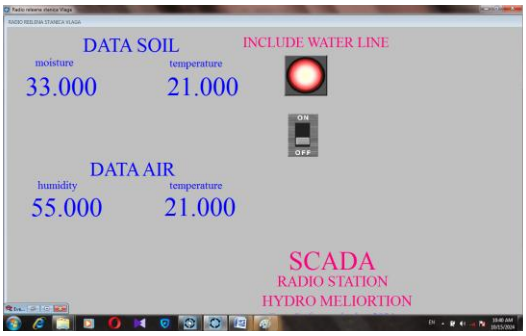


Figure 13. Setting graphic symbols

The graphics editor in CX- Supercisor uses a Graphic Object Toolbar and a floating window known as the Palette to construct and control objects within the project interface. These tools are user-friendly and intuitive. Several small icons are visible on the Graphic Object toolbar, each representing a different graphical object that can be used to build the application interface. Some of these objects are graphical primitives, such as straight lines, ellipses, rectangles, while others are more advanced like the gauge object, which includes built-in functionality for visualization and control.

Design of the SLAVE 2 Station

Figure 14 represents the block diagram of SLAVE 2 station, which represents a subsystem of the overall architecture shown in Figure 2.

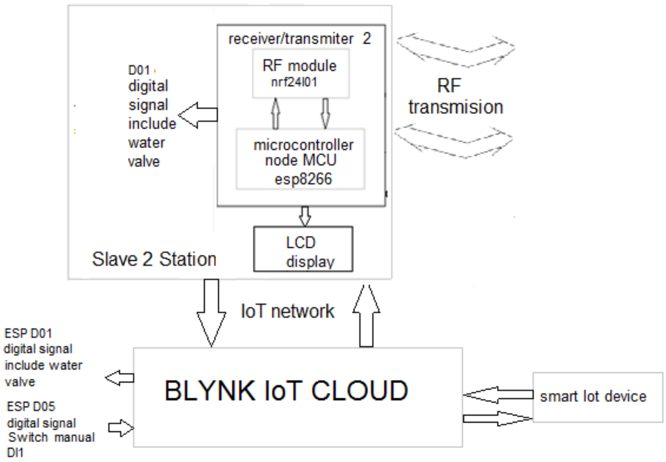
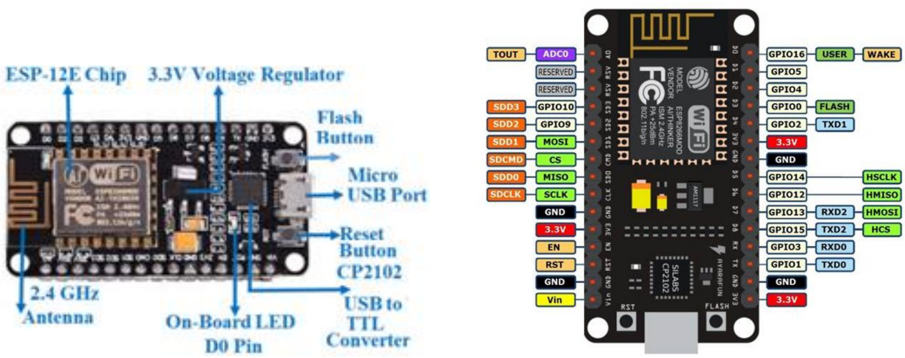


Figure 14. Block diagram of SLAVE 2 station

The SLAVE 2 station consists of an RF module, NodeMCU ESP8266 microcontroller and 20x4 LCD display.

NodeMCU ESP8266-12E



a.) b.)
Figure 15. a.) NodeMCU ESP8266 and b.) pinouts

This NodeMCU is a development board based on ESP-12E module containing ESP8266 chip featuring Tensilica Xtensa 32-bit LX106 RISC microprocessor, (ESP8266, 2020). This microprocessor supports real-time operating systems (RTOS) and operates at adjustable clock frequency ranging from 80MHz to 160 MHz. The NodeMCU is equipped with 128 KB of RAM and 4MB of Flash memory for storing data and programs. Its high processing power with built-in Wi-Fi / Bluetooth capabilities, as well as support for Deep Sleep make it ideal for IoT projects. The board can be powered via Micro USB jack or VIN pin (for external supply pin). Additionally, it supports a range of communication interfaces including UART, SPI, and I^2C interface. Figure 15 shows the NodeMCU ESP8266 along with its pinouts. NodeMCU is an open-source firmware and development board specifically designed for IoT-based applications. It includes firmware that runs on the ESP8266 WIFI SoC developed by Espress Systems, and hardware based on the ESP-12 module.

