

A SMART WEATHER STATION BASED ON SENSOR TECHNOLOGY

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Abstract. *In this paper a new approach to utilize technology in a practical and meaningful manner within a smart weather station system is presented. This system is primary intended for use in agriculture and meteorological stations, but its application is not limited here. Weather parameters observing plays an important role in human live, so the observing, collecting and storing of information about the temporal dynamics of weather changes is very important. The primary goal is to design a low cost smart system for storing data obtained by measuring various physical parameters in the atmosphere without human involvement. Realized system use Internet of Things technology to storage measured results, and allows the user to access the results anytime and anywhere. In this research Internet of Things is used as technology for storing measured data, because this technology is an advanced and efficient solution for connecting the things to the Internet and to connect the entire world of things in a network. The proposed smart weather station system is based on the following steps: direct environment sensing, measuring and storing data and then allowing user to customize the settings. This research will present the design and implementation of a practical smart weather station system, which can be further extended. The system is based on: group of embedded sensors, Peripheral Interface Microcontroller (PIC) microcontroller as a core and server system and wireless internet using Global System for Mobile Telecommunications (GSM) module with General Packet Radio Service (GPRS) as a communication protocol.*

Key words: *Smart weather station, Internet of Things, PIC microcontroller, Sensor technology, General Packet Radio Service (GPRS)*

1. INTRODUCTION

As Internet of Things technology developed and became more and more affordable, there are more and more smart devices based on this technology. Internet of Things is a network of physical objects in which electronics are incorporated, as well as software, microcontrollers and sensors that allow users to obtain timely and accurate data through services for data exchange between users or other connected devices. The main concept

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behind the Internet of Things (IoT) technology used in researches as this is to connect various electronic devices as smart weather station through a network and then retrieve the data from these devices (sensors) which can be distributed in any fashion, upload them to any cloud service where one can analyze and process the gathered information. The smart weather stations is device which can observe, measure and storage meteorological/ambient parameters without human involvement. Smart weather station can be used in meteorological stations for observing various physical parameters in the atmosphere, in agriculture can help in improving the productivity of crops. In mines, smart weather stations can be used to detect, besides the basic meteorological parameters, the possible danger of excessive concentration of CH₄ methane, carbon dioxide, LPG gas, etc. to save lives of miners. Technological development offers easier solutions for the realization better devices than in the past. It also offers new sensors with improved precision and response times, from the other side that sensors miniaturized electronic devices and power consumption. The use of sensors on Internet of Things devices ensures a seamless connection between the electronic devices and the physical world [1]. The atmosphere is a complicated system, which consists of a lot of parameters that have an impact on one another. Small change of one of the parameters, have large influence on life quality. From that reason, it is difficult to predict in atmospheric parameters and weather forecasts at whole. The devices such as smart weather station, it can facilitate the prediction of atmospheric changes and its environmental impacts. This device is designed for meteorological measurements, observations and data storage, wherever measurement and monitoring of ambient parameters such as production halls, mines, hospitals, laboratories, libraries, museums, botanical gardens, etc. are necessary. This system includes the wireless communication technology and Internet of Things technology as in researches [2-4]. Previous research was based on the storage of data on media that cannot be accessed during the measurement to give the end user an insight into the current results. The smart weather station based on Internet of Things technology updates the information to the database on Cloud or database on webserver after observing and measuring the weather conditions periodically. The realized smart weather station for sending data to Cloud uses Global Packet Radio Service, so that the device can be used in inaccessible places, unlike W-Fi Internet modules that must have access to the Internet. By updating the data to the Cloud or database, end user can maintain the weather conditions of a particular place that can be known readily verified anywhere in the world.

The development of this system aims to meet the needs of the user by employing networked low-power sensors sensitive to the environment, so it can be applied to make life easier.

The realized device expect DC power supply and batteries offers the possibility of solar power, which is an advantage in the need of measuring atmospheric parameters in difficult accessible locations. In accordance with the use of solar power, the number of measuring points, i.e. as the surface of the solar panel increases, and number of measurement points will increase over an hour.

The device has a wide application based on meteorological/ambient parameters that measure:

- Temperature [°C] or [°F],
- Humidity [%],
- Atmospheric pressure [mBar],
- Altitude [m],

- Wind speed (Anemometer) [m/s] or [km/h],
- Lighting [lx],
- Detection and measurement of gas (LPG) [%].

All measurements are accompanied by information on the time and date of measurement. Time and date information are present during the storage of data on the server and are available when downloading the results.

There are a large number of modular devices for measuring and acquiring atmospheric parameters on the market, but there are no devices that combine all modules for measuring/observing both ambient and atmospheric parameters.

2. THEORETICAL BACKGROUND

The smart weather station is essentially a data acquisition system remotely able to collect information based on meteorological/ambient parameters and store it in the Cloud or database on the webserver [5]. Data acquisition system such as smart weather station are based on Internet of Things technology. This smart weather station can be called “smart” in relation to research related to so-called non-smart weather stations that do not use Internet of Things technology. Non-smart weather station use only wired connected media to store measurement results, such as Security digital (SD) memory card, flash memory, EEPROM memory, etc. [6]. The areas of application point out include, e.g., the smart industry, where the development of intelligent production systems and connected production sites is often discussed under the heading of Industry 4.0. [7].

