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Ternopil Ivan Puluj National Technical University

Faculty Of Computer Information Systems and Software Engineering
(Full name of faculty)
Computer Systems and Networks Department
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TIME SCHEDULE

LN	Paper stages	Paper stages deadlines	Notes
1	*Analysis of technical task.*		
2	*Analysis of characteristics of the object.*		
3	*Methods and means of measuring parameters microclimate*		
4	*Formation of hardware platform and data transfer interfaces.*		
5	*Description of the software implementation.*		
6	*Occupational safety and health.*		
7	*Graphic materials.*		
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ABSTRACT

Multifunctional software-hardware module for management and monitoring of the microclimate for a residential object //Qualifying paper // Obaidiku Augustine Raheem // Ternopil Ivan Puluj National Technical University, Faculty of Computer Information Systems and Software Engineering, group ICI-62 //Ternopil, 2021 // p. - 88, fig. - 25, tables- 5, code snip. - 1, append. - 2, bibliography - 17.

Key words: microclimate, information system, monitoring of microclimate parameters, software, software and hardware module for monitoring climatic indicators.

The purpose of the work is to develop a software and hardware module for monitoring of the parameters of the microclimate of the building and the environment.

Theoretical and practical aspects of software and hardware module of development for monitoring of building microclimate parameters were considered in the work. The choice of means of software development of the hardware and software complex is substantiated.

During the research were carried out: research of areas of application of the system of measurements of environmental parameters, formation of requirements to the system of measurements, development of structure and software of the system.

In the course of this work, a software and hardware module for monitoring of the parameters of the microclimate was developed and implemented, which measures the ambient temperature, relative humidity and atmospheric pressure without human intervention.

TABLE OF CONTENT

LIST OF SYMBOLS

JSON	—	JavaScript object notation
UI	—	User interface
HTTPS	—	Hypertext Transfer Protocol Secure
UML	—	Unified modeling language
DHT	—	Distributed hash table
MQTT	—	Message Queue Telemetry Transport
TCP	—	Transmission Control Protocol

INTRODUCTION

The microclimate in buildings has a great influence on the human body. It includes such physical parameters as temperature, relative humidity, atmospheric pressure, air velocity and thermal radiation of objects. Microclimate is a combination of physical parameters that affect the exchange of human thermal energy with the environment [1].

The need to obtain information about the current state of the microclimate of the building arises in the control of working conditions, production and storage of products in the premises.

High temperatures contribute to rapid fatigue of the worker and can lead to heat stroke, and prolonged exposure - the disease. On the other hand, low temperatures can cause colds.

At high temperatures and relative humidity contributes to overheating of the human body. At low temperatures - increases heat transfer from the skin surface, which leads to hypothermia. Also, low humidity causes drying of human mucous membranes.

The speed of air flow promotes heat transfer by the human body and has a positive effect at high temperatures and negatively at low temperatures.

The traditional approach to monitoring climate parameters using portable or wall-mounted devices with the need to record readings manually is inefficient and often extremely difficult in terms of time spent by staff. In addition, manual monitoring is not without the influence of human factors.

The object of study - the process of monitoring the parameters of the microclimate, which without human intervention measures ambient temperature, relative humidity and atmospheric pressure.

Subject of research - models, methods and means of building hardware and software of the microclimate control system.

Research methods. Used to solve the tasks the following methods:

- analysis and generalization - when conducting a survey and analysis of varieties microclimate control systems and methods of their control, analyzed the influence of the parameters of the microclimate.

- mathematical modeling - in the development of mathematical providing of the system,

- design and programming - in the development of hardware and software component of the microclimate control system;

- experiment and measurement - to test the results qualification work.

The aim of the work is to develop a software and hardware module for monitoring the parameters of the microclimate of the building and the environment.

The main task of the microclimate control system is to continuously automatically monitor the parameters of the microclimate of the building and the environment and store them in a single database.

To achieve this goal, it is necessary to perform the following tasks:

1. Analyze existing monitoring software applications microclimate parameters in order to form requirements for the development of a new one system;

2. Develop the architecture and functionality of the software application monitoring of microclimate parameters;

3. Analyze tools and libraries for implementation the proposed architecture that would ensure mobility, scalability, multichannel;

4. Develop a software and hardware module for monitoring parameters microclimate of the building and the environment;

5. Develop test cases for testing the software and hardware module.

Scientific novelty of the obtained results. First developed and analytically described hardware and software for monitoring microclimate parameters.

The practical significance of the results. The hardware and software of the computer microclimate control system allows you to automatically collect, process and transmit information to the data center. It is possible to quickly add new devices. Implemented the ability to transfer information to remote devices via Ethernet

Publications. The results of the master's qualification work were presented at the International Scientific Conference "Science as a Social Network" (Kyiv, 2021). Also published an article in the international scientific journal "Bulletin of Science" (№36, Odessa, 2021).

Structure of work. The work consists of an explanatory note and a graphic part. The explanatory note consists of an introduction, five chapters, conclusions, a list of sources and appendices.

CHAPTER 1
ANALYSIS OF EXISTING SOFTWARE ADDITIONS FOR MONITORING OF MICROCLIMATE PARAMETERS BUILDINGS

1.1. The need to create comfortable indoor conditions

Creating comfortable conditions indoors is an important social task, because the internal environment directly affects the human condition.

Microclimate is a set of air factors that reflects the impact on heat transfer of the human body indoors [2].

In residential and public buildings, it is important to ensure the most optimal microclimate parameters for a particular area.

The main parameters that can characterize the indoor microclimate are:

-air humidity;

-air temperature;

-Speed of air movement.

Necessary microclimate parameters: optimal, permissible or their combination should be set depending on the purpose of the premises and the period of the year, taking into account the requirements of relevant regulations.

Optimal and permissible microclimate parameters in the service area of residential premises should be taken for the relevant period of the year within the values of the parameters.

1.2. Analysis of existing means of control of climatic indicators indoors

The problem of ensuring indoor air quality remains one of the most pressing in recent decades.

Climate control systems are used to maintain and change the parameters of temperature, humidity and fresh air circulation indoors.

Modern climate control systems are quite complex automatic control systems that maintain air parameters in controlled volumes within specified limits on the basis of signals from temperature and humidity sensors.

The paper describes the system of temperature and humidity control in the room by means of wireless technology of transmission of measuring information. This remote monitoring system is based on the software and hardware of the Arduino platform with Atmega328P microcontroller [3].

The DHT21 sensor chip is used as a temperature and humidity sensor because it has higher metrological characteristics. Data transfer from the sensor to the PC is implemented using the principle of code-pulse modulation.

The transmitter of the measuring radio channel 433 MHz is made on a typical circuit and has an output power at a load equivalent of 50 Ohms to 15 mW.

This system of monitoring the climatic conditions of the server room performs measurements and transmits measurement information to the system administrator's console.

The microcontroller, in turn, on the receiving side processes the received information with the subsequent output on the monitor and the device. At the time of recording the critical temperature or humidity, the acoustic warning device is activated.

In addition to the system described above, there is another option to ensure climate control in the room. To implement this project in the main elements of the device are the microcontroller AVR Atmega8515 and temperature sensor DS18B20 [4].

The principle of operation of this device is as follows: when you turn on the device, the display shows information about the connected temperature sensors. The readings from the sensors are then displayed.

This is followed by a comparison of the ambient temperature with the temperature that must be maintained indoors. At the analysis of this indicator the decision which allows to include the conditioner or a heating element if necessary is deduced. The temperature to be maintained in the room is set programmatically.

In order to maintain the necessary climatic regime in the room was developed a system of local control and monitoring of temperature and humidity. The local system is developed under the control of the Arduino microcontroller UNO, and as a sensor of temperature and humidity used DHT22 due to its small error and large range of reading data. To work with this system, it must be connected to a computer via USB port and run appropriate program.

The system transmits data online and sends updated data to the screen with an interval of about two seconds. The data collected after starting the program is stored until the user closes it. To track changes, you can view graphs of changes in temperature and humidity over time. In addition, the system can connect an audible alarm, which allows you to warn the user if you exceed the specified standards.

It is also possible to connect thermostats, dehumidifiers or humidifiers, which will work automatically, maintaining user-defined temperatures and humidity.

In addition to the climate control systems described above, there is a device that allows remote monitoring of the environment based on wireless sensor network technology.

This utility model is designed for continuous monitoring of temperature, humidity, lighting in the atmosphere, residential and industrial premises.

The device comprises at least one temperature sensor, light signaling unit, control system, variable programmable module consisting of a microcontroller, external memory and a receiver connected to an interface unit which is connected to at least the sensor output, a device with connection to a personal computer, as well as the power supply unit [5].

The main advantages of this device are low power consumption and high speed, due to the processing of micro-controller signals received in real time with a temperature sensor. Thanks to the universalization and the possibility of autonomous operation of the device, you can work with different types of temperature sensors without changing its structure and as part of the sensor network can perform remote monitoring in hard-to-reach places.

1.3. Generalization of analysis results and setting research objectives

There is an urgent problem of providing individual temperature and humidity in different rooms, especially in the rooms of the third group, which are characterized by a high coefficient of thermal energy.

The main disadvantage of the following devices is the lack of a universal software and hardware platform for implementing applications based on sensor network technology. This disadvantage is significant in cases where it is necessary to implement continuous monitoring of climate indicators. Also one of the most important disadvantages is the difficulty in using and providing power to devices. Therefore, to ensure uninterrupted operation, it is advisable to use external power.

Analysis of the state of the issue shows that to date there is no effective solution to the problem of providing comfortable temperature conditions in the premises.

1.4. Requirements for the software module for monitoring the parameters of the building

Based on the possible areas of application of the system of measuring environmental parameters, we can identify a number of requirements for the developed system.

Mobility. The measurement system should be mobile, this will help make it easier for users to use, as well as provide a larger coverage area. Mobility can be provided by wireless

data transfer from the System node to the computer and relatively small dimensions.

Scalability means that the system allows you to increase the number of functional nodes, while its performance does not deteriorate. The possibility of integrating the developed system with others should be realized. To ensure the scalability of the measurement system, the ability to add and remove sensors from its composition must be implemented.

Modularity. It should be possible to use the developed system individually or as a module in other systems. Thus, it is necessary to provide the ability to integrate the system being developed into other systems.

Multichannel. It is necessary to ensure speed and, accordingly, less time spent on the operation of the system, as well as the possibility of simultaneous measurement of several disparate physical quantities. This can be achieved by having a set of sensors operating in parallel.

Reporting. The developed system of measurements should automatically generate reports. The measurement protocol must contain all the necessary information in a user-friendly form, for example, in the form of tables and graphs.

Based on the requirements for the system when measuring the parameters of the microclimate, a list of physical quantities that will be measured by the developed system was formed.

Most often, microclimate parameters such as:

— Ambient air temperature;

—Relative humidity of ambient air;

-atmospheric pressure;

-light.

CHAPTER 2

METHODS AND MEANS OF MEASURING PARAMETERS MICROCLIMATE AND FIELDS OF APPLICATION

2.1. Ambient temperature

Temperature - a measure of the kinetic energy of oscillating particles, which characterizes the state of equilibrium, proportional to the kinetic energy of the chaotic motion of particles in the system [6]. The temperature is usually expressed in degrees Kelvin, Celsius or Fahrenheit.

Temperature is a significant factor that determines human activity, efficiency and quality of industrial production, reliability of devices and systems.

Various measuring instruments such as thermocouples, semiconductor temperature sensors and others are used to measure temperature.

The principle of operation of thermocouples is based on the Seebeck phenomenon: when two metals are heated, a thermopower proportional to the temperature is formed at the terminals.

A thermocouple is a thermoelectric converter and is a circuit consisting of two or more interconnected conductors.

The thermistor is a passive sensor, ie to convert the temperature it is necessary to pass current through it. The basis of the thermistor is the property of changing the electrical conductivity of metals with changing temperature.

When connecting temperature sensors to the measuring part of the thermometer, it is necessary to take into account the resistance of the connecting wires and parasitic thermocouples occurring at the joints.

Recently, semiconductor devices have been used as temperature sensors: diodes, transistors and special integrated circuits.

Semiconductor temperature sensors are designed to measure temperatures from minus 55 ° C to 150 ° C. The physical principle of operation of a semiconductor thermometer is based on the dependence of the voltage drop temperature on the p-n junction shifted in the forward direction. This dependence is close to linear, which allows you to create sensors that do not require complex correction schemes.

Semiconductor thermometers can be found on integrated circuit chips due to modern technologies in their production. They are very common in electronics. Such sensors are integral parts of microprocessor systems, microprocessors, microcontrollers and measuring devices.

The main representative of such sensors are digital temperature sensors, which have a built-in ADC and transmit data via 1-Wire, I2C and SPI interfaces. One of the most important advantages of semiconductor thermometers is their rich functionality. Unlike the use of thermocouples, for semiconductor thermometers there is no need to develop a cold junction compensation scheme and a circuit for linearizing the output signal. Also, such temperature sensors are compact, relatively cheap, and can be easily integrated into various electronic devices. At the same time they have a high sensitivity and enough high accuracy.

2.2. Relative humidity of ambient air

Humidity is a quantity that characterizes the presence of water vapor in the Earth's atmosphere. Relative humidity is a number that characterizes the ratio of current humidity to the maximum absolute humidity at current temperature. This parameter is usually expressed as a percentage.

A device that measures the level of humidity is called a hygrometer or simply a humidity sensor.

According to the principle of operation, hygrometers can be divided into:

— Capacitive hygrometers - condensers with air as a dielectric gaps. It is known that the dielectric constant in air is associated with humidity, and changes in the humidity of the dielectric lead to changes in the capacity of the air condenser;

— Resistive humidity sensors include two electrodes, which are applied to the substrate, and on top of the electrodes themselves is applied a layer of material, which has a fairly low resistance, but highly variable depending on humidity;

— Thermistor humidity sensors consist of a pair of thermistors - nonlinear electronic components in which the resistance depends on temperature.

One of the thermistors is placed in a chamber with holes in the air in which you want to determine the relative humidity. Another thermistor is located in a sealed chamber, which is filled with dry air. In the case when the voltage at the output terminals is zero, the temperatures of both components are equal, therefore, the same humidity.

In the case where the output will be not zero voltage, it indicates the presence of a difference in humidity in the chambers. So according to the value of the voltage obtained by measuring the humidity;

— Optical humidity sensors at the heart of their work contain a phenomenon associated with the concept of "dew point". It consists of a diode that shines on a mirror, the mirror in turn reflects light on the photodetector. The mirror can be heated or cooled by a special high-precision temperature control device.

A temperature sensor is installed on the mirror. At the beginning of the measurement, the mirror temperature is set to a level above the dew point. Then there is a gradual cooling. As soon as the temperature crosses the dew point, drops begin to appear on the mirror and the beam of light refracting from them is scattered, which causes a decrease in the current at the output photodetector. The photodetector is connected to the mirror temperature control device by means of feedback. This device with the help of signals from the photodetector will keep the temperature equal to the dew point, no more and no less, and the temperature sensor emits a signal corresponding to this temperature. At a known pressure on this information, it will be possible to define all indicators of humidity;

The advantages of capacitive humidity sensors are their low temperature coefficient, the ability to work at high temperatures, as well as complete recovery from condensate and moderate resistance to chemical evaporation.

2.3. Atmospheric pressure

Atmospheric pressure is the pressure produced by the atmosphere on the objects in it and on the earth's surface, which is expressed in pascals, bars or millimeters of mercury [8].

Absolute pressure sensors are sensors for measuring the pressure of atmospheric air, other gases, vapors, liquids, which starts from zero pressure, ie from absolute vacuum. Any pressure transducer counts the measured pressure relative to the reference.