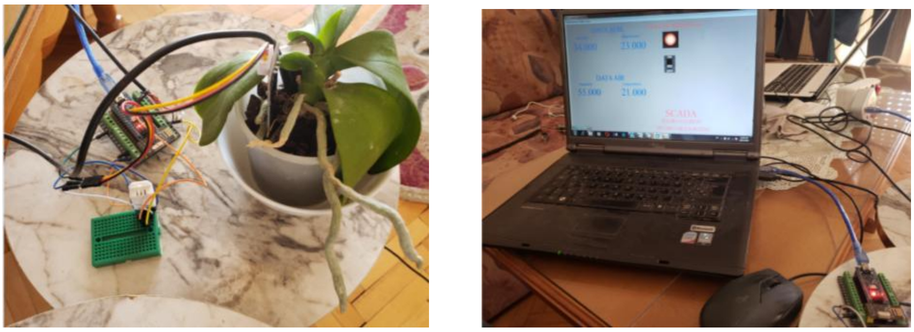
NodeMCU ESP8266 specifications &features

- Microcontroller: Tensilica 32-bit RISC CPU Xtensa LX106
- Operating Voltage: 3.3V
- Input Voltage: 7-12V
- Digital I/O Pins (DIO): 16
- Analog Input Pins (ADC): 1
- UARTs: 1
- SPIs: 1
- I2Cs: 1
- Flash Memory: 4 MB
- SRAM: 64 KB
- Clock Speed: 80 MHz
- USB-TTL based on CP2102 is included onboard, Enabling Plug n Play
- PCB Antenna
- Small Sized module to fit smartly inside your IoT projects

The NodeMCU ESP8266 board can be easily programmed with Arduino IDE since it is easy to use.

Experimental Results

Figure 16 shows the prototype on the SLAVE 1 station, and Figure 16 b shows the prototype on the MASTER station.



a) b)

Figure 16. Prototype on design SCADA monitoring data system: a) prototype on SLAVE station, b) prototype on MASTER station

From Figure 16(a) it can be seen that the DS18B20 soil temperature sensors, the V2.0 soil moisture sensor and the DHT22 air humidity and temperature sensor are connected to the Arduino Nano board. Figure 16(b) illustrates the connection between the MASTER station implemented using an Arduino Nano board and the SCADA screen. The waveforms of the measured values obtained in real-time in CX Supervision are represented in Figure 17. The blue line in the waveforms shown in Figure 17 represents the humidity on air, the yellow line is the moisture on soil, the green is soil temperature while the red line is the temperature on air. A sample of the data log file for the measured values obtained in CX Supervision is represented in Figure 18.