Main elements of the smart weather station are:

1. Network for communication – wire, cable (Local Area Network (LAN)), wireless.
2. Intelligent control – microcontroller to manage the system.
3. Embedded sensors – products which can be used to observe and measure meteorological/ambient parameters.

There are many different implementations of smart weather stations, which are reflected in the way in which communications and storage media are realized. Most of the implementations use wireless technologies for communication between the sensor part and the main unit.

The main problem is how to realize a smart weather station that will be as cheap as possible and as safely as possible to store the measured data. Also, how to make a weather station that will help people to automate regular daily activities. For example, store data so that the end-user can easily access them, access the results of the measurement from anywhere, manipulate stored data, etc. Based on these needs, smart weather stations have been developed based on different technologies:

1. Smart weather station based on custom microcontroller and mobile application. Smart weather station is using Bluetooth for communication between the mobile application and the weather station. Limitation of the system like this is Bluetooth range.
2. Smart weather station based on custom microcontroller and computer. Smart weather station is using Radio Frequency (RF) for communication between the computer and weather station. It is based on a computer as entry point for

communication between user and smart weather station. Computer is connected using wire to microcontroller.

3. Smart weather station based on NodeMCU running ESP8266 Wi-Fi module and Cloud or database on webserver. Wi-Fi Internet is using for communication between weather station and database. Limitation of the system like this is because ESP8266 need to have access to the Internet.
4. Smart weather station based on custom microcontroller and Cloud or database on webserver. Smart weather station is using Global System for Mobile Telecommunications for communication with General Packet Radio Service for communication between weather station and Cloud or database on webserver. Advantage of this system is that the Global System for Mobile Telecommunications does not require Internet access and can be used in difficult accessible locations.

Most smart weather stations are based on wireless Internet communication and data storage on the Cloud or database on webserver using Wi-Fi modules. Also, the smart weather stations offer solution based on wireless Internet communication and data storage on the Cloud or database on webserver using General Packet Radio Service for communication. Smart weather stations offers similar functionality to the end user. That functionality is based on:

1. Integration with smart appliances.
2. Integration with embedded sensors for observing and measuring meteorological/ambient parameters.
3. Access to data from anywhere
4. Remote control of smart weather station.

In the research the authors [8] analyzed smart weather monitor based on NodeMCU microcontroller and Internet of Things. This system are based on two main parts. First, NodeMCU as heart of the device which provides the platform of Internet of Things. Sensors connected to this microcontroller are DHT11 which are used to measure temperature and humidity and Light Dependent Resistor (LDR) as light intensity sensor. Second part based on ThingSpeak Internet of Things platform for storing data using ESP module. The developer of NodeMCU is ESP8266 Opensource Community. It has an operating system called XTOS. The CPU is ESP8266 (LX106). It has an in-built memory of 128 kBytes and a storage capacity of 4MBytes. It includes firmware which runs on the ESP8266 Wi-Fi SoC from Espressif Systems and hardware which is based on the ESP module. DHT11 sensor are used to measure temperature and relative humidity. This sensor includes a resistive-type humidity measurement component and an NTC temperature measurement component. The accuracy of the temperature measurement is weaker than the digital calibrated sensor used in this smart weather station. Light Dependent Resistor used as light intensity sensor. Analog sensor has not been calibrated, and measurement is not precision in relation to the digital sensors used in the smart weather station described in this paper. NodeMCU need to have access to the Internet to send data to the Cloud, which is another limitation of this research.

In another research, authors [9] analyzed Arduino based smart weather station based on Wi-Fi Internet technology and Arduino. The implemented system consists of a microcontroller (ATmega328) as a main processing unit for the entire system. Sensors used in this research are LM35 as temperature sensor, Light Dependent Resistor as light intensity sensor, microphone as sound sensor for detecting decibel level and Carbon Monoxide (CO) sensor. Temperature sensor LM35, are analog sensor with weaker accuracy than digital

sensor used in this smart weather station. Also, it can measure temperature only above 0°C (from 0°C to 100°C), on the other digital sensor used in this weather station have operating range from -40°C to +85°C. For sending data to Cloud authors used Wi-Fi ESP8266 module. Limitation of this system is that ESP8266 need to have access to the Internet to send data to the Cloud.

In a research [10] about temperature and humidity monitoring system for agriculture, authors analyzed weather monitoring system based on Raspberry Pi and ThingSpeak. Authors used Raspberry Pi 3 model B, it has a 1.2 GHz 64-bit quad core ARMv8 CPU, and RAM of 1GB. it also has 40 GPIO pins, Full HDMI port, 4 USB ports, Ethernet port, 802.11n wireless LAN connectivity, etc. Operating voltage of system is 5V. For measuring temperature and humidity authors used DHT11 sensor with 8-bit microcontroller. DHT11 sensor offer temperature measuring in range from 0°C to 55°C, and relative humidity in range from 20% to 90%. In compared with sensor used in this manuscript BME280, DHT11 provides weaker range of temperature and humidity measurement. Authors used Local Area Network wired Internet connectivity for send data of measured temperature and humidity to ThingSpeak.