So, the absolute pressure sensor counts down the measured pressure relative to zero. There are also pressure transducers in which the measured pressure is calculated relative to atmospheric, pressure transducers in which the discharge pressure is calculated relative to atmospheric pressure, pressure transducers in which the difference between the two pressures is measured.

At the heart of the design of the absolute pressure sensor is sensitive element, on one side of which is a vacuum chamber, and on the other side effects the pressure of gas or liquid. Receiving the output signal from the sensor, the electronic unit estimates the absolute pressure.

Recently, piezoresistive electronic pressure sensors have become widespread. Execution of piezoresistive sensors is possible of two types: for work in the aggressive and non-aggressive environment. The difference in performance in the transfer of pressure on the sensitive element.

When working in a non-aggressive environment, the effect is directly on the sensitive element, or the sensitive element is filled with silicone gel, which transmits the effect of pressure. Stainless steel membrane sensors are used for aggressive environments.

The principle of operation of such a sensor is based on the unbalance of the bridge when bending the membrane under the influence of the measured medium. The more the membrane bends, the higher the degree of imbalance of the bridge.

Monosilicon crystals have high elasticity, which contributes to the stability of readings at any pressure.

One of the advantages of piezoresistive pressure sensors is a wide range of measured pressure, they are also sensitive to temperature and usually have the ability to measure it in order to further adjust the measurement results.

2.4. Light

Illuminance is a physical quantity determined by the ratio of the luminous flux incident on a surface element containing the point in question to the area of that element. The unit of illumination is luxury [9].

Luxmeters with measuring transducers are used to measure illuminance. Once on the element, the light flux releases electrons in the semiconductor. It allows

photocell begin to conduct an electric current that is directly proportional to the illuminance of the photocell.

2.5. Environmental monitoring

Measuring environmental parameters affects many areas of human activity, such as industry or a high-precision measurement laboratory, a private home, or a weather station.

Also, high-quality production of any product requires certain environmental conditions. That is why recently produce continuous measurements of environmental parameters and their automation.

The system of measuring environmental parameters can be used in various fields, such as environmental monitoring, the system "Smart Home", registration of factors influencing the verification of measuring instruments, as well as measuring the microclimate of industrial and residential premises.

State ecological monitoring is understood as complex observations of the state of the environment, including components of the natural environment, natural ecological systems, what happens in them, phenomena, assessment and forecast of changes in the state of the environment.

The main purpose of environmental monitoring is to prevent critical situations that are harmful or dangerous to human health, the well-being of other living beings, their communities, natural and man-made objects.

The monitoring system is a source of information necessary for making environmentally significant decisions and does not exclude activities related to environmental quality management.

The objects of research in environmental monitoring are the atmosphere, hydrosphere, land and geological environments.

The main procedures of the monitoring system are:

—Selection and inspection of the object of observation;

—Assessment of the state of the object of observation;

—Predicting changes in the state of the object of observation;

—Presentation of information in a user-friendly form.

Meteorology - is the science of the Earth's atmosphere, its structure, properties and occur in it. The properties of the atmosphere and occurring in it are considered in connection with the properties and effects of the surface. The main task of meteorology is to forecast the weather for different periods.

The meteorological station is the main component of regular observations of the state of the atmosphere, which is designed to:

—Measurement of temperature, pressure and humidity;

—Wind speed and direction;

—Control of clouds, precipitation levels, visibility, solar radiation.

2.6. “Smart Home”

An automated building is a building equipped with multiconnected multidimensional automated engineering systems that interact with each other and the environment to perform their intended functions [10].

Home automation or "smart home" is the automation of buildings, which includes control and automation of lighting, heating, ventilation, air conditioning and security, as well as household appliances such as washing machines or dryers, stoves or refrigerators. Wi-Fi is often used to remotely monitor and control such a system.

In today's world, heating, lighting, plumbing, alarm in the apartment can be controlled using the "Smart Home" system. Based on measurements of environmental parameters, a decision can be made, for example, the need to include additional lighting or increase the heating of the room.

The most common devices that receive information about external conditions in climate management are:

— Moisture sensors;

— Temperature sensors;

— Hygrostats for maintenance of constant humidity or its regulation;

— Thermoregulators that control the heating power;

— Thermostats that maintain a constant temperature and automatically regulate.

The main task of smart home devices in this case - automatically regulate the operation of climate systems so as to simultaneously provide a comfortable microclimate and reduce maintenance costs.

The system of measuring the parameters of the microclimate of buildings can be used as part of the system "smart home".

CHAPTER 3

FORMATION OF HARDWARE PLATFORM AND DATA TRANSFER INTERFACES

3.1. Temperature and humidity sensor DHT22

DHT22 temperature and humidity sensor was used to develop this device.

DHT22 is a well-known sensor for determining relative humidity and temperature, consisting of a capacitive humidity sensor and a thermistor.

This sensor has a built-in ADC that converts analog to digital. At the output of the ADC, the obtained data are presented in digital code, which simplifies the circuit of this device [11].

This digital sensor is based on a protocol that uses a single wire / bus with an open collector for communication, so it is mandatory to tighten the resistor 5-10kO to the plus power supply.

In Figure 3.1. the appearance of the temperature and humidity sensor DHT22 is presented.

Fig. 3.1. - Appearance of the DHT22 sensor

The main technical characteristics of the sensor are presented in table 3.1.

Table 3.1 Technical characteristics of the DHT22 sensor

Supply voltage	3.0 V … 5.5 V
Relative measurement accuracy humidity	
Measurement accuracy temperature	<± 0.5°C (1%)
Measured range temperature	-40 °C … +80 °C
The range of the measured relative humidity	0 % … 100 %
Current in operating mode	1 mA … 1.5 mA
Standby current	40 uA … 50 uA
Standby current	4
Minimum measurement period	2 s

3.2. Digital temperature sensor DS18B20

The DS18B20 digital temperature sensor is a compact, accurate and inexpensive digital temperature sensor. The sensor uses a 1-Wire interface developed by Dallas. This interface is widespread and fairly easy to learn. An additional advantage is the ability to connect multiple sensors in parallel on one data bus.

The DS18B20 sensor chip can simply be connected to microcontrollers based on Arduino, AVR, PIC, ARM. To work with Arduino, there is a ready-made library created by the manufacturer [12].

Figure 3.2 shows the appearance of the ds18b20 sensor

Fig. 3.2 - Appearance of the ds18b20 sensor

The main technical characteristics of the sensor are presented in table 3.2.

Table 3.2 Technical characteristics of the ds18b20 sensor

Measuring range temperatures	
Precision	± 0,5 ° C (-10 ... + 85 ° C)
Data acquisition time	94 ms
Supply voltage	3-5,5 V
Current at inactivity	750 nA
Current in the survey	1 mA

3.3. Ethernet module WIZnet W5500

The W5500 was chosen as the Ethernet module. The W5500 is used to connect various microcontroller devices to the Ethernet network. The appearance of the module is shown in Figure 3.3.

Fig. 3.3 - Appearance of the W5500

The module can be used to "communicate" with devices on the local network via "TCP" or "UDP", and interact with remote devices (with servers in particular) using the protocol "HTTP" [13]. The main technical characteristics of the sensor are presented in table 3.3.

Table 3.3 Technical characteristics of the WIZnet W5500 sensor

Chip	W5500
Supply voltage	3.3 / 5V
Logical levels	3.3V (up to 5V)
Chip supported protocols	TCP, UDP, ICMP, IPv4, ARP, IGMP, PPPoE
Maximum open at the same time sockets	8
Built-in transmission buffer data	32 kbyte

3.4. Arduino Uno central microcontroller

Arduino Uno is based on the ATmega328 chip. This allows the platform to provide the user with 14 digital inputs or outputs. Among them as PWM 6 pins can be used, and also the platform provides 6 analog inputs, the USB socket for connection to computers, the socket intended for power supply of the microcontroller, the quartz generator calculated on 16 MHz, the ICSP socket and the button to reboot the system [14].

For the device to work properly, it is important to connect the platform with a USB cable to a computer, or connect the power supply to the appropriate pins. The microcontroller is shown in Figure 3.4.

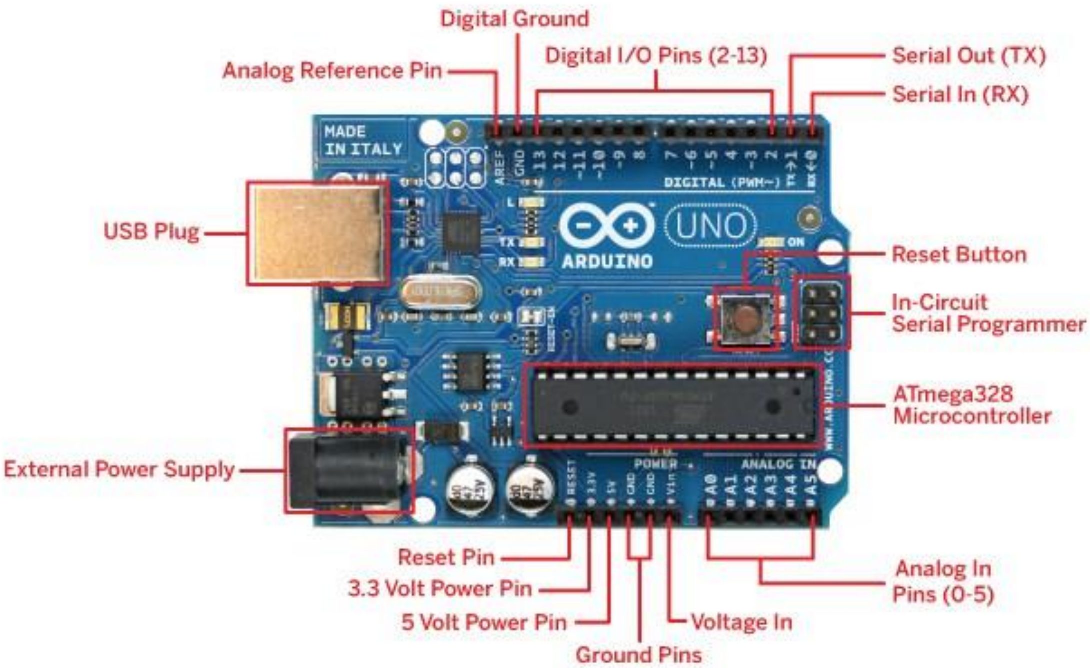

Fig. 3.4 - Arduino Uno microcontroller

The platform has a built-in voltage stabilizer, so it can operate at voltages from 6 V to 20 V.

3.5. IEEE 802.11 wireless standard

The origin of the common abbreviation Wi-Fi in some sources was originally derived from the English phrase Wireless Fidelity, which can be translated as "high accuracy wireless data transmission".

The acronym Wi-Fi is used to denote the Wi-Fi Alliance brand and refers to the technology of wireless networks built using the IEEE 802.11 standard [15]. Under this designation the whole set of standards of transfer of digital data on radio communication channels develops. The IEEE 802.11 standard operates at the lower two levels of the OSI model, the physical and channel levels.

This standard defines two types of equipment. One of them is a client who has a wireless network card. The other is the access point, which acts as a bridge and connects wired and wireless networks.

Wi-Fi is characterized by the following parameters:

—Modifications of IEEE 802.11 b, g, n;

—Frequency range - 2.4 GHz;

—Channel width - 20 MHz;

—Transmitter power - up to +10 dB;

—Coverage range - up to 150 m.

3.6. Inter-Integrated Circuit interface

Inter-Integrated Circuit (I^2C) is a data bus that connects integrated circuits and uses two lines for messaging. For The SDA bus uses the SDA data line and the SCL synchronization line [16].

When transmitting data, one device is the "master". It generates signals for synchronization and initiates data transfer. Another device is called a "slave", which on the command of the master bus can start data transmission.

Devices that are connected to the I^2C bus have unique addresses. When transmitting data, the unique address of the device is sent first. Other devices check the address that was transmitted to the master device. Two tires work in the opposite mode. The master acts as a transmitter while the master is the receiver. Otherwise, the master is the transmitter and the master acts as the receiver. In any case, the clock signal is generated by the master.

3.7. Single-channel data transmission interface

The DHT22 device uses simplified single-channel communication. A single bus is a single data line, a data exchange system controlled by a data line to complete.

The microprocessor connects to the data line through the port to prevent the device from sending data to release the bus, while other devices use the bus. A single bus usually requires an external 4.7 kO resistor, so when the bus is in standby mode, its condition is high.

The interaction between the microprocessor and the sensor is based on the principle of "master-slave", ie the master device calls the sensor, the sensor responds, and to access the sensor, the master must strictly follow the sequence of a single bus. If the sequence is violated, the sensor will not respond to the call.

For communication and synchronization between the microprocessor and DHT22 a single bus data format (SDA) is used to transmit 40 bits of data.

3.8. Construction of hardware and software module

The hardware consists of many elements that work simultaneously to solve a specific problem. The main elements of this system are:

—Power supply 5 volts;

—Arduino microcontroller;

—WIZNet W5500 module for communication with Ethernet network;

—Atmospheric pressure sensor BMP 280;

— Temperature and relative humidity sensor DHT 11;

—Digital temperature sensors ds18b20.

A 5-volt power supply was chosen to provide the system with energy.

It is shown in Figure 3.5.

Fig. 3.5 - 5-volt power supply

It is connected to an uninterruptible power supply, which allows the system to work in the event that the light in the house is lost.

The main center of the system is the Arduino microcontroller, which is shown in Figure 3.6.

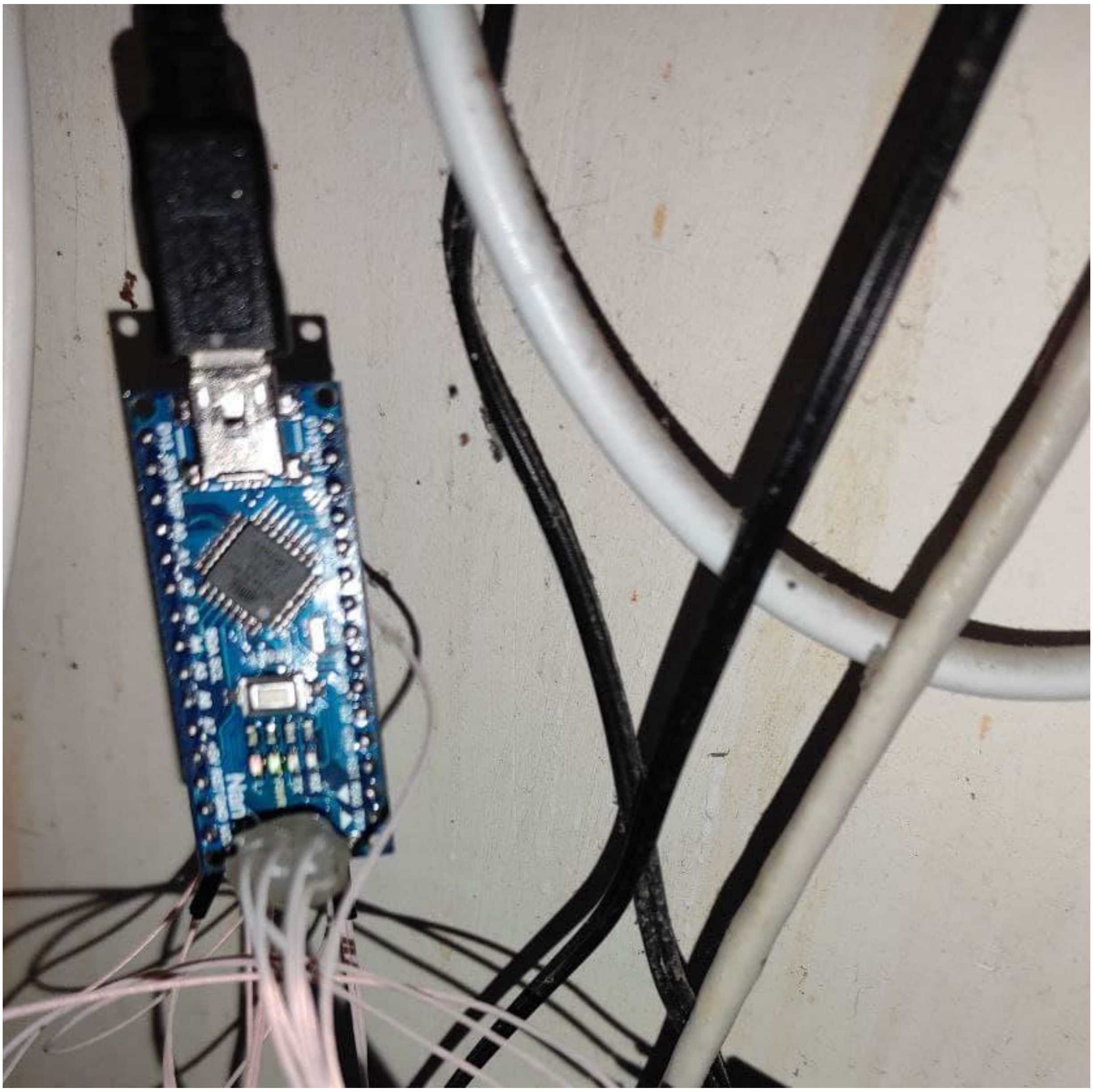

Fig. 3.6 - Arduino microcontroller

It has the advantages of AVR microcontrollers in a small case, so it is among the top three in popularity among amateur radio programmers.