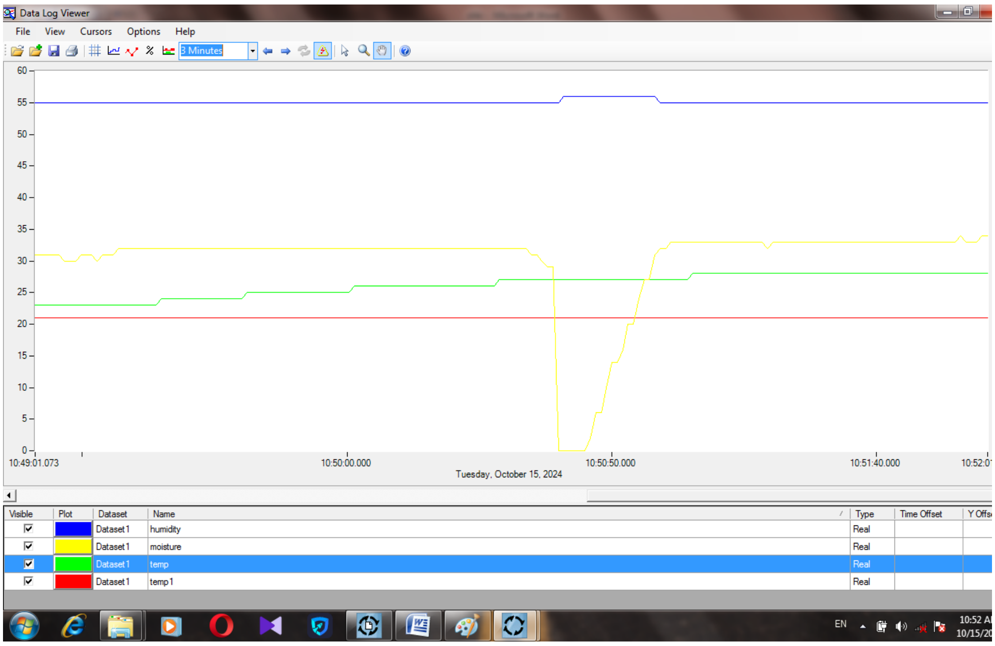
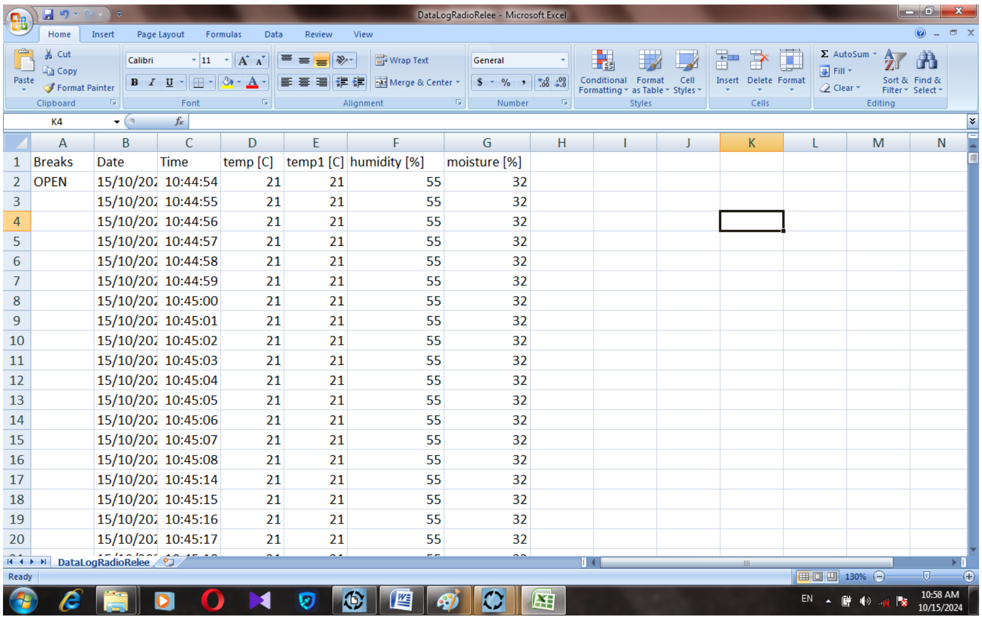
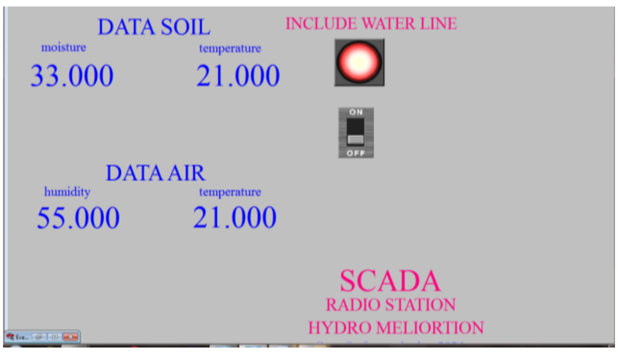


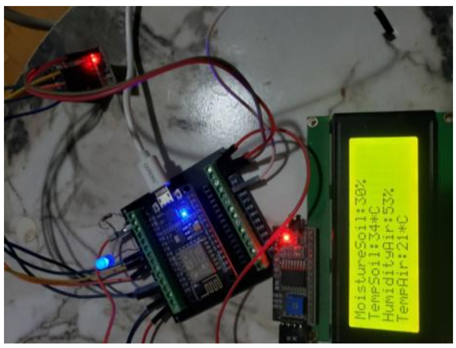
Figure 17. The waveforms of the measured values in real time