Authors in next researches [11] and [12] analyzed smart weather station based on Raspberry Pi and mobile application. In proposed system architecture ARM11 processor is center core. In this system single core 32 bit ARM11 processor is used. It is having 512MB RAM. This board has on-board USB ports, Ethernet port, HDMI port, etc. It is easy to give internet connection to this board by using Ethernet port. The operating voltage of this board is 5V. For temperature and pressure measurement authors use BMP180 sensor with weaker accuracy than BME280 sensor and equipped with humidity sensor. Authors for upload data in ThingSpeak using Ethernet via Local Area Network (LAN) module on Raspberry Pi. General Packet Radio Service module have advantage in relation than Ethernet because General Packet Radio Service use Wireless communication to upload data on ThingSpeak database.

In a research [13] related to the development of weather station based on solar powered, authors used a microcontroller MSP430 and ZigBee wireless transmitter for communication. ZigBee wireless module are used for communication between weather station and the monitoring part. In that research, authors use Light Dependent Resistor for detecting solar radiation level, temperature and humidity sensor and small circuit designed for rain level detection. The disadvantage of this system is that the authors do not store measured data on any medium, but only monitor measured values using the LCD display.

Recent developments in Internet of Things made possible to collect the data in-situ. The user can access this data anywhere in the world, at any time through Internet. Internet of Things refers to giving objects representation in the digital realm through giving them a unique ID and connecting them in a network [14]. In other words, these things are connected to the internet and are able to automatically transfer data without relying on human interaction - hence being "Machine to Machine" (M2M) interaction [15]. A Machine to Machine talk (M2M) system maybe generally seen as a wireless sensor network where sensor nodes are embedded systems referred to as M2M terminals. Embedded software running inside M2M terminal should manage concurrent tasks efficiently and reliably within limited hardware resources and with real-time constraints. [16].

ThingSpeak, is an Application Programming Interface (API) and web service for the Internet of Things. The ThingSpeak Application Programming Interface is an open source

interface which listens to incoming data, timestamps it, and outputs it for both human users (through visual graphs) and machines (through easily parse-able code) [17].

ThingSpeak is a part of Cloud computing as Platform as a Service (PaaS), including operating system, programming-language execution environment, database, and web server.

ThingSpeak allows to build applications around data collected by sensors. It offers near real-time data collection, data processing, and also simple visualizations for its users (see Fig. 1). Data is stored in so-called channels, which provides the user with a list of features.

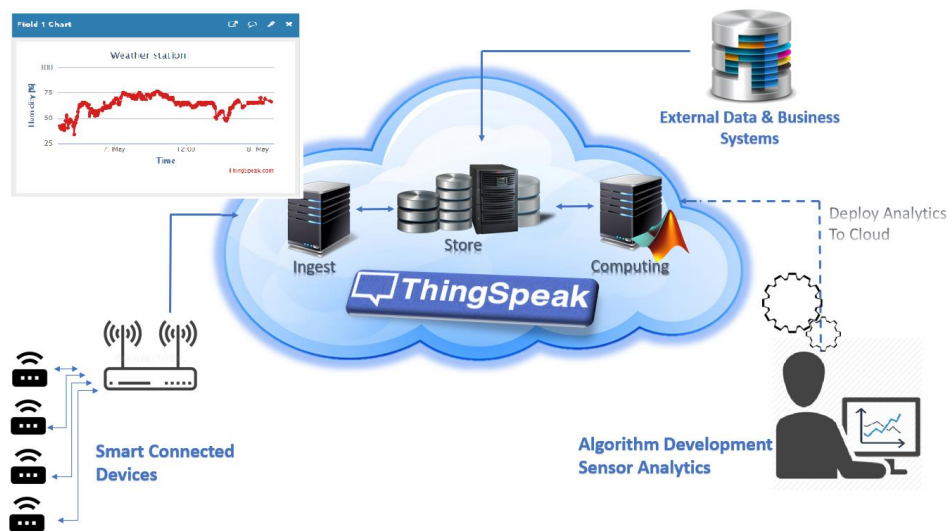


Fig. 1 ThingSpeak principle of work [15].

Once when user create a channel, data can be published by accessing the ThingSpeak API with a *write key*, a randomly created unique alphanumeric string used for authentication. From the other side, a *read key* is used to access channel data in case it is set to keep user data private (the default setting). User channels can also be made as public in which case no read key is required.

Each user ThingSpeak channel can have up to 8 fields to store data of measured meteorological/ambient parameters such as temperature, humidity, pressure, etc. All entries from smart device are stored with a unique identifier and a date and time stamp. Also, user can import existing data from a Comma-Separated Values (CSV) file to the channel.

3. THE WORKING PRINCIPLE

This paper presents the model of smart weather station based on PIC microcontroller and Cloud platform. The system is designed to be scalable and easy to setup and extend. It is based on powerful PIC microcontroller which manage the whole system. It includes embedded sensors for observing and measuring of the environment or places where is that necessary and GPRS module which upload data to Cloud platform.

3.1. Design of solution

A weather station is realized so that it consists of six segments, shown in Fig. 2. The power supply serves all other blocks. The microcontroller PIC18F45K22 [18], which represents the core of the entire device, manages the sensor block, which serves for meteorological measurements and observations. Also, the GSM block, realized using the SIM8001 module [19], is controlled by the above microcontroller.