The WIZNet W5500 module, which is controlled by a microcontroller via the SPI bus, is used for Ethernet communication. This combination can be seen in Figure 3.7.

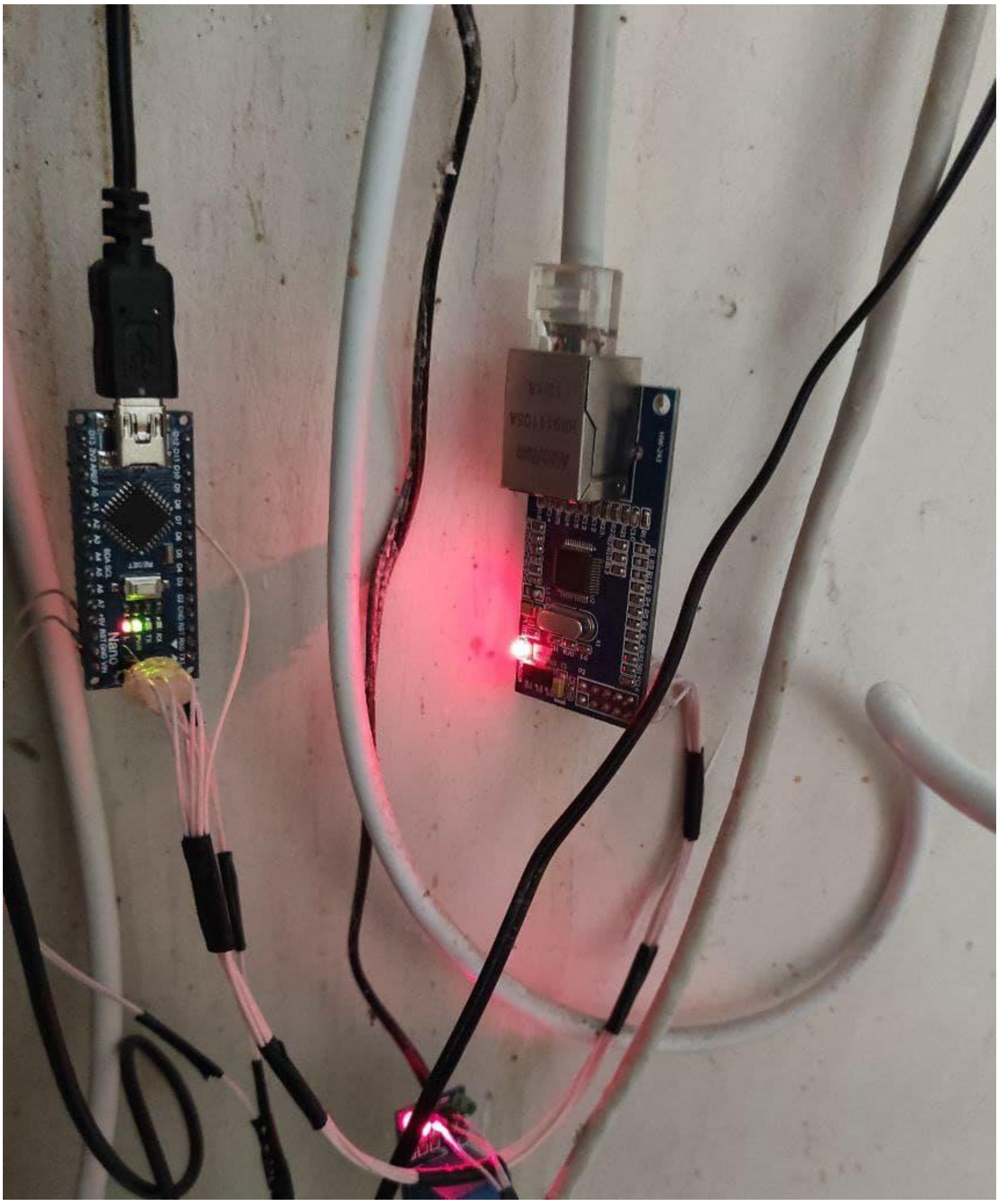

Fig. 3.7 - The microcontroller is connected to the Ethernet module

The BMP 280 sensor is used to obtain the atmospheric pressure value. In this system, it transmits data to the microcontroller via the I2C bus. The atmospheric pressure sensor is shown in Figure 3.8.

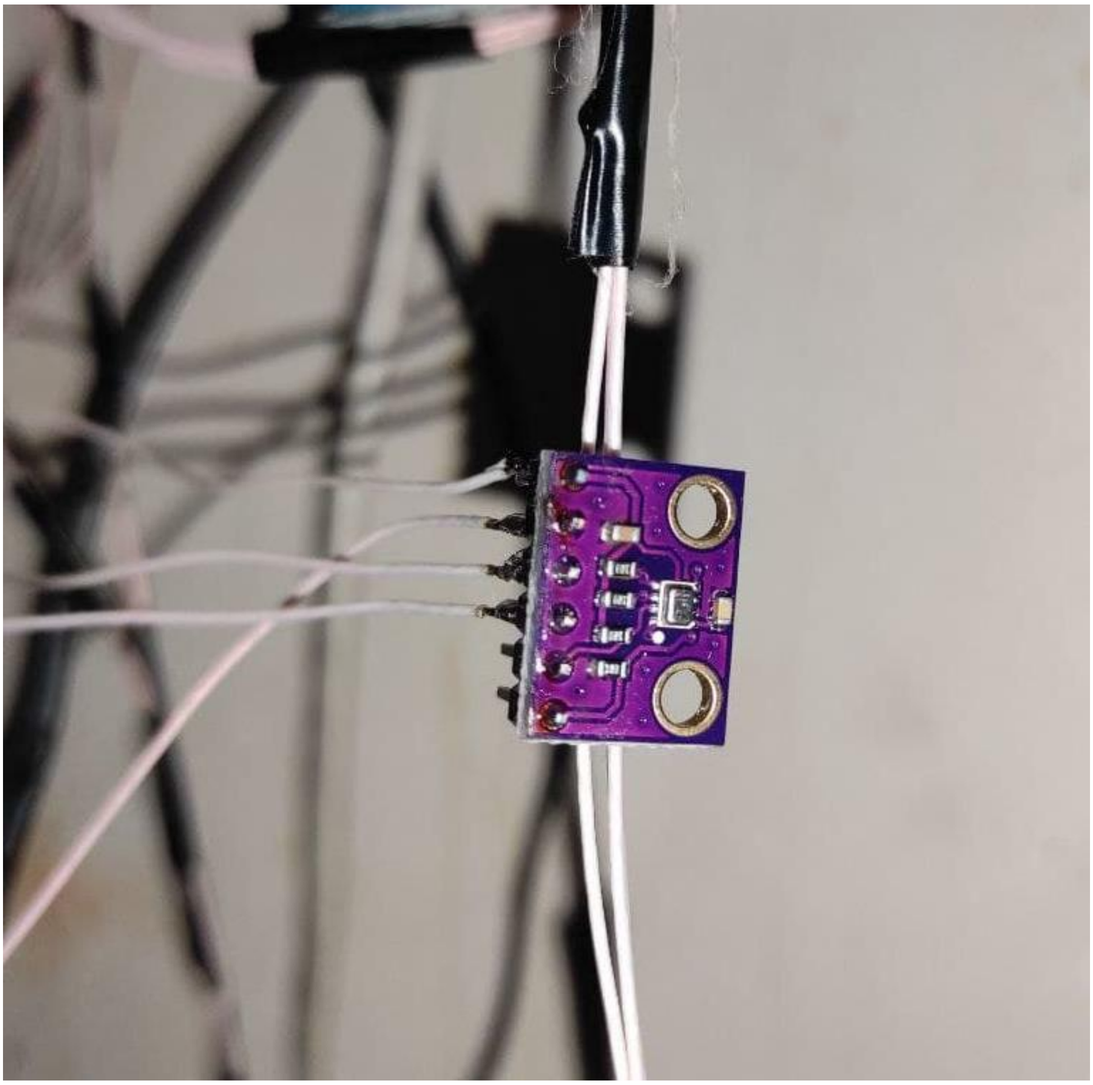

Fig. 3.8 - Atmospheric pressure sensor BMP 280

In order for the user to be able to find out the humidity value through the digital pin of the microcontroller, the DHT 11 temperature and humidity sensor is connected in Figure 3.9.

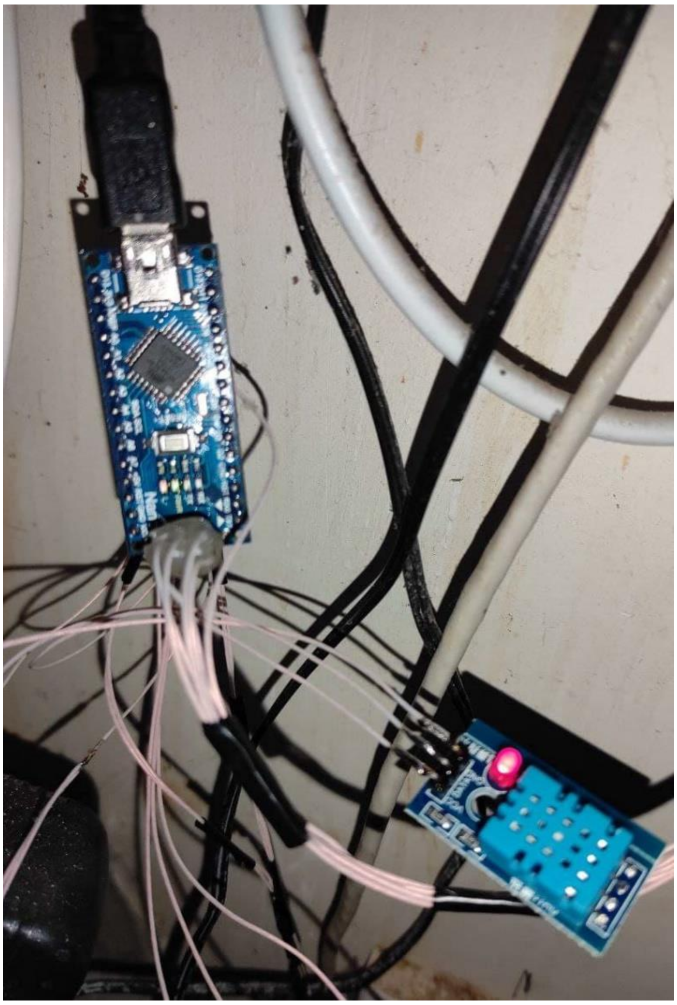

Fig. 3.9 - Temperature and relative humidity sensor DHT 11

Several ds18b20 temperature sensors that use the 1-Wire connection interface are located on the same data line and are identified in the system using unique addresses. In particular, the connection can be seen in Figure 3.10.

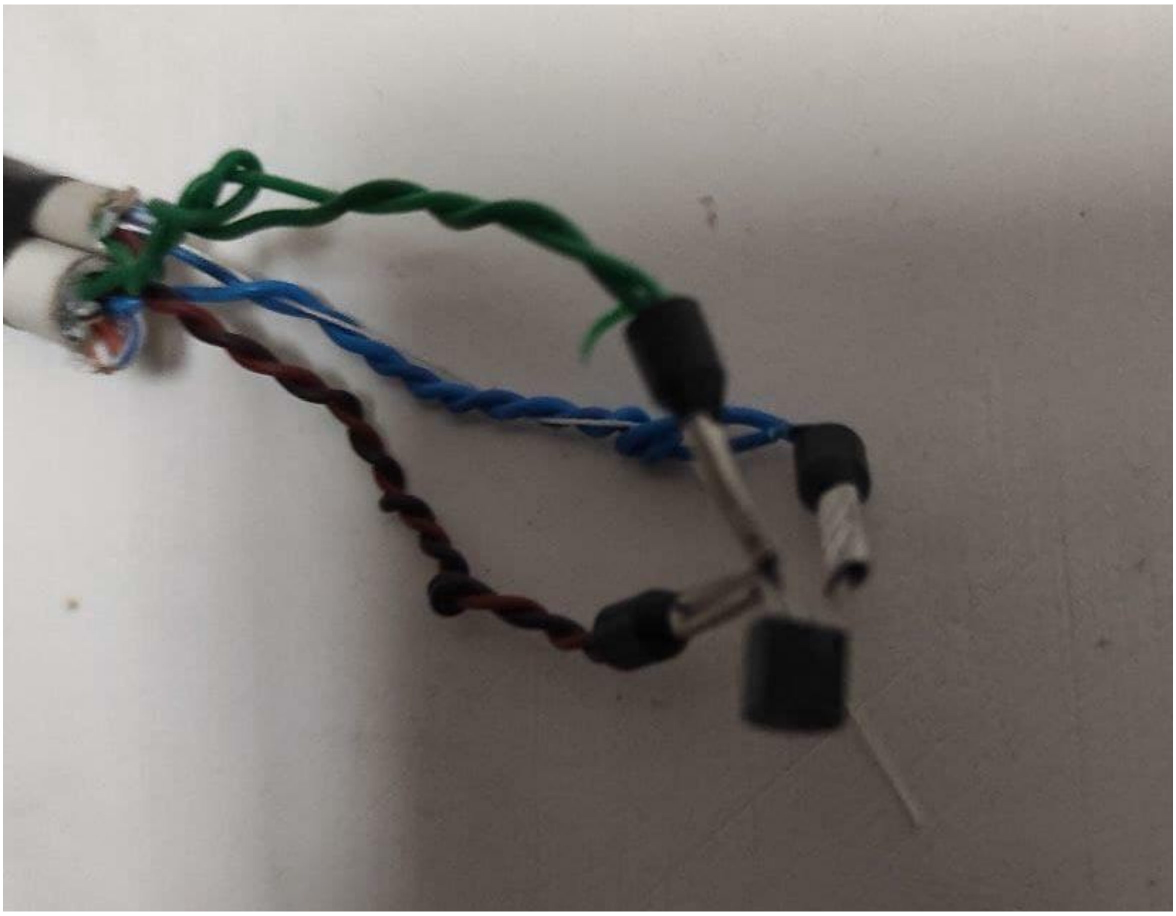

Fig. 3.10 - Connection of the temperature sensor ds18b20

3.9. Conclusions to the section

1. In accordance with the established requirements, the hardware architecture is developed

parts of the hardware and software complex;

2. The choice of hardware platform components is substantiated;

3. Implemented data transfer interfaces.

CHAPTER 4

DESCRIPTION OF THE SOFTWARE IMPLEMENTATION

4.1. Software module architecture

The basis of the software is the methodology of object-oriented programming, the essence of which is to present in the form of a set of objects of the software product, each of which is an instance of its class.