	A	B	C	D	E	F	G
1	Breaks	Date	Time	temp [C]	temp1 [C]	humidity [%]	moisture [%]
2	OPEN	15/10/202	10:44:54	21	21	55	32
3		15/10/202	10:44:55	21	21	55	32
4		15/10/202	10:44:56	21	21	55	32
5		15/10/202	10:44:57	21	21	55	32
6		15/10/202	10:44:58	21	21	55	32
7		15/10/202	10:44:59	21	21	55	32
8		15/10/202	10:45:00	21	21	55	32
9		15/10/202	10:45:01	21	21	55	32
10		15/10/202	10:45:02	21	21	55	32
11		15/10/202	10:45:03	21	21	55	32
12		15/10/202	10:45:04	21	21	55	32
13		15/10/202	10:45:05	21	21	55	32
14		15/10/202	10:45:06	21	21	55	32
15		15/10/202	10:45:07	21	21	55	32
16		15/10/202	10:45:08	21	21	55	32
17		15/10/202	10:45:14	21	21	55	32
18		15/10/202	10:45:15	21	21	55	32
19		15/10/202	10:45:16	21	21	55	32
20		15/10/202	10:45:17	21	21	55	32

Figure 18. Data log file of measured value

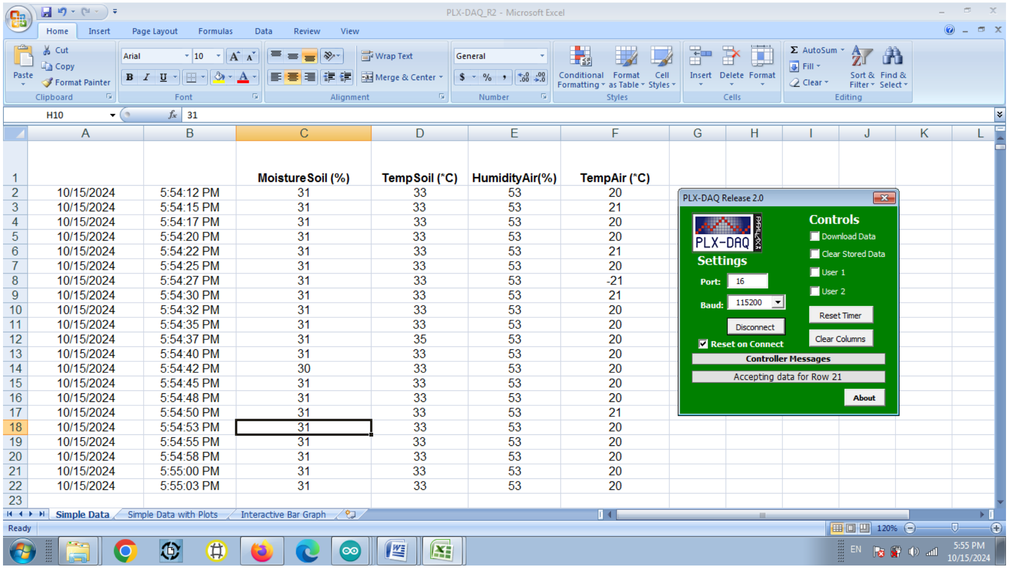




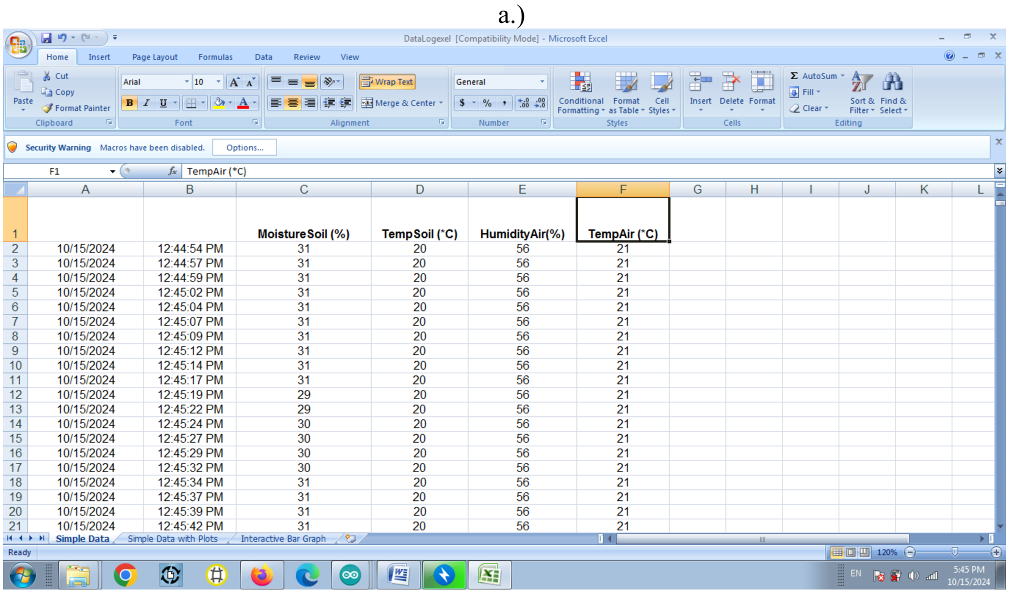
a.) b.)