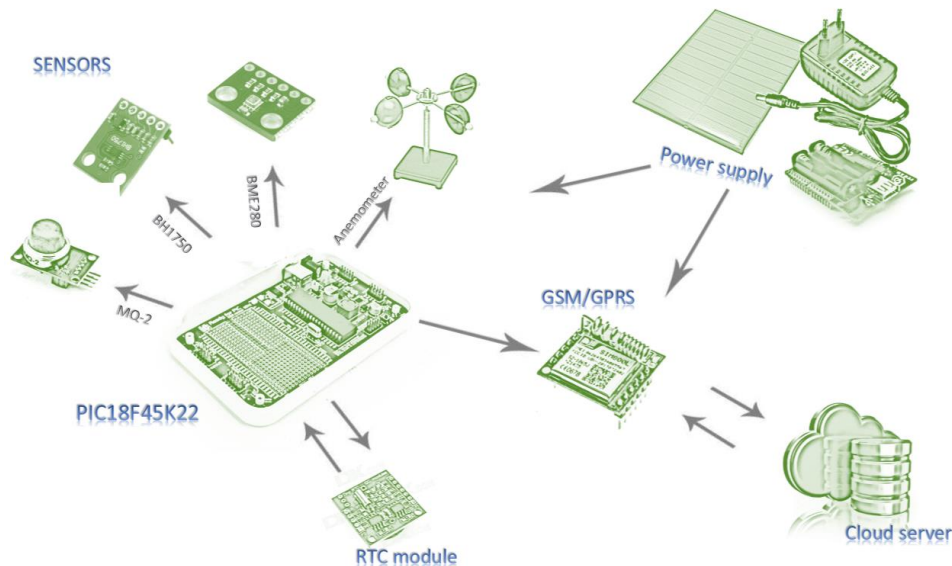


Fig. 2 Block schematic of smart Weather Station.

The sensor part of weather station consists of the following sensors:

- BME280 [20]:
 - Temperature [°C] or [°F],
 - Humidity [%],
 - Atmospheric pressure [mBar],
 - Altitude [m].

BOSCH Sensortec BME280 sensor allows the measurement of temperature in the range of -40°C to $+85^{\circ}\text{C}$, relative air humidity ranging from 0% to 100% RH and air pressure in the range of 300 to 1100 hPa. Also, based on the measurement of atmospheric pressure, it is possible to calculate the altitude at which the measurement is performed. Supply voltage of this sensor is in the range of 1.71V to 3.6V. The sensor used is on the same printed circuit board with the voltage regulator (from 5V to 3.3V), so that the power supply voltage is 5V. Startup time of BME280 is less than 2ms.

The resolution of the humidity measurement is fixed at 16 bit ADC output. Absolutely accuracy tolerance is $\pm 3\%$ RH. The resolution of the pressure data depends on the Infinite Impulse Response (IIR) filter and the oversampling setting. Accordingly, when the IIR filter is enabled, the pressure resolution is 20 bit, in case of when the IIR filter is disabled, pressure resolution is 16+ bit (e.g. 18 bit). Absolutely accuracy tolerance is ± 1 hPa (in

operation temperature ranged from 0°C to 65°C). Similar to the measurement of atmospheric pressure, in case when IIR filter is enabled, the temperature resolution is 20 bit, if IIR filter is disabled, the temperature resolution is 16+ bit. Absolutely accuracy tolerance is $\pm 0.5^\circ\text{C}$, at operating temperature 25°C and $\pm 1^\circ\text{C}$, in operating temperature ranged from 25°C to 65°C.

- Anemometer [21]:
 - Wind speed [m/s] or [km/h].

Anemometer are realized using Revolution per Minute (RPM) sensor. The wind speed is calculated based on time of detection rotation, the length of the blades, the circumference of the circle by which it is rotated, the number of blades and the weight of the blades.

- BH1750 [22]:
 - Lighting [lx].

ROHM Semiconductor BH1750 sensor is Ambient Light Sensor with voltage power supply ranged from 2.4V to 3.6V. This sensor is placed on same board with voltage regulator, so it is possible to power supply 5V. It is possible to detect wide range at High resolution ranged from 1 - 65535 lx. It is possible to detect minimum 0.11 lx to 100000 lx using function for influence of optical window. Operating temperature is ranged from -40°C to 85°C.

- MQ-2 [23]:
 - Detection and measurement of gas (LPG) [%].

The MQ-2 sensor allows measuring in range from 300 to 10000 ppm of combustible gas (LPG, Hydrogen, Oxygen, Propane and Methane). Operating voltage is ranged from 4.9V to 5.1V, heather consumption is $\leq 900\text{mW}$.

Also, there is and Real Time Clock (RTC) module DS1307 [24], which serves to set how long the measurements take.

3.2. Implementation (hardware and software)

Realization of the measurement system can be seen on electrical scheme of the smart weather station shown in Fig. 3.

The microcontroller used for the realization of the weather station, operates at a frequency of 8 MHz, using an external oscillator. For the speed of the PIC18F45K22 microcontroller, it is possible to use a high-frequency internal oscillator with the highest frequency of 16 MHz, with the possibility of a 4-time multiplier (PLLEN) frequency increase - at 64 MHz. Also, it is possible to use an external oscillator, which also has the ability to operate at a frequency of 64 MHz, using the PLLEN multiplier of the oscillator operating frequency. Master Reset (MCLR) is software off, but a pull-up resistor of 10 k Ω is also installed in the realization, in order to see the possibility of hardware disconnection of the MCLR pin on the microcontroller.