The Arduino microcontroller module is responsible for reading readings from all sensors and devices available in the system. But the most important thing in his work is to respond to external influences with messages sent by various teams. The diagram of precedents is shown in Figure 4.1.

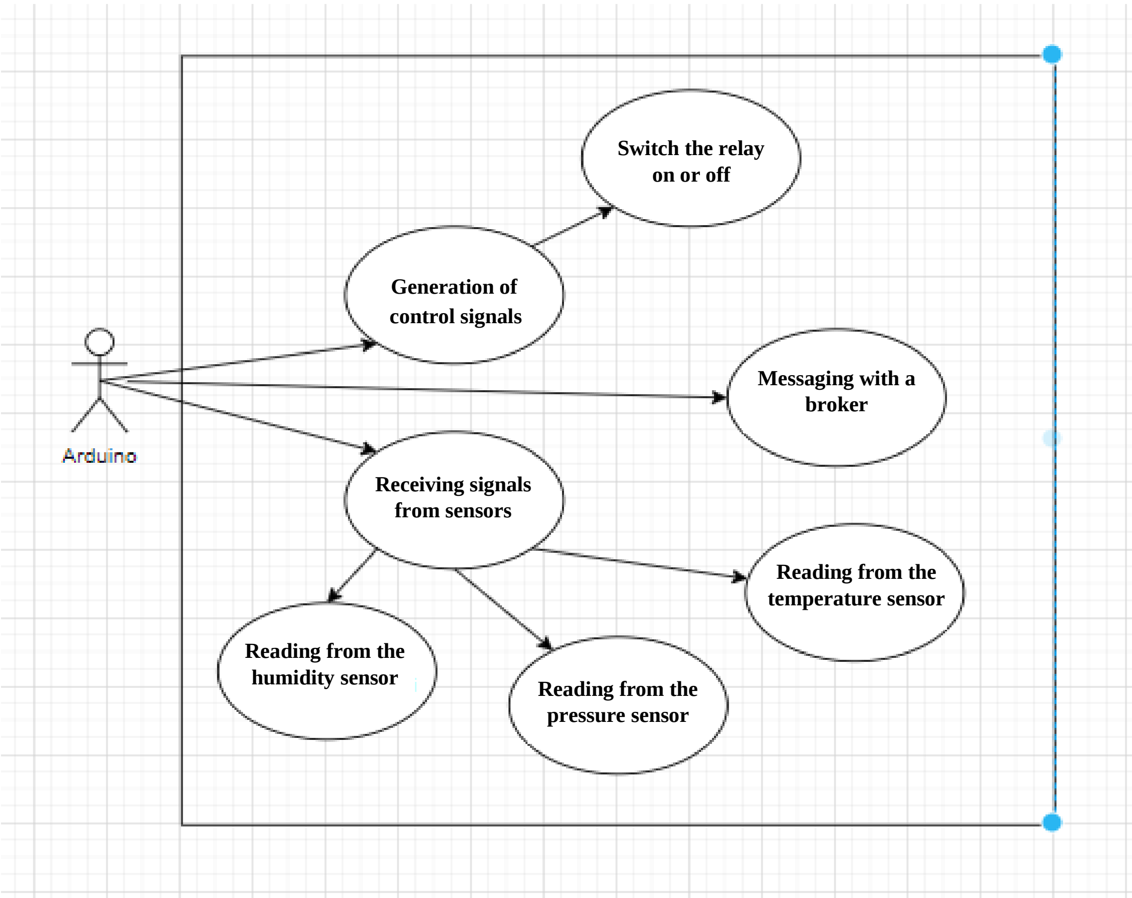

Fig. 4.1 - Precedent diagram for Arduino microcontroller

The diagram shows the main features of the module - it's generation control signals and initialization of data acquisition from sensors. Association from "Broker messaging" should be understood as the automatic transfer of data from the broker to the Arduino microcontroller, and vice versa. The precedents "Signal Generation" and "Sensor Data Retrieval" are described in detail in the diagram.

Response to external influences is carried out by means of program interruptions as follows: as soon as the message in JSON format from the broker arrives, sending of data from sensors stops. At this point, you must read the data and report the successful or unsuccessful operation of the sender. The notification of receipt of the message is presented in the form of a flag, a separate parameter, which is sent together with the readings of the sensors. The class diagram for the Arduino module is shown in Figure 4.2.

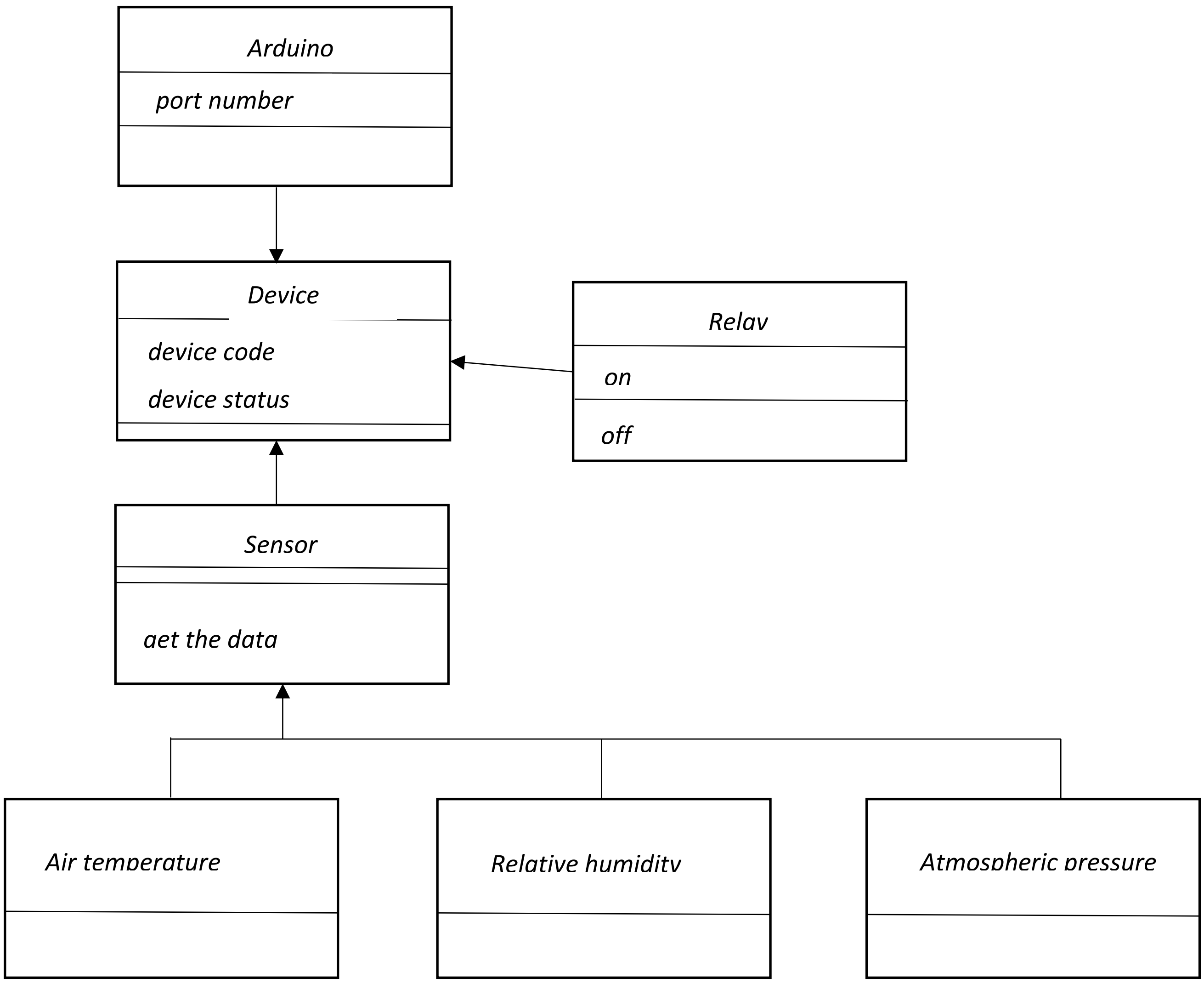

Fig. 4.2 - Class diagram for the Arduino microcontroller

The microcontroller interacts with existing devices. The "Device" class has its successors: it is directly sensors and relay control systems. The sensors have a data acquisition function, and the systems only have on or off options.

The sensor repository is a database managed by the PostgreSQL database. A separate table is created for each of the sensors using the CREATE method, which is a standard procedure of the PostgreSQL database. Each table consists of a set of columns: most of them are the names of a sensor. There are also service columns: they store the time of recording readings, the state of sensors and devices. If something fails, the moment when it happened will be displayed in the table.

To organize the connection to the repository, the database name, login and password to access it, the host and port on which the database is open, were used. The advantages of this structure are as follows:

—Ability to work with several connections to the database at the same time;

—If necessary, you can set up an automatic increase

simultaneous connections if there are too many requests in the queues;

—When the database server suddenly restarts, automatically again

establish a connection and monitor that queries that were lost during the database server restart were executed.

The above benefits allow you not to worry that any user will not be able to get the necessary information about the system.

4.2. MQQT protocol

MQTT is a protocol made specifically for IoT. Open and simple, it is designed to exchange information between different devices and modules. Simplifies the connection of communication channels quickly, efficiently and in a timely manner. Responsible for connection security, data transfer speed and practical operation of systems and programs. Protects from all sorts of failures and problems, doing its job well. The range of possibilities of this protocol is very large. It allows the exchange of information between larger "items", as well as the systematization of local area networks on the Internet.

The MQTT protocol runs at the application level over TCP / IP and uses 1883 by default and 8883 by SSL. Figure 4.3 shows the OSI hierarchical model.

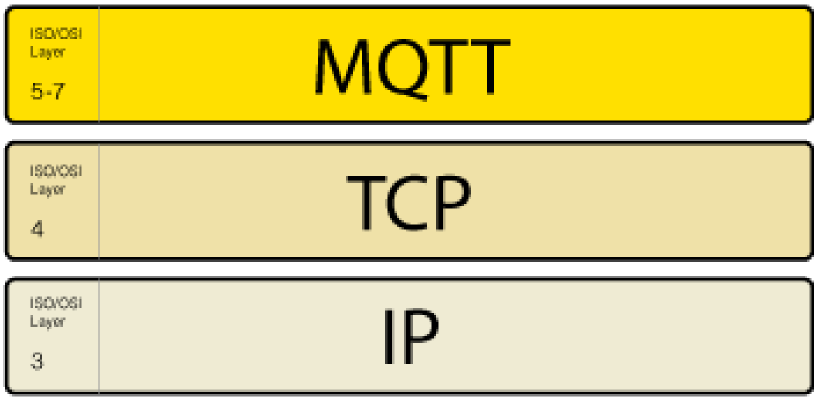

Fig. 4.3 - OSI model levels

The MQTT protocol consists of an MQTT broker, MQTT subscriber agents and executors. They all clearly know and perform the programmed task, working clearly and coherently. Artists publish data intended for subscribers. This is their main function, without which the connection will not work [17].

The provided hierarchical structure of topics is used for addressing of messages in the MQQT protocol. They can be single-level and multi-level and are separated by a special character "/". An example of a multi-level topic is "home / bedroom / temperature". Figure 4.4 shows the hierarchy of topics.

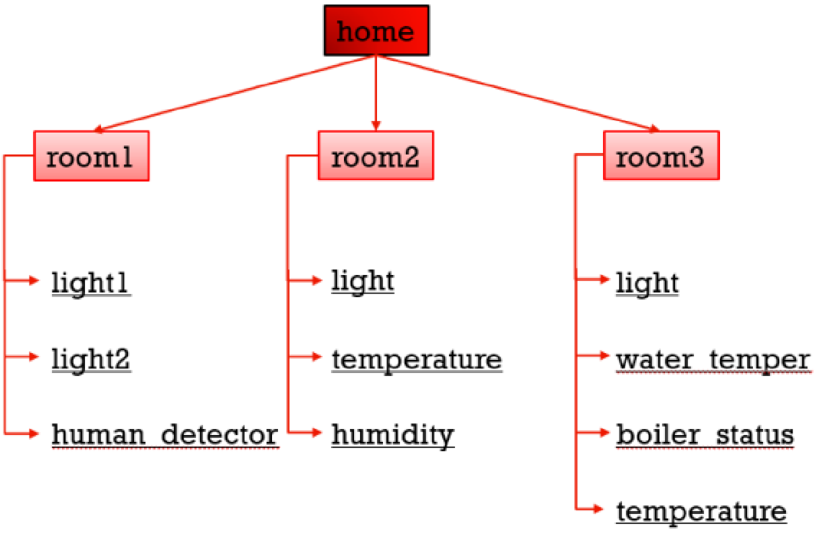

Fig. 4.4 - Topic hierarchy in the MQQT protocol

To transfer messages between the MQQT broker on devices
the following types of messages are used, which can be seen in table 4.1.

Table 4.1 Main types of messages for communication with MQQT broker

Connect	establish a connection with a broker
Disconnect	break the connection with the broker
	publish data to the broker
Subscribe	subscribe to the broker's topic
Unsubscribe	unsubscribe from the topic
Puback	confirmation of sending
Pubrec	message received
Pubcomp	publication completed
Connack	confirmation of successful connection

The system supports a special QoS flag. Respectively this is the main difference between the Constrained Application Protocol (CoAP) and MQTT protocol. By the way it allows to use any different levels of service. Depending on the selected level, all messages can be confirmed or processed without confirmation.

The QoS 0 flag indicates that the publisher publishes the message from broker and does not require it to be guaranteed to delivered. Than the broker can send same message to the subscriber.

The schematic diagram of the flags level QoS 0 is shown in Figure 4.5.