Figure 19. a) Screen of the design SCADA exchange radio station and b) prototypes on SLAVE 2

Figure 19(a) shows the interface screen of the SCADA exchange radio station design, while Figure 19(b) displays the prototype of the SLAVE 2 station. SLAVE 2 station visualizes the measured values on an LCD screen, creates a data log file in Excel on the connected personal computer and sends the data to the Blink Cloud IoT network, (Blynk, 2025). Figure 20 a, show a screenshot of the data log file on the personal computer connected to the SLAVE 2 station, and Figure 20 b shows a screen of the data log file in the Blink cloud.

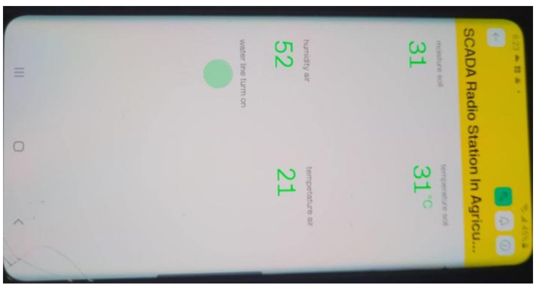


a.)

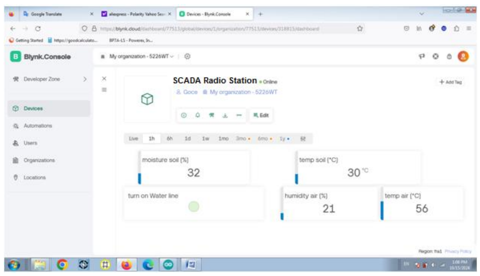


b.)

Figure 20. Screenshot: a.) Screen of the data log file from the personal computer connected to the SLAVE 2 station and b.) Screen of the data log file in the Blink cloud



a)



b)

Figure 12. Data transmission from the SCADA radio Station within IoT network: a) screen display on mobile device, b) interface on IoT Blynk cloud network

Figure 21(a) shows a data screen on a mobile device showing information transferred from a SCADA Radio station data system within IoT network, and Figure 21(b) represents the correcponding screen on the IoT Blynk cloud network (Microchip, n.d.).

Analysis of the Results

The solution in the paper provides an opportunity to apply a smart electronic system in agriculture. In the paper, the main benefit is the radio transmission of moisture and temperature signals from the irrigation line to the MASTER station. This eliminates the need for a wired connection of the sensors to the MASTER station. The used RF modules have been tested and enable radio transmission of process data from 100 to 5000m SCADA monitoring of process data is built into the MASTER station with support for waveforms of real-time quantities as well as a data log file for them. A radio connection was established among three points: SLAVE 1, MASTER and SLAVE 2. In the SLAVE 2 station, an IoT microcontroller is built-in, which enables the transmission of measurement data in the Internet network. The SLAVE 2 station allows the measurement data to be stored in a data log file on a personal computer connected to the microcontroller, as well as a data log file on the Blynk IoT cloud. The implemented system provides storage of measurement data in three data log files, in SCADA at the MASTER station as well as in two data log files at the SLAVE 2 station (on the local PC and on the IoT Blink Cloud).

Conclusion

This paper presents the design and experimental deployed prototype on SCADA radio relay station for data transmission in agriculture plants. A solution was implemented that enables RF communication between the soil sensors located in the irrigation line and the control room, where the main electronic equipment and the internet connection hardware are located. The tested nRF24L01 modules provide the possibility of remote wireless transmission of signals from 100m up to 5km in open air. The SLAVE 1 stations receive both digital and analog signals from soil and air sensors and transmit them to MASTER and SLAVE 2 stations. The SCADA system visualizes the data from SLAVE 1 on the control room screen, while SLAVE 2 displays the data on a local LCD and sends it IoT cloud computers and mobile smart devices (mobile telephone, tablet, etc.). To ensure data integrity, three data log files have been generated, one stored in the MASTER station and two stored in the SLAVE 2 station.

Scientific Ethics Declaration

* The authors declare that the scientific ethical and legal responsibility of this article published in EPSTEM journal belongs to the authors.

Conflict of Interest

*The author declares that there is no conflict of interest.

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