This microcontroller has 2 USART (Universal Synchronous Asynchronous Receiver Transmitter) modules [25]. With this it is possible to manage hardware modules communicating with the microcontroller via the I2C or SPI bus, and also via the RX/TX serial terminal.

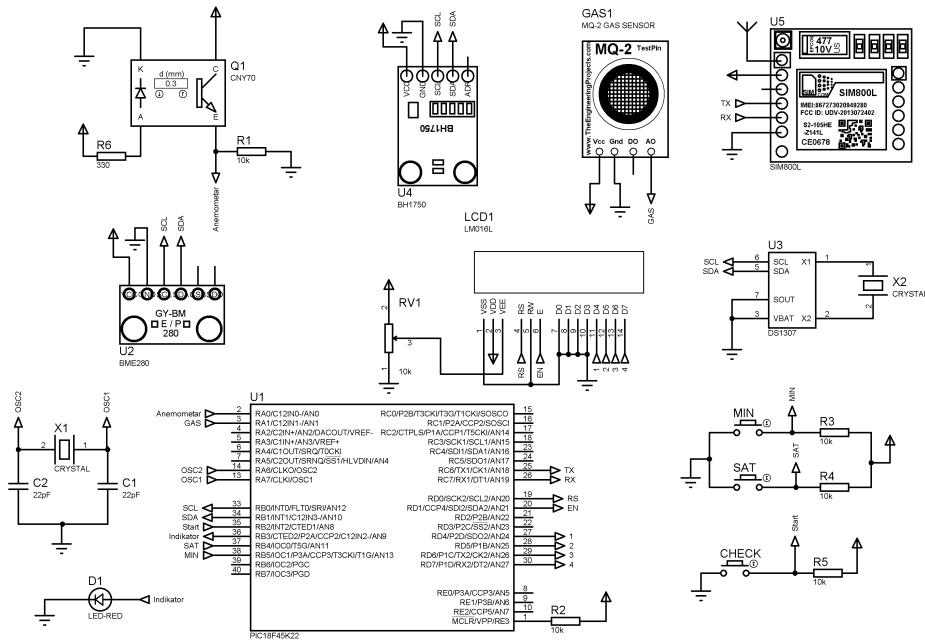


Fig. 3 Electrical scheme of weather station.

The BME280 (BOSCH Sensortec) sensor was used to measure air humidity, temperature and atmospheric pressure, and an altitude was also determined based on atmospheric pressure. The PIC18F45K22 microcontroller communicates with this sensor via the I2C bus [26]. The I2C bus is software implemented using RB.1 and RB.2, port B of the used microcontroller. The BME280 barometric sensor provides a wide range of measurements:

- air humidity from 0 to 100% RH,
- temperature from -40 °C to +85 °C and
- atmospheric pressure from 300 to 1100 hPa (mBar).

Anemometer, a wind speed sensor, was realized using a speed sensor. The communication of this sensor with the microcontroller was used RA.0 pin of microcontroller port A. Calibration was necessary for the operation of this sensor in order to obtain the value of the wind speed.

Measurement of illumination is done by the sensor BH1750 (ROHM Semiconductor), which communicates with the microcontroller via the software realized I2C bus. The used sensor provides a wide range of high resolution measurement (0-65535 lx).

A MQ-2 sensor was used to detect gas of LPG. This sensor provides the possibility of digital and analogue output. In this case an analog output was used and, therefore, the RA.1 microcontroller pin was used to work with this sensor. At port A, the microcontroller has an A/D converter, which is used to determine the percentage of gas of LPG in the environment. The MQ-2 sensor also offers wide application, i.e. possibility to measure several different parameters, such as: LPG - liquid petroleum gas, CH4 - methane, CO - carbon monoxide, alcohol, smoke and propane.

The DS1307 is an integrated circuit that is used as a Real Time Clock (RTC). This circuit works at a frequency of 32.768 kHz, using an external oscillator. Also, this circuit for communication with the microcontroller uses the software realized I2C bus. The RTC DS1307 can be used as a clock and as a calendar. Time calculation starts from 00:00:00 in the format hh:mm:ss. The time adjustment is done using the hour and minute keys, realized through RA.2 (hours) and RA.5 (minute) pins of the microcontroller. These keys are also used to adjust the operation of the weather station, where one additional button is used via the RB.2 pin of the microcontroller. This button is used to select the weather station mode setting.

The GSM/GPRS module SIM800I serves to send data to ThingSpeak in the cloud. Also SIM800I module serves to send an SMS to the user with information that the measurement has been completed. This module communicates with the microcontroller via the RX/TX UART serial module using AT commands [27]. RX/TX UART is implemented via the first UART microcontroller module on RC.6 (TX) and RC.7 (RX) pins.

To interact with the user while working with the weather station, an 2x16 character LCD display is used [28].