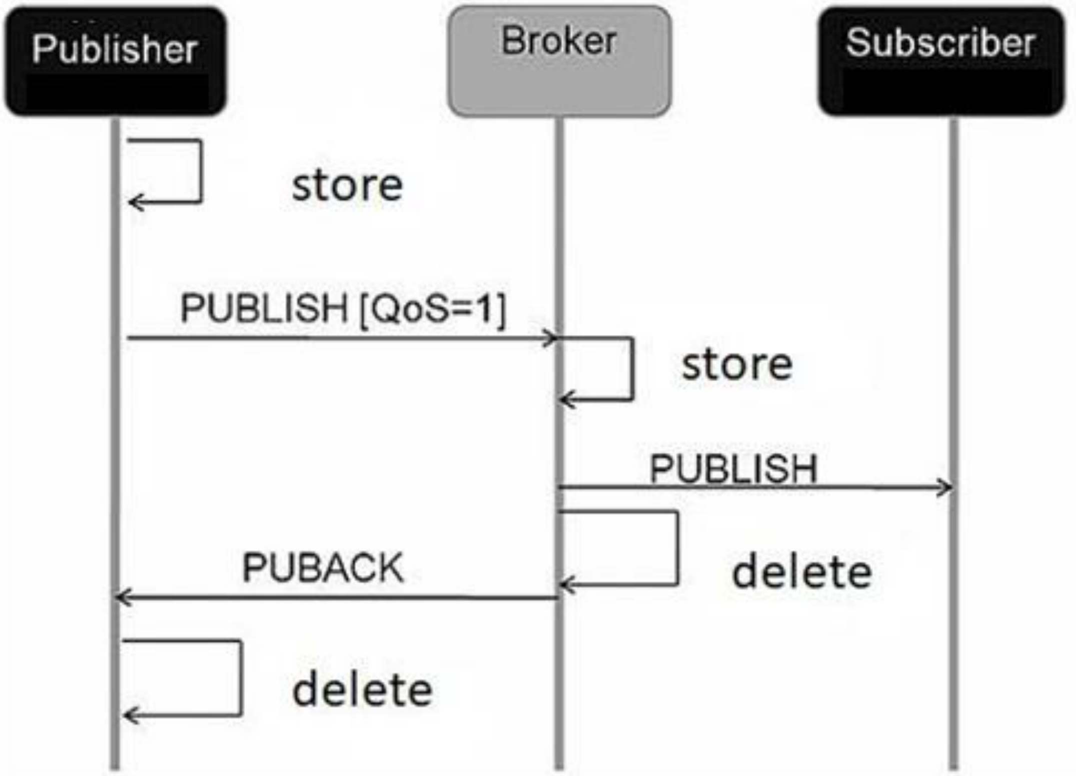

Fig. 4.5 - QoS transmission rate 0

This means that the subscriber may not receive this message, but it will not be tracked by the publisher.

The described scenario is used for cases where data loss is not critical. For example, with constant temperature monitoring, when the loss of a single measurement does not play a significant role in the overall picture.

The QoS 1 flag indicates that the message sent by the publisher will be saved and sent to the subscriber, and only then will a confirmation be sent to the publisher. The schematic diagram of the QoS level 1 flag is shown in Figure 4.6.

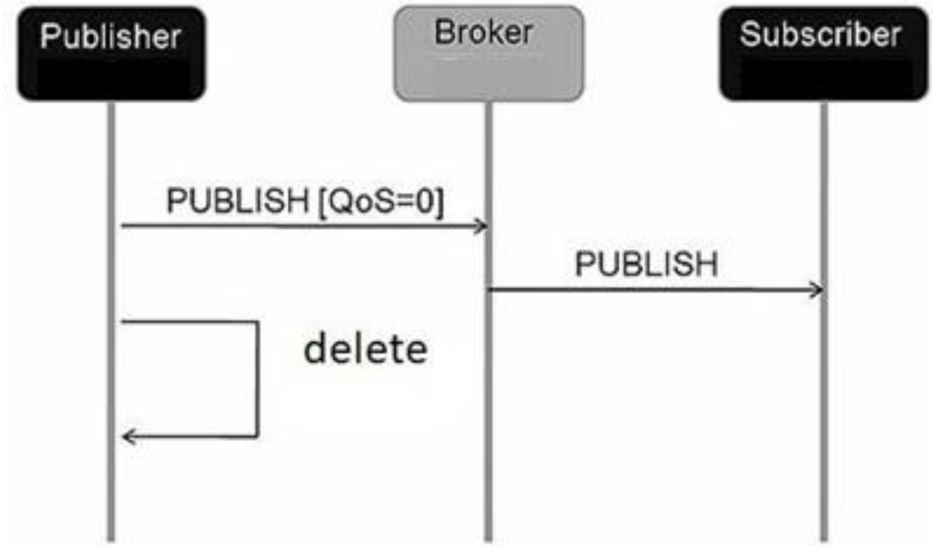

Fig. 4.6 - QoS transmission rate 1

This means that the message will be sent to the broker and the subscriber until the publisher receives confirmation. This will guarantee that you will receive the message at least once.

The delivery of the message and will prevent duplication of messages using special procedures pubrec, pubrel, pubcomp will be guarantee by the QoS 2 flag.

The schematic diagram of the flag level QoS 2 is shown in Figure 4.7.

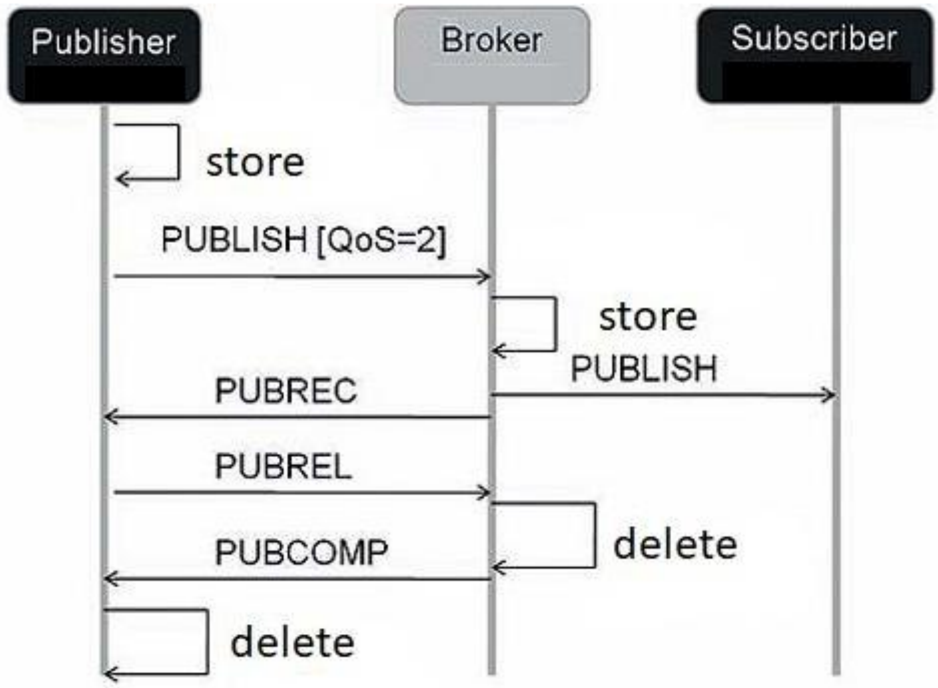

Fig. 4.7 - QoS transmission rate 2

This flag is used in cases where you want to ensure subscriber's receiving of the message from the publisher and to avoid duplication. An example is the operation of an alarm and sending a message to the emergency service.

The computational requirements for the MQTT protocol are very small because it is designed for low-power embedded devices. Even if the networks have low bandwidth, MQTT maintains high quality communication and does not overload the system. This is one of the main advantages of this protocol. There is almost no functional information in the data structure transmitted by the protocol, compared to other communication protocols. What characterizes the ego in terms of quality. For example, HTTP transmits all service data, but there is no urgent need for this.

A distinctive feature of the publisher-subscriber data transfer rule from the client-server approach is that the clients that send some messages and the clients that receive messages are usually separated.

Publisher and subscriber do not send messages to each other directly. They may not know about each other.

The broker directly sends the message to the subscriber from the publisher and vice versa.

The broker is a central element of the publisher-subscriber system. He is responsible for the correct reception of messages from publishers, their filtering. The broker decides who is interested in receiving these messages and sends messages to all clients who are waiting for them.

The whole process of information transfer can be described as follows:

The publisher sends a message with the data to the broker, indicating when this topic to which this data relates.

The broker analyzes which of the subscribers have subscriptions to certain topics.

Subscribers who subscribe to the topic will be sent a message with data from the sensors broker.

In this way, different subscribers can use topics from different devices and receive the necessary data.

4.3. Development environment for Arduino

The Arduino development environment interface contains the following basic elements: writing code text editor, a message part, a text console, a toolbar with traditional buttons and a main menu. This software allows the computer to interact with Arduino for both data transfer and firmware to the controller. It can be founded on the official website.

Pros of the program:

—Free;

—Open-source code;

—A huge library;

—Easy installation and setup.

After connecting the sensors and peripherals, you need to install the appropriate

for them a code library to write a program for them. This system can be used to control the microclimate in the apartment or house, it can also be expanded by connecting local controllers and other equipment for the "smart home".

4.4. MajorDoMo management system

Software platform for integrated home automation control, as well as for detailed information support. The selected system does not require powerful resources from the user's system and can be installed on a personal computer. Tasks that can be solved using the majordomo system:

—Media system;

—Microclimate system;

—Security system;

—Organizer.

4.5. Fibaro control system

Fibaro is a wireless intelligent building automation system running on the Z-Wave protocol. The system constantly scans all sensors and warns you about the event. The user interface allows you to control groups of devices. You can control lighting, air conditioning, heating, etc.

4.6. Open Remote management system

OpenRemote is a server that receives commands from mobile or web applications and then transmits them to another controller or server.

OpenRemote is:

—Smart home server, works on ten platforms, even on NAS

Synology and Windows.

—Online Wednesday for program development.

—Mobile application that downloads data for its work from the development environment.

Supported technologies:

1-Wire, VLC, MythTV, AMX, FreeBox, KNX, Lutron, Denon AVR, Z-Wave,

panStamps, EnOcean, xPL, Insteon, X10, Russound, Infrared, GlobalCache, IRTrans, XBMC and others.

4.7. NetPing management system

The main areas where NetPing can be used are indoor monitoring and remote control. Tasks solved by this device:

— Remote control of power supply with the possibility of forced reboot;

—Control of access to a remote object;

—Sensors for opening and closing doors, movement, impact, anti-vandal

surveillance camera systems;

—Monitoring of the indoor microclimate;

—Sensors of temperature, humidity, air flow rate, air conditioning control via IR;

—Sensors of smoke, water flow;

—Control of automatic telephone exchange on RS-232 port;

—Remote change of system settings depending on the situation;

—Remote access to servers through the console - for example, installation operations without the presence of the administrator;

—Receiving instant messages with time and failures important events from many channels: SMS, mail, Jabber;

—Access to all parameters is realized through SNMP and HTTP protocols;

—Control on and off lights and any other devices on schedule;

—Remote control of communication channels.

4.8. Work with the system of monitoring microclimate parameters

A token is used to transfer the microclimate parameters from the microcontroller. An example can be seen in Figure 4.8.

Channel Token:token_ErBbYiKNAaT3hrdD

Fig. 4.8 - Example of a token

It is after him that the user will be identified in the system.

In order to add a new sensor you need to specify its topic, fill in the description and select the type of data that will be returned by the sensor. To add new devices, click the "+ Resource" button. Adding a new topic is shown in Figure 4.9

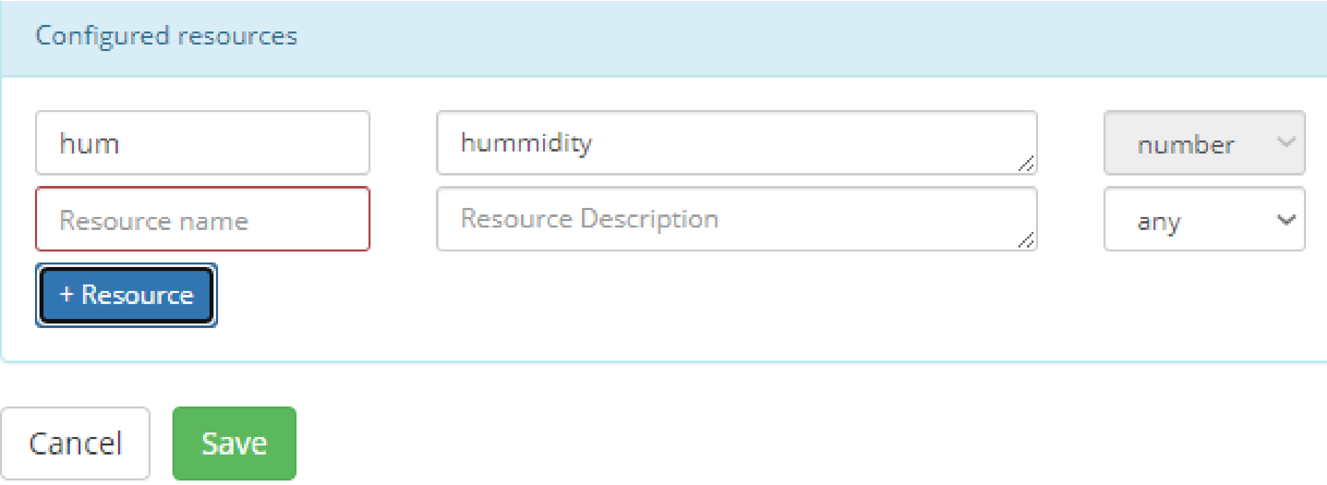

Fig. 4.9 - Adding a new topic

To add a new widget, click on the "Add Widget" button, specify a name and select the widget type, data source and size. An example of adding a new widget can be seen in Figure 4.10.

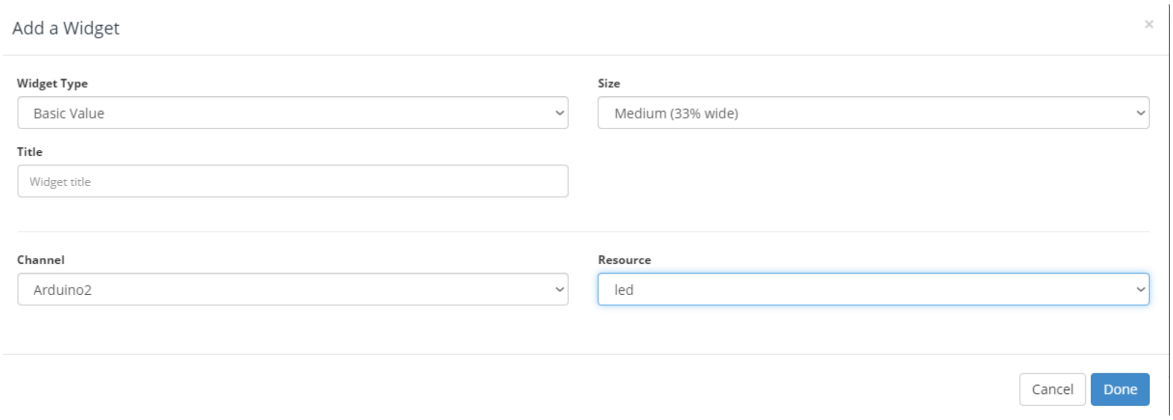

Fig. 4.10 - Adding a widget

In order to graph an indicator, you need to select a linear widget type and choose the color of the curve. The graph of the linear view can be seen in Figure 4.11.

Fig. 4.11 - Linear graph of temperature

It is possible to display several graphs on one. To do this, select a widget that displays several graphics, name each one, and choose colors for them. An example of a multi-line graph is shown in Figure 4.12.