Power supply of the device is possible in several ways:

- Using a DC power supply (5V - 12V),
- Solar power, through the built-in solar cell, where, as indicated by the number of measurement points in one hour, it depends on the dimensions of the solar panel.
- Using batteries (the ability to use rechargeable batteries that are charged on the spot using solar power).

When starting the device, a message with the accompanying animation of Internet of Things and the name of the device appears on the LCD display screen. Thereafter, a selection of the language will be used, which will be used for further adjustment and operation. Then follows the time setting, which consists of the following:

- Setting the current time when the measurement starts;
- Setting the time when the user wants the smart weather station to complete the measurement.

When the measurement start and stop time are set, then enter the user's API key in which the measurement results will be stored. The API key consists of 16 characters, consisting of a combination of letter characters (A-Z) and numbers (0-9). After that, the number of the phone to which the SMS (Short Message Service) is sent will be entered.

Finally, check all settings, i.e. information to the user about the entered API key of the channel in which the results of the measurement will be stored, so that at the end of the setup the countdown begins before the start of the measurement. Each task in measurement is defined as shown in Fig. 4 as algorithmic mode of displaying software.

The **Main** thread is responsible for starting the other threads. It also sends diagnostic messages to the LCD display and receives simple commands from the keyboard, affecting the application's execution flow (e.g. stop, restart). The **Main** thread contains all the settings necessary (e.g. settings of A/D converter, the values of registers for the sensors that work through the I2C bus, interrupt routines) for the proper operation of the smart weather station. Also, this thread contain the settings of the measuring time (start/stop) that will be sent to the **Measurement** thread.

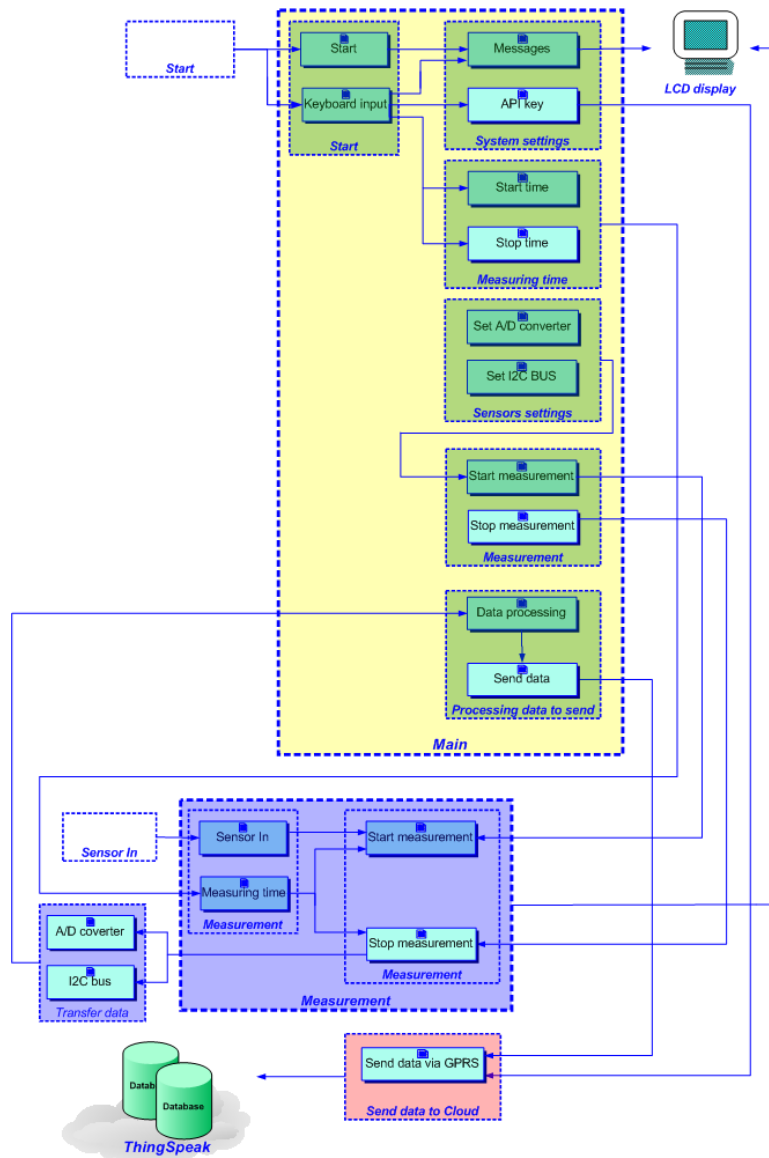


Fig. 4 Basic algorithm of the embedded software of smart weather station.

The **Measurement** thread is receive settings from the **Main** thread before start measurement. This thread is used for the acquisition of the measurement results from the sensors, storing them in the variables (variables are defined for each parameter that is measured separately) through **Transfer** thread.

The **Transfer** thread transfer data from sensors to microcontroller (from A/D converter, I2C bus). When data is transferred to the **Main** thread from sensors, the data

must be processed before sending. All data of the Integer type must be converted to the String data type and then with the defined API key send to the **Send** thread.