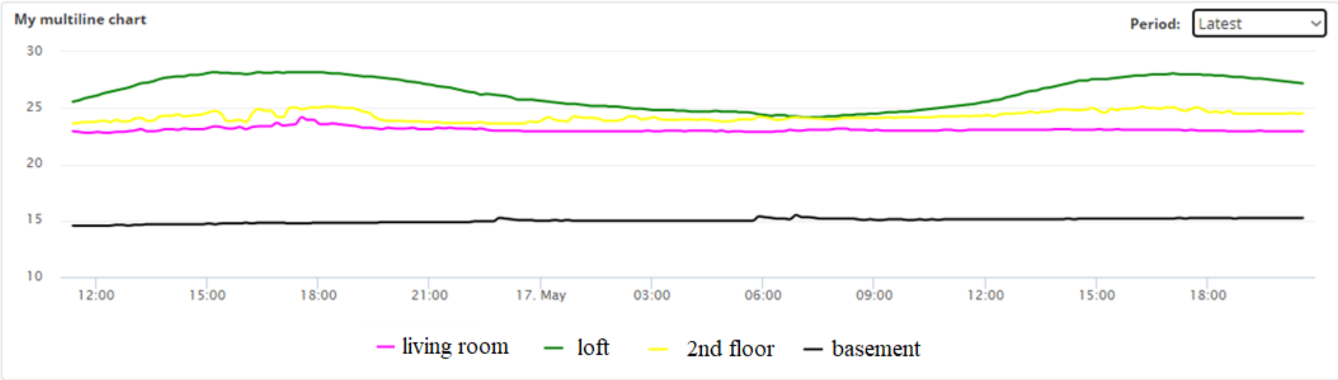

Fig. 4.12 - Multiline graph

To control electrical appliances, you can use a relay, the widget of which is shown in Figure 4.13.

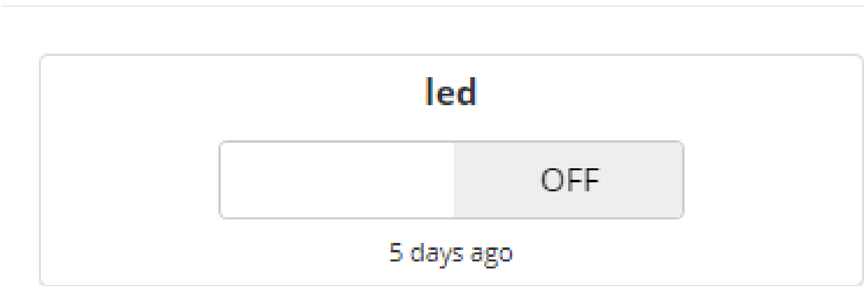

Fig. 4.13 - Relay control widget

For easy viewing of data from multiple sensors, it is convenient to use small widgets that display the current temperature. An example of widgets can be seen in Figure 4.14.

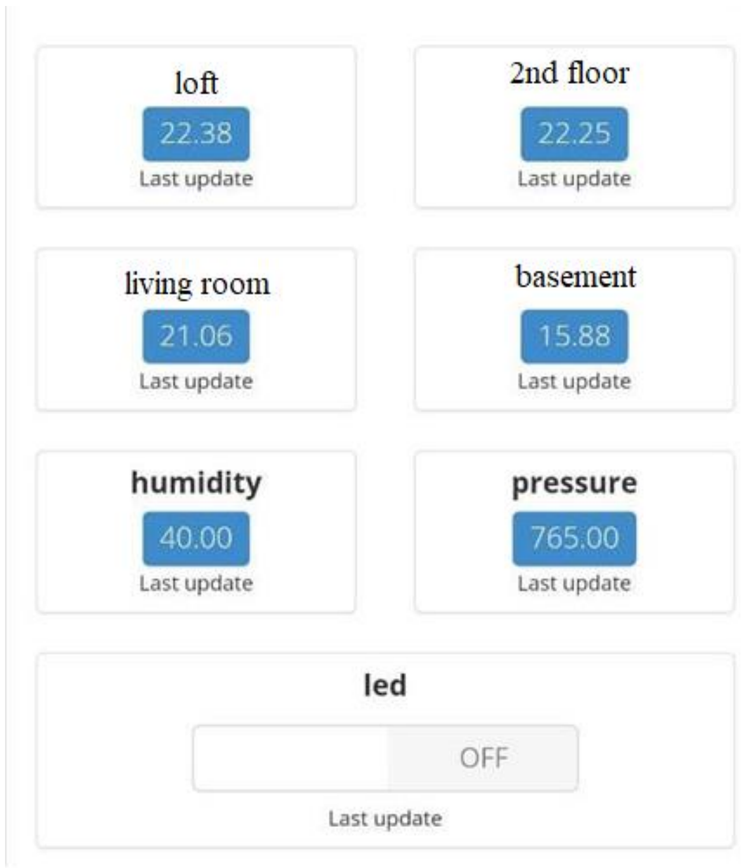

Fig. 4.14 - Widgets to display the current value of the sensors

To view the information for a certain period of time, you can select the desired period, as shown in Figure 4.15.

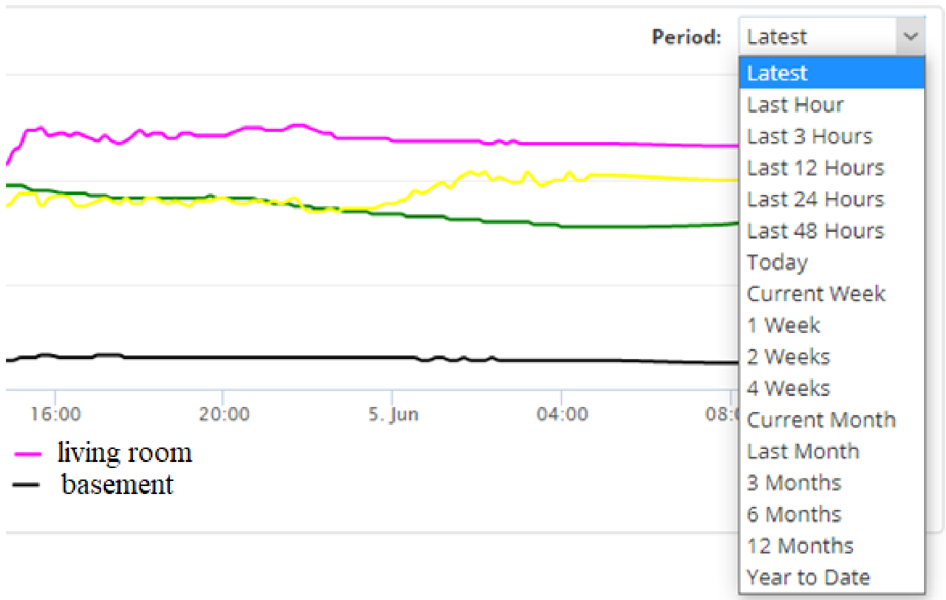

Fig. 4.15 - Select the interval for displaying information

In this case, only the information you are interested in will be displayed. At viewing a long observation period will display the average daily temperature.

4.9 Conclusions to the section

1. Developed hardware software architecture microclimate monitoring software package;
2. Formed protocols for data transfer to the server;
3. Developed class diagrams that allow you to see the entities systems;
4. Developed diagrams of precedents, which allows you to detect key actors and system functionality.
5. The choice of means of software development is substantiated software package;
6. The choice of libraries is substantiated and new libraries for ensuring the functionality of the system taking into account the features software and hardware architecture.
7. Developed a user interface that meets the objectives supplied by the system;
8. The interface provides visualization of microclimate parameters environment. It allows you to view measurements during a given measurement period.

CHAPTER 5
OCCUPATIONAL HEALTH AND SAFETY IN EMERGENCIES

5.1. Effects of electromagnetic radiation on the human body

A large body of literature exists on the response of tissues to electromagnetic fields, primarily in the extremely-low-frequency (ELF) and microwave-frequency ranges. In general, the reported effects of radiofrequency (RF) radiation on tissue and organ systems have been attributed to thermal interactions, although the existence of nonthermal effects at low field intensities is still a subject of active investigation. This chapter summarizes reported RF effects on major physiological systems and provides estimates of the threshold specific absorption rates (SARs) required to produce such effects. Organ and tissue responses to ELF fields and attempts to characterize field thresholds are also summarized. The relevance of these findings to the possible association of health effects with exposure to RF fields from GWEN antennas is assessed.

Nervous System

The effects of radiation on nervous tissues have been a subject of active investigation since changes in animal behavior and nerve electrical properties were first reported in the Soviet Union during the 1950s and 1960s.1 RF radiation is reported to affect isolated nerve preparations, the central nervous system, brain chemistry and histology, and the blood-brain barrier.

In studies with in vitro nerve preparations, changes have been observed in the firing rates of Aplysia neurons and in the refractory period of isolated frog

sciatic nerves exposed to 2.45-GHz microwaves at SAR values exceeding 5 W/kg.2,3,4 Those effects were very likely associated with heating of the nerve

preparations, in that much higher SAR values have not been found to produce

changes in the electrical properties of isolated nerves when the temperature was controlled.5, 6 Studies on isolated heart preparations have provided evidence of bradycardia as a result of exposure to RF radiation at nonthermal power densities,7 although some of the reported effects might have been artifacts caused by currents induced in the recording electrodes or by nonphysiological conditions in the bathing medium.8,9,10 Several groups of investigators have reported that nonthermal levels of RF fields can alter Ca2+ binding to the surfaces of nerve cells in isolated brain hemispheres and neuroblastoma cells cultured in vitro (reviewed by the World Health Organization11 and in Chapters 3 and 7 of this report). That phenomenon, however, is observed only when the RF field is amplitude-modulated at extremely low frequencies, the maximum effect occurs at a modulation frequency of 16 Hz. A similar effect has recently been reported in isolated frog hearts.12 The importance of changes in Ca2+ binding on the functional properties of nerve cells has not been established, and there is no clear evidence that the reported effect of low-intensity, amplitude-modulated RF fields poses a substantial health risk.

Results of in vivo studies of both pulsed and continuous-wave (CW) RF fields on brain electrical activity have indicated that transient effects can occur at SAR values exceeding 1 W/kg.13,14 Evidence has been presented that cholinergic activity of brain tissue is influenced by RF fields at SAR values as low as 0.45 W/kg.15 Exposure to nonthermal RF radiation has been reported to influence the electroencephalograms (EEGs) of cats when the field was amplitude-modulated at frequencies less than 25 Hz, which is the range of naturally occurring EEG frequencies.16 The rate of Ca2+ exchange from cat brain tissue in vivo was observed to change in response to similar irradiation conditions.17 Comparable effects on Ca2+ binding were not observed in rat cerebral tissue exposed to RF radiation,18 although the fields used were pulsed at EEG frequencies, rather than amplitude-modulated. As noted above, the physiological significance of small shifts in Ca2+ binding at nerve cell surfaces is unclear.

A wide variety of changes in brain chemistry and structure have been reported after exposure of animals to high-intensity RF fields.19 The changes include decreased concentrations of epinephrine, norepinephrine, dopamine, and 5-hydroxytryptamine; changes in axonal structure; a decreased number of Purkinje cells; and structural alterations in the hypothalamic region. Those effects have generally been associated with RF intensities that produced substantial local heating in the brain.

Extensive studies have been carried out to detect possible effects of RF radiation on the integrity of the blood-brain barrier.20,21 Although several reports have suggested that nonthermal RF radiation can influence the permeability of the blood-brain barrier, most of the experimental findings indicate that such effects result from local heating in the head in response to SAR values in excess of 2 W/kg. Changes in cerebral blood flow rate, rather than direct changes in permeability to tracer molecules, might also be incorrectly interpreted as changes in the properties of the blood-brain barrier.

Effects of pulsed and sinusoidal ELF fields on the electrical activity of the nervous system have also been studied extensively.22,23 In general, only high-intensity sinusoidal electric fields or rapidly pulsed magnetic fields induce sufficient current density in tissue (around 0.1-1.0 A/m2 or higher) to alter neuronal excitability and synaptic transmission or to produce neuromuscular stimulation. Somewhat lower thresholds have been observed for the induction of visual phosphenes (discussed in the next section) and for influencing the electrical activity of Aplysia pacemaker neurons when the frequency of the applied field matched the endogenous neuronal firing rate.24 Those effects, however, have been observed only with ELF frequencies and would not be expected to occur at the higher frequencies associated with GWEN transmitters. Recent studies with human volunteers exposed to 60-Hz electric and magn.

Electromagnetic radiation can be classified into two types: ionizing radiation and non-ionizing radiation, based on the capability of a single photon with more than 10 eV energy to ionize oxygen or break chemical bonds. Ultraviolet and higher frequencies, such as X-rays or gamma rays are ionizing, and these pose their own special hazards: see radiation and radiation poisoning. By far the most common health hazard of radiation is sunburn, which causes over one million new skin cancers annually.

5.2 Types of hazards

Electrical hazards.

Very strong radiation can induce current capable of delivering an electric shock to persons or animals. [citation needed] It can also overload and destroy electrical equipment. The induction of currents by oscillating magnetic fields is also the way in which solar storms disrupt the operation of electrical and electronic systems, causing damage to and even the explosion of power distribution transformers, blackouts (as occurred in 1989), and interference with electromagnetic signals (e.g. radio, TV, and telephone signals).

Fire hazards.

Extremely high power electromagnetic radiation can cause electric currents strong enough to create sparks (electrical arcs) when an induced voltage exceeds the breakdown voltage of the surrounding medium (e.g. air at 3.0 MV/m). These sparks can then ignite flammable materials or gases, possibly leading to an explosion.

This can be a particular hazard in the vicinity of explosives or pyrotechnics, since an electrical overload might ignite them. This risk is commonly referred to as Hazards of Electromagnetic Radiation to Ordnance (HERO) by the United States Navy (USN). United States Military Standard 464A (MIL-STD-464A) mandates assessment of HERO in a system, but USN document OD 30393 provides design principles and practices for controlling electromagnetic hazards to ordnance.

On the other hand, the risk related to fueling is known as Hazards of Electromagnetic Radiation to Fuel (HERF). NAVSEA OP 3565 Vol. 1 could be used to evaluate HERF, which states a maximum power density of 0.09 W/m^2 for frequencies under 225 MHz (i.e. 4.2 meters for a 40 W emitter)/

Biological hazards.

The best understood biological effect of electromagnetic fields is to cause dielectric heating. For example, touching or standing around an antenna while a high-power transmitter is in operation can cause severe burns. These are exactly the kind of burns that would be caused inside a microwave oven.[citation needed]

This heating effect varies with the power and the frequency of the electromagnetic energy, as well as the distance to the source. A measure of the heating effect is the specific absorption rate or SAR, which has units of watts per kilogram (W/kg). The IEEE and many national governments have established safety limits for exposure to various frequencies of electromagnetic energy based on SAR, mainly based on ICNIRP Guidelines, which guard against thermal damage.

There are publications which support the existence of complex biological and neurological effects of weaker non-thermal electromagnetic fields , including weak ELF magnetic fields and modulated RF and microwave fields. Fundamental mechanisms of the interaction between biological material and electromagnetic fields at non-thermal levels are not fully understood.

Lighting.

Fluorescent lights.

Fluorescent light bulbs and tubes internally produce ultraviolet light. Normally this is converted to visible light by the phosphor film inside a protective coating. When the film is cracked by mishandling or faulty manufacturing then UV may escape at levels that could cause sunburn or even skin cancer.

LED lights.

High CRI LED lighting.

Blue light, emitting at wavelengths of 400–500 nanometers, suppresses the production of melatonin produced by the pineal gland. The effect is disruption of a human being's biological clock resulting in poor sleeping and rest periods.

EMR effects on the human body by frequency

Warning sign next to a transmitter with high field strengths

While the most acute exposures to harmful levels of electromagnetic radiation are immediately realized as burns, the health effects due to chronic or occupational exposure may not manifest effects for months or years.[citation needed]

Extremely-low frequency.

High-power extremely-low-frequency RF with electric field levels in the low kV/m range are known to induce perceivable currents within the human body that create an annoying tingling sensation. These currents will typically flow to ground through a body contact surface such as the feet, or arc to ground where the body is well insulated.

Shortwave

Shortwave (1.6 to 30 MHz) diathermy heating of human tissue only heats tissues that are good electrical conductors, such as blood vessels and muscle. Adipose tissue (fat) receives little heating by induction fields because an electrical current is not actually going through the tissues.

5.3 Road Transport Safety

The basic strategy of a Safe System approach is to ensure that in the event of a crash, the impact energies remain below the threshold likely to produce either death or serious injury. This threshold will vary from crash scenario to crash scenario, depending upon the level of protection offered to the road users involved. For example, the chances of survival for an unprotected pedestrian hit by a vehicle diminish rapidly at speeds greater than 30 km/h, whereas for a properly restrained motor vehicle occupant the critical impact speed is 50 km/h (for side impact crashes) and 70 km/h (for head-on crashes).

As sustainable solutions for all classes of road have not been identified, particularly low-traffic rural and remote roads, a hierarchy of control should be applied, similar to classifications used to improve occupational safety and health. At the highest level is sustainable prevention of serious injury and death crashes, with sustainable requiring all key result areas to be considered. At the second level is real time risk reduction, which involves providing users at severe risk with a specific warning to enable them to take mitigating action. The third level is about reducing the crash risk which involves applying the road design standards and guidelines (such as from AASHTO), improving driver behavior and enforcement.

5.4 Conclusions to the section

A serious workplace injury or death changes lives forever for families, friends, communities, and coworkers too. Human loss and suffering is immeasurable. Occupational injuries and illnesses can provoke major crises for the families in which they occur. In addition to major financial burdens, they can impose substantial time demands on uninjured family members. Today, when many families are operating with very little free time, family resources may be stretched to the breaking point. Every person who leaves for work in the morning should expect to return home at night in good health. Can you imagine the knock on the door to tell you your loved one will never be returning home? Or the phone call to say he’s in the hospital and may never walk again? Ensuring that husbands return to their wives, wives to their husbands, parents to their children, and friends to their friends that is the most important reason to create a safe and healthy work environment. But it isn’t the only reason.

REDUCING INJURIES REDUCES COSTS TO YOUR BUSINESS: If a worker is injured on the job, it costs the company in lost work hours, increased insurance rates, workers' compensation premiums and possible litigation. Productivity is lost when other workers have to stop work to deal with the injury. Even after the injured employee has been sent home or taken to the hospital, other employees may be distracted or need to take time off from work in the aftermath of the incident. Even a single injury can have far-reaching and debilitating effects on your business.

SAFE WORKERS ARE LOYAL WORKERS: Any business knows that employee attrition and absenteeism can be major obstacles. When you create a healthy and safe workplace, you reduce those issues in several ways. By budgeting for safety improvements and making safety part of your operational plan, you engender trust. By involving employees in safety decisions through reporting, committees, walk-throughs and meetings you show that their opinion matters to you. By following through on their input and improving safety, you prove quite tangibly that you care about their well-being. Workers typically respond by working harder, showing more pride in their jobs and remaining loyal.

SAFETY IMPROVES QUALITY: Time and again, companies that put safety first turn out higher quality products. In some cases, that’s because a safe workplace tends to be a more efficient one, free of debris and tangles of cords. In other cases, it’s a matter of focus. By working in a clean, efficient environment, workers are able to reduce distractions and truly focus on the quality of what they do. The results? Better products that create customer loyalty, bigger margins and increased sales. In these ways and others workplace safety is about much more than legislation. It’s about creating the kind of productive, efficient, happy and inspiring workplace we all want to be part of. It’s about creating a highly profitable company. And that’s why it’s important.

CONCLUSIONS

In the course of this work, a software and hardware module for monitoring the parameters of the microclimate was developed and implemented, which measures the ambient temperature, relative humidity and atmospheric pressure without human intervention.

Based on the results of the work, the following conclusions can be drawn:

1. The analysis of the existing software applications of monitoring is carried out microclimate parameters allowed to identify strengths and weaknesses and to form requirements to the developed system;

2. The choice of software development tools is justified software, taking into account the features of software and hardware architecture;

3. Describes the architecture of the software being developed systems;

4. Developed a software and hardware module for monitoring parameters microclimate of the building and the environment;

5. Developed test cases allowed to test the work software and hardware;

The developed system can be used as a meteorological station or module as part of the "Smart Home" system, as well as to control the parameters of the microclimate in the premises.

The designed monitoring system meets the requirements of mobility, scalability, modularity, multichannel, and automatically generates reports.

The main advantages of this development are the following criteria:

1. The developed system works in the automatic mode of collecting, processing and transfer of information to the data center;

2. In the management system there is a possibility to quickly add new one’s devices;

3. External power is used to ensure the operation of the device; 4. Implemented the ability to transfer information to remote devices via Ethernet.

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Appendix A – Publications.

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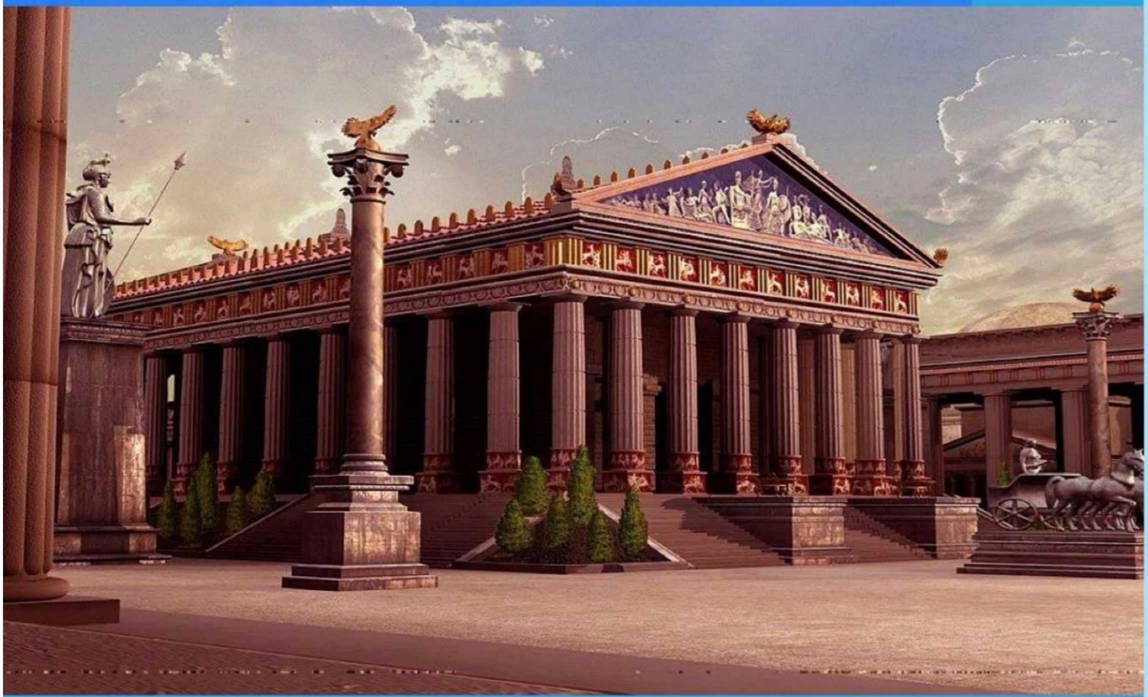

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ЗМІСТ (CONTENT)

ГУМАНІТАРНІ НАУКИ (HUMANITARIAN SCIENCES)

ЕКОНОМІЧНІ НАУКИ ТА МЕНЕДЖМЕНТ (ECONOMIC SCIENCE & MANAGEMENT)

ТЕХНІЧНІ НАУКИ (TECHNICAL SCIENCE)

УДК 004.67 : 004.032

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ПРОЕКТУВАННЯ ІНФОРМАЦІЙНОЇ СИСТЕМИ МОНІТОРИНГУ КЛІМАТИЧНИХ ДАНИХ З ВИКОРИСТАННЯМ ХМАРНИХ ТЕХНОЛОГІЙ

***Анотація**: дослідження присвячено розробленню конструктивного та програмного рішення щодо реалізації інформаційної системи моніторингу та прогнозування кліматичних умов з використанням платформи Arduino.*

***Ключові слова**: інформаційна система, алгоритм, кліматичний моніторинг, програмований логічний контролер, хмарні технології.*

Метеомоніторинг є важливим аспектом планування діяльності у різних сферах. На території великих підприємств наявні метеостанції під конкретні вимоги обліку погоди, вони вносять інформацію про опади, температуру, вітер. Точність метеоданих від загальнодоступних метеосервісів не є достатньою для локального використання. Адже погода також залежить від різних факторів, зокрема відстань до водойм, рельєф.

Персональна метеостанція – це певний набір давачів для вимірювання погоди, що використовуються приватною особою, асоціацією, бізнесом.

На сьогодні актуально та зручно використовувати метеостанції, котрі можна конфігурувати та адаптувати під певні, чітко визначені, вимоги [1].

Метеостанції, мають цифрову панель, що забезпечує отримання зібраних даних. Вони взаємодіють з персональним комп'ютером або сервером, де дані можна зберігати та відображати. Персональні метеостанції можуть використовуватись виключно для особистих цілей або водночас бути частиною інших проектів.

Основне завдання нашого дослідження полягає в розробці апаратного та програмного забезпечення для обробки запитів до бази метеорологічних даних й збереження їх в єдиній базі даних [2].

Для досягнення поставленої мети необхідно було виконати наступні завдання:

1. Провести аналіз існуючих програмних застосунків моніторингу параметрів мікроклімату з метою формування вимог для розробки нової системи;

2. Розробити архітектуру та функціонал програмного застосунку метеомоніторингу;

3. Розробити програмний модуль для моніторингу параметрів метеомоніторингу навколишнього середовища;

В ході виконання проведених досліджень обґрунтовано вибір алгоритмів прогнозування які застосовуються в системі моніторингу, було розроблено та реалізовано програмно-апаратний модуль для метеомоніторингу, який без участі людини вимірює температуру навколишнього повітря, відносну вологість, атмосферний тиск та інші параметри. Спроектовано та реалізовано установку метеостанції на базі програмованого логічного контролера Arduino, що у співвідношення якість-ціна дозволяє реалізувати дану систему якісно і в повній мірі.

Розроблена метеостанція має в основі мікроконтролер Arduino Leonardo, комунікаційну плату на базі мікросхеми WizNet5100, давач BME280 (вимірює температуру, вологість, атмосферний тиск).

Апаратна частина забезпечує наступну функціональність системи: час, дата, температури, атмосферний тиск, атмосферний тиск на рівні моря, вологість, короткочасний місцевий прогноз погоди.

Клієнтська частина передбачає веб-сайт з адміністративною формою входу, панель відображення інформації у вигляді блоків, сторінку з графічним представленням даних (Рисунок 1).

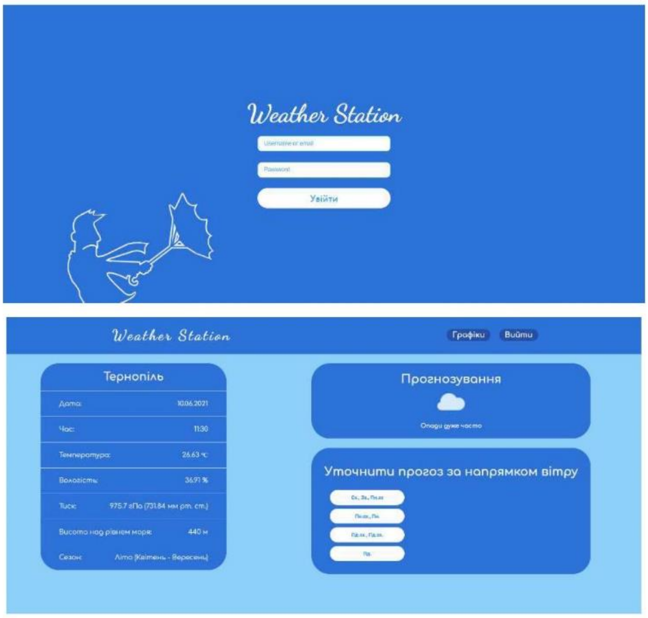

Рисунок 1 - Вхід в адміністративну панель
та головна сторінка адміністративної панелі

Розроблена система забезпечує моніторинг кліматичних даних у м. Тернопіль з можливістю прогнозування, віддаленого контролю та збору статистичних даних.

Впровадження розробленої системи дозволить покращувати локальне та короткотермінове прогнозування, покращуючи інформування про погодні умови для критичних областей життєдіяльності людини.

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DESIGN OF CLIMATE DATA MONITORING INFORMATION SYSTEM USING CLOUD TECHNOLOGIES

Abstract: *the study is devoted to the development of constructive and software solutions for the implementation of information system for monitoring and forecasting of climatic conditions using the Arduino platform.*

Keywords*: information system, algorithm, climate monitoring, programmable logic controller, cloud technologies.*

СЕРТИФІКАТ

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ЗМІСТ (CONTENT)

ГУМАНІТАРНІ НАУКИ (HUMANITARIAN SCIENCE)

ТЕХНІЧНІ НАУКИ (TECHNICAL SCIENCE)

УДК 004.67 : 004.032

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МЕТОДИ РЕАЛІЗАЦІЇ ПРОГРАМНО-АПАРАТНОГО КОМПЛЕКСУ ДЛЯ КЕРУВАННЯ ПАРАМЕТРАМИ МІКРОКЛІМАТУ

***Анотація**: в роботі розглянуто методи реалізації програмно-апаратного комплексу системи управління параметрами мікроклімату з використанням платформи Arduino та протоколу MQTT. Приведено алгоритм роботи такої системи.*

***Ключові слова**: контролер, дистанційний контроль, мікроклімат, інформаційна система.*

Великий вплив на організм людини має мікроклімат у будівлях. До нього прийнято відносити такі фізичні параметри, як температура, відносна вологість, атмосферний тиск, швидкість течії повітря та теплове випромінювання предметів. Мікроклімат — це поєднання фізичних параметрів, які впливають на обмін теплової енергії людини з навколишнім її середовищем [1].

Необхідність отримання інформації про поточний стан мікроклімату будівлі виникає при контролі умов праці, виробництва та зберігання продукції в приміщеннях.

Традиційний підхід до моніторингу кліматичних параметрів за допомогою портативних переносних або настінних приладів з необхідністю фіксування показань вручну неефективний, а часто і вкрай скрутний з точки зору витрат часу з боку персоналу. До того ж ручний моніторинг не позбавлений впливу людського фактору.

Основні завдання системи контролю мікроклімату полягає в безперервному автоматичному моніторингу параметрів мікроклімату будівлі та навколишнього середовища й збереження їх в єдиній базі даних.

Для досягнення поставленої мети необхідно було виконати наступні завдання:

1. Провести аналіз існуючих програмних застосунків моніторингу параметрів мікроклімату з метою формування вимог для розробки нової системи;

2. Розробити архітектуру та функціонал програмного застосунку моніторингу параметрів мікроклімату;

3. Провести аналіз інструментарію та бібліотек для реалізації запропонованої архітектури, що дозволив би забезпечити мобільність, масштабованість, багатоканальність;

4. Розробити програмно-апаратний модуль для моніторингу параметрів мікроклімату будівлі та навколишнього середовища;

5. Розробити тест-кейси для тестування програмно-апаратного модуля.

В ході виконання проведених досліджень було розроблено та реалізовано програмно-апаратний модуль для моніторингу параметрів мікроклімату, який без участі людини вимірює температуру навколишнього повітря, відносну вологість і атмосферний тиск. Його було реалізовано на базі програмованого логічного контролера Arduino, що у співвідношення якість-ціна дозволяє реалізувати дану систему якісно і в повній мірі.