In the **Send** thread, converted data and API key is concatenated into one String data. The GSM/GPRS module must be configured to work as a GPRS (wireless Internet) module using AT commands to send data to the ThingSpeak database in the Cloud. Data from smart weather station is sent and received via simple “Hypertext Transfer Protocol” (HTTP) POSTs, such as going to a web page and filling out a form. This communication happens through plaintext, JSON or XML. If the weather station is used in places like high depths in mines, where there is no Global System for Mobile Telecommunications (Global Packet Radio Service) signal, it is possible to use local storage as Security digital memory card or flash memory as an alternative.

3.3. Usage scenario

During the measurement, the user is able to see the remaining measurement time on the LCD screen, i.e. how much is left until the end of the measurement, in the form of a progress bar, followed by information in percentages. Measurement interval is 5 minutes (adjustable).

When each measurement cycle is performed, it is necessary to convert the results from the integer type into the String data type, so that the same using the GSM/GPRS module is forwarded to the Internet and placed in the database.

At the end of the measurement, the message on the completed measurement is printed on the LCD display, the device sends a text message using the GSM module. The user will receive a SMS on the completed measurement on his mobile phone, whose number was previously entered during the weather station setup. The message text will depend on the previously selected device language. In this way, the user himself is not obliged to be while working next to the device. When the SMS is sent to the user with the completed measurement information.

The prototype of the smart weather station is practically realized on protoboard in laboratory conditions (see Fig. 5). The prototype was realized using the Ready for PIC development environment developed by the company Mikroelektronika [29].

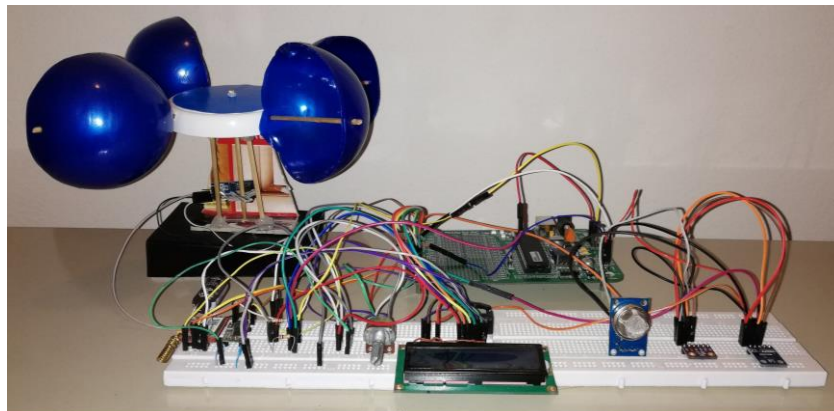


Fig. 5 The prototype of the smart weather station.

4. RESULTS

The meteorological/ambient parameters were measured with prototype of smart weather station during 7 days (from 8th of July to 14th of July, 2018). When the measurement was started (8th of July), there was a rainy period, which can be noticed on the basis of the results measured for the relative humidity of the air, as can be seen from Fig. 6.

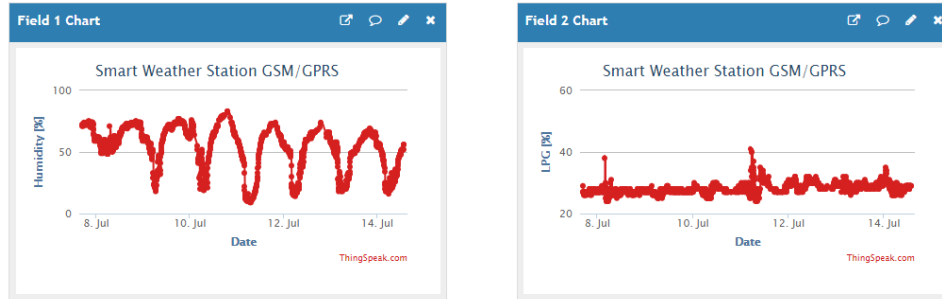


Fig. 6 Humidity (Field 1 Chart) and LPG detection (Field 2 Chart) during measurements.

It can be seen that the highest relative humidity values were recorded at that time, when the relative humidity value of the day did not fall below 50%. After the rainy period was followed by a period of sunshine, accordingly, the relative humidity of the air, whose value was changed in the range of 80% during the 10th of July to 18% during the 11th of July, was changed. The highest concentration of LPG gas was recorded in period from 15:00 to 21:00 hours on July 11th and that values was in range from 23% to 42% (lunch and dinner preparation period).

In accordance with the period of measurement when the precipitation was present, there was also a decrease in temperature, as well as light intensity (see Fig. 7).

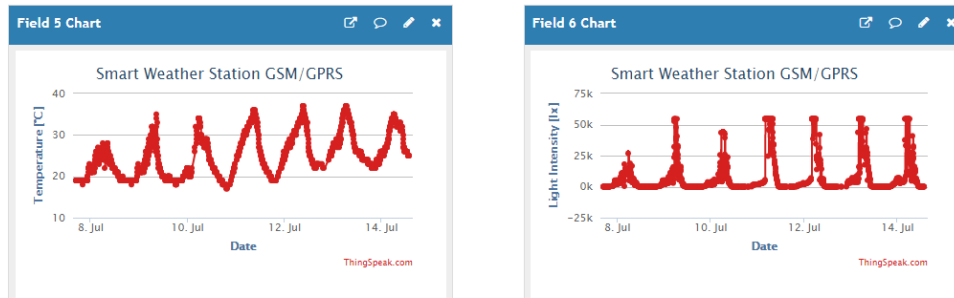


Fig. 7 Results of Temperature (Field 5 Chart) and Light intensity (Field 6 Chart).