На рисунку 1 наведений алгоритм визначення кількості аероіонізаторів, які необхідно встановити у заданому приміщенні або робочій зоні, а на рисунку

2 – алгоритм функціонування системи автоматизованого забезпечення оптимального мікроклімату виробничого приміщення у вигляді блок-схеми.

Вибір кількості аероіонізаторів відбувається за таким алгоритмом. Поточні значення геометричних розмірів приміщення і сили випромінювання іонізатора порівнюються з табличними величинами [2].

Відповідно до отриманих результатів розрахунку здійснюється видача рекомендацій щодо кількості аероіонізаторів заданої сили випромінювання, які необхідно встановити у заданому приміщенні або робочій зоні.

Алгоритм функціонування системи автоматизованого забезпечення оптимального мікроклімату міститься у наступному. Спочатку визначаються нормовані показники температури робочого приміщення і нормовані показники аероіонізації.

Далі ці показники порівнюються з поточними значеннями температури і аероіонізації, які надійшли від вимірювальних приладів. В залежності від отриманих результатів порівняння блок управління видає управляючий вплив: включити або виключити кондиціонер, включити або виключити аероіонізатор. Поточний стан параметрів мікроклімату і виконавчих приладів (вкл./відк.) фіксується на табло.

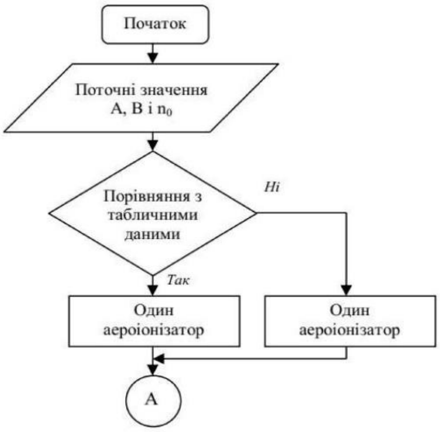

Рисунок 1 – Алгоритм системи автоматизованого контролю визначення параметрів повітря.

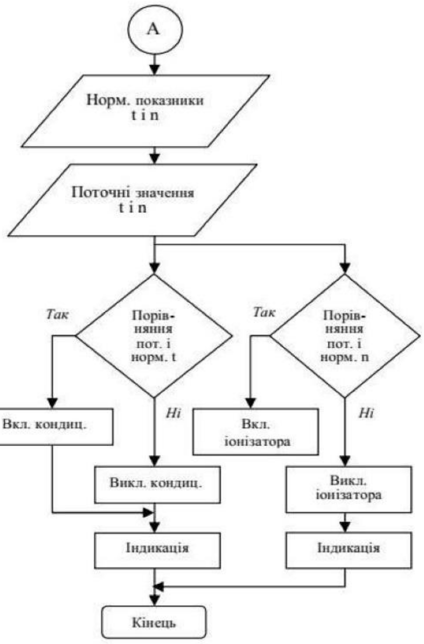

Рисунок 2 – Блок схема роботи системи автоматичного регулювання.

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METHODS OF IMPLEMENTATION OF SOFTWARE AND HARDWARE COMPLEX FOR CONTROL OF MICROCLIMATE PARAMETERS

Abstract: *The methods of realization of the software and hardware complex of the microclimate control system using the Arduino platform and the MQTT protocol are considered in the work. The algorithm of operation of such system is given.*

Keywords: *controller, remote control, microclimate, information system.*

Appendix B - Program listing

monitoring.ino

```
#include <SPI.h>
#include <Wire.h>
#include <OneWire.h>
#include <DallasTemperature.h>
#include <Ethernet.h>
#include <PubSubClient.h>
#include <ArduinoJson.h>
#include <Adafruit_BMP280.h>
#include <dht.h>
#define ONE_WIRE_BUS 5
#define BBT "mqtt.beebotte.com"
#define TOKEN "token_4g41ZmAfLWgAI29d"
#define Channel "Arduino2"
#define CoResource "res"
#define first "first"
#define second "second"
#define third "third"
#define fourth "fourth"
#define pres "pres"
#define hum "hum"
#define test "test"
#define Write true
#define DHT11_PIN 7
OneWire oneWire(ONE_WIRE_BUS);
DallasTemperature sensors(&oneWire);
```

```
Adafruit_BMP280 bmp280;
dht DHT;
long lastMsg = 0;
long lastReconnectAttempt = 0;
const int powerled1=3;
const int powerled2=4;
EthernetClient ethClient;
PubSubClient client(ethClient);
byte mac[] = {0xDE, 0xAD, 0xBE, 0xEF, 0xFE, 0xED};
IPAddress ip(192, 168, 1, 50);
IPAddress gateway(192,168,1,1);
IPAddress subnet(255,255,255,0);
uint8_t sensor1[8] = { 0x28, 0xB0, 0xA7, 0x01, 0x3B, 0x19, 0x01, 0xEB };  uint8_t sensor2[8] = { 0x28, 0xB0, 0xB9, 0xE5, 0x3A, 0x19, 0x01, 0xD9 };  uint8_t sensor3[8] = { 0x28, 0x6E, 0xC8, 0x5A, 0x3B, 0x19, 0x01, 0x0E };  uint8_t sensor4[8] = { 0x28, 0xB9, 0x79, 0xC1, 0x3E, 0x19, 0x01, 0x8D };  uint8_t sensor5[8] = { 0x28, 0xE6, 0x9F, 0xEF, 0x3A, 0x19, 0x01, 0x3A };  float temp1;
float temp2;
float temp3;
float temp4;
float temp5;
void setup() {
  Serial.begin(9600);
  sensors.begin();
  pinMode(powerled1, OUTPUT);
  pinMode(powerled2, OUTPUT);
  digitalWrite(powerled1, LOW);
  digitalWrite(powerled2, HIGH);
  client.setServer(BBT, 1883);
```

```
while (!Serial) {;}
if (Ethernet.begin(mac) == 0) {
  Serial.println("Failed to configure Ethernet using DHCP"); Ethernet.begin(mac, ip, gateway, subnet);
}
delay(1000);
Serial.println("connecting...");
lastReconnectAttempt = 0;
client.setCallback(onMessage);
}
void onMessage(char* topic, byte* payload, unsigned int length) { StaticJsonBuffer<128> jsonInBuffer;
JsonObject& root = jsonInBuffer.parseObject(payload);
if (!root.success()) {
  Serial.println("parseObject() failed");
  return;
 }
bool data = root["data"];
digitalWrite(powerled1, data ? HIGH : LOW);    digitalWrite(powerled2, data ? LOW : HIGH);    Serial.print("Received message of length ");
Serial.print(length);
Serial.println();
Serial.print("data ");
Serial.print(data);
Serial.println();
}
void readSensorData()
{
sensors.requestTemperatures();
```

```
  temp1 = getTemperature(sensor1);
  temp2 = getTemperature(sensor2);
  temp3 = getTemperature(sensor3);
  temp4 = getTemperature(sensor4);
  temp5 = getTemperature(sensor5);
  float pressure = bmp280.readPressure();
  int chk = DHT.read11(DHT11_PIN);
  if (!isnan(temp1 )) {
     publish(test, 22, Write);
     publish(CoResource, temp1, Write);
     publish(first, temp2, Write);
     publish(second, temp3, Write);
     publish(third, temp4, Write);
     publish(fourth, temp5, Write);
     publish(pres,   pressure*0.00750062,   Write);                    publish(hum,
DHT.humidity, Write);
   }
}

float getTemperature(DeviceAddress deviceAddress)
{
  float temp = sensors.getTempC(deviceAddress);
  return temp;
 }
void publish(const char* resource, float data, bool persist)
{
   StaticJsonBuffer<128> jsonOutBuffer;
   JsonObject& root = jsonOutBuffer.createObject();
   root["channel"] = Channel;
```

```
    root["resource"] = resource;
    if (persist) {
      root["write"] = true;
    }
    root["data"] = data;
    char buffer[128];
    root.printTo(buffer, sizeof(buffer));
    char topic[64];
    sprintf(topic, "%s/%s", Channel, resource);
    client.publish(topic, buffer);
  }

  const char chars[] =
"abcdefghijklmnopqrstuvwxyzABCDEFGHIJKLMNOPQRSTUVWXYZ1234567890";
char id[17];

  const char * generateID()
  {
   randomSeed(analogRead(0));
   int i = 0;
   for(i = 0; i < sizeof(id) - 1; i++) {
    id[i] = chars[random(sizeof(chars))];    }
   id[sizeof(id) -1] = '\0';
   return id;
  }

  void reconnect() {
   while (!client.connected()) {
```

```
    Serial.print("Attempting MQTT connection...");     if (client.connect(generateID(), TOKEN, "")) {     Serial.println("connected");
      client.subscribe("Arduino2/led");
    } else {
      Serial.print("failed, rc=");
      Serial.print(client.state());
      Serial.println(" try again in 5 seconds");     delay(5000);
    }
  }
}
void loop() {
  if (!client.connected()) {
    reconnect();
  }
  client.loop();
  long now = millis();
  if (now - lastMsg > 600000) {   lastMsg = now;
   readSensorData();
  }
}
```

PubSubClient.h

```
#ifndef PubSubClient_h
#define PubSubClient_h
#include <Arduino.h>
#include "IPAddress.h"
#include "Client.h"
#include "Stream.h"
#define MQTT_VERSION_3_1     3
```

```
#define MQTT_VERSION_3_1_1    4
#ifndef MQTT_VERSION
#define MQTT_VERSION MQTT_VERSION_3_1_1  #endif
#ifndef MQTT_MAX_PACKET_SIZE
#define MQTT_MAX_PACKET_SIZE 128
 #endif
#ifndef MQTT_KEEPALIVE
#define MQTT_KEEPALIVE 15
#endif
#ifndef MQTT_SOCKET_TIMEOUT
#define MQTT_SOCKET_TIMEOUT 15
#endif
#define MQTT_CONNECTION_TIMEOUT     -4
#define MQTT_CONNECTION_LOST        -3
#define MQTT_CONNECT_FAILED         -2
#define MQTT_DISCONNECTED           -1
#define MQTT_CONNECTED               0
#define MQTT_CONNECT_BAD_PROTOCOL    1
#define MQTT_CONNECT_BAD_CLIENT_ID   2
#define MQTT_CONNECT_UNAVAILABLE     3
#define MQTT_CONNECT_BAD_CREDENTIALS     4     #define
MQTT_CONNECT_UNAUTHORIZED    5
#define MQTTCONNECT     1 << 4
#define MQTTCONNACK     2 << 4
#define MQTTPUBLISH     3 << 4
#define MQTTPUBACK      4 << 4
#define MQTTPUBREC      5 << 4
#define MQTTPUBREL      6 << 4
#define MQTTPUBCOMP     7 << 4
```

```
#define MQTTSUBSCRIBE   8 << 4
#define MQTTSUBACK      9 << 4
#define MQTTUNSUBSCRIBE 10 << 4
#define MQTTUNSUBACK    11 << 4
#define MQTTPINGREQ     12 << 4
#define MQTTPINGRESP    13 << 4
#define MQTTDISCONNECT  14 << 4
#define MQTTReserved    15 << 4
#define MQTTQOS0        (0 << 1)
#define MQTTQOS1        (1 << 1)
#define MQTTQOS2        (2 << 1)
 #define MQTT_MAX_HEADER_SIZE 5
#if defined(ESP8266) || defined(ESP32)
#include <functional>
#define MQTT_CALLBACK_SIGNATURE std::function<void(char*, uint8_t*,
unsigned int)>  callback
#else
#define MQTT_CALLBACK_SIGNATURE void (*callback)(char*, uint8_t*,
unsigned int)
#endif
#define CHECK_STRING_LENGTH(l,s) if (l+2+strlen(s) >
MQTT_MAX_PACKET_SIZE)
{_client->stop();return false;}
   class PubSubClient : public Print {
  private:
  Client* _client;
  uint8_t buffer[MQTT_MAX_PACKET_SIZE];
  uint16_t nextMsgId;
  unsigned long lastOutActivity;
```

```
unsigned long lastInActivity;
bool pingOutstanding;
MQTT_CALLBACK_SIGNATURE;
uint16_t readPacket(uint8_t*);
boolean readByte(uint8_t * result);
boolean readByte(uint8_t * result, uint16_t * index);
boolean write(uint8_t header, uint8_t* buf, uint16_t length);
uint16_t writeString(const char* string, uint8_t* buf, uint16_t pos);
size_t buildHeader(uint8_t header, uint8_t* buf, uint16_t length);
IPAddress ip;
const char* domain;
uint16_t port;
Stream* stream;
int _state;
public:
PubSubClient();
PubSubClient(Client& client);
PubSubClient(IPAddress, uint16_t, Client& client);
PubSubClient(IPAddress, uint16_t, Client& client, Stream&);

PubSubClient(IPAddress, uint16_t, MQTT_CALLBACK_SIGNATURE,Client& client);
PubSubClient(IPAddress, uint16_t, MQTT_CALLBACK_SIGNATURE,Client& client,
Stream&);
PubSubClient(uint8_t *, uint16_t, Client& client);
PubSubClient(uint8_t *, uint16_t, Client& client, Stream&);
PubSubClient(uint8_t *, uint16_t, MQTT_CALLBACK_SIGNATURE,Client& client);
```

```
PubSubClient(uint8_t *, uint16_t, MQTT_CALLBACK_SIGNATURE,Client&
client, Stream&);
PubSubClient(const char*, uint16_t, Client& client);
PubSubClient(const char*, uint16_t, Client& client, Stream&);
PubSubClient(const char*, uint16_t, MQTT_CALLBACK_SIGNATURE,Client&
client);
PubSubClient(const char*, uint16_t, MQTT_CALLBACK_SIGNATURE,Client&
client,
Stream&);
PubSubClient& setServer(IPAddress ip, uint16_t port);
PubSubClient& setServer(uint8_t * ip, uint16_t port);
PubSubClient& setServer(const char * domain, uint16_t port);
PubSubClient& setCallback(MQTT_CALLBACK_SIGNATURE);
PubSubClient& setClient(Client& client);
PubSubClient& setStream(Stream& stream);
boolean connect(const char* id);
boolean connect(const char* id, const char* user, const char* pass);
boolean connect(const char* id, const char* willTopic, uint8_t willQos, boolean
willRetain, const
char*  willMessage);
boolean connect(const char* id, const char* user, const char* pass, const char*
willTopic, uint8_t
willQos, boolean willRetain, const char* willMessage);
boolean connect(const char* id, const char* user, const char* pass, const char*
willTopic, uint8_t
willQos,  boolean willRetain, const char* willMessage, boolean cleanSession);
void disconnect();
boolean publish(const char* topic, const char* payload);
boolean publish(const char* topic, const char* payload, boolean retained);
```

boolean publish(const char* topic, const uint8_t * payload, unsigned int plength);

boolean publish(const char* topic, const uint8_t * payload, unsigned int plength, boolean

retained);

boolean publish_P(const char* topic, const char* payload, boolean retained);

boolean publish_P(const char* topic, const uint8_t * payload, unsigned int plength, boolean

retained);

boolean beginPublish(const char* topic, unsigned int plength, boolean retained);   int endPublish();

virtual size_t write(uint8_t);

virtual size_t write(const uint8_t *buffer, size_t size);

boolean subscribe(const char* topic);

boolean subscribe(const char* topic, uint8_t qos);

boolean unsubscribe(const char* topic);

boolean loop();

boolean connected();

int state();

};

#endif