During the period of rain time in accordance with the change in relative humidity, the temperature was changed, so that the temperature values were the lowest during the rainy period (from 18° to 28°C). The highest values of the temperature were measured in the period of July 11th, where the temperature value ranged from 19° to 37°C.

Cloudy weather influenced the change in the light intensity, so the lowest values was recorded on the July 8th (from 246 lx to 26267 lx). The highest values were recorded in the period after the precipitation (from 7567 lx to 54612 lx) excluding measurements during the night when the light intensity values were 0 lx.

Atmospheric pressure also changed according to weather conditions, so the highest change in atmospheric pressure was recorded during the rainy period (985 to 992 mBar), on the basis of which the period of sunny weather could be observed. The value for air pressure during the sunny weather were ranged from 987 mBar to 995 mBar (see Fig. 8). On the basis of air pressure, the altitude was measured.

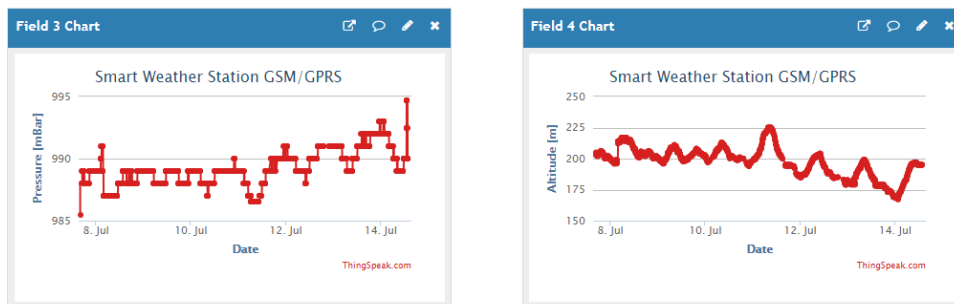


Fig. 8 Changing of air pressure (Field 3 Chart) during measurements.

The strongest wind blows were recorded during the rainy period, when wind speeds ranged from 5 to 47km/h. After precipitation, the winds were weakened, so wind speeds were recorded in the range of 2 to 32 km/h. All measurements were made on the location indicated on the map (Latitude - 43.320304, Longitude - 21.925792) shown in Fig. 9.

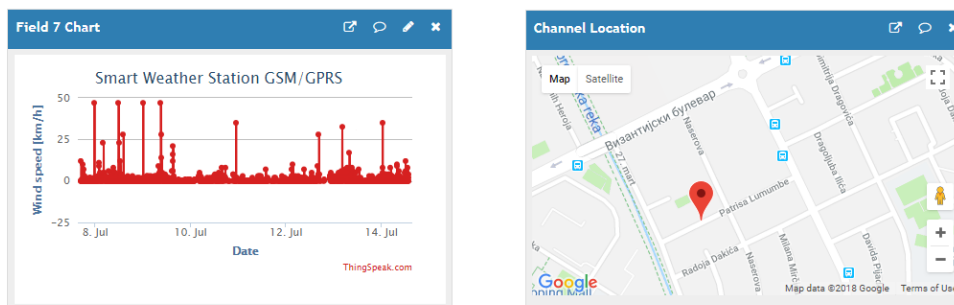


Fig. 9 Wind speed (Field 7 Chart) results and measurement location.

During the measurement, the user can have access to the measurement results by accessing the database stored on the user channel on ThingSpeak platform. Also, the user can change the way the results are displayed, starting with the color of the values themselves, the background to the way of representing whether it is in the form of lines, bars, steps, etc. It is also possible to choose how many points are displayed on the graphics for the visibility of the results. Then, if the measurements are done over a period of several hours or days, it is possible to choose whether the results are displayed for one or more hours, or for one or more days.

5. CONCLUSION

Further development of the device is planned, in the form of simultaneous sending of data from several smart weather stations at the same time to the same channel. In this way, the user would have an insight into the change of measured parameters in multiple locations in order for the user to have an insight into the change of measured parameters in several locations. It is also possible to add new sensors to measure other meteorological/ambient parameters. Some of the sensor can be added as sensor for rain gauge, wind direction, Geiger counter radiation detector, etc.

The development of an Android application is planned, so that the end-user can use the smartphone to monitor the measurement/observation and eventual changes in the measured parameters.

In the era of the Internet of Things technologies, more and more new smart devices are developing to use it as a storage resource. That part of Internet of Things technology is ThingSpeak platform as a part of it. ThingSpeak is an Internet of Things platform which allows the user to collect and store sensor data in the Cloud and develop Internet of Things application. ThingSpeak Internet of Things platform provides applications that allows the user to analyze and visualize data, and then act on the data. For analyzing and visualizing data which are stored in channel ThingSpeak use power of MATLAB.

One of the devices that builds its work on Cloud computing technology is the smart weather station described in this paper. The smart weather station apart from the possibility of storing data on Cloud or database on webserver, offer the possibility of the system to be solar powered. In this way, it is possible to measure atmospheric parameters in difficult accessible locations. There is also the possibility of operating this device in four different languages.

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