ONLINE WEB - BASED PERSONALIZED WEATHER STATION

Aleksandar Žorić[1], Siniša Ilić[1], Đurđe Perišić[2]

[1]*Faculty of technical sciences – University of Priština, Republic of Serbia*
[2]*Faculty of Information Technology, Slobomir P University, Slobomir, BiH*

Abstract

A simple online Web-based weather station, developed to be used in an indoor environment and for personal needs, is described in this paper. This application is based on the NodeMCU Wi-Fi development platform and a new Bosch's environmental sensor BME680, and may be very useful in the indoor environments like a vehicle, home, business facility or a laboratory. Owing to the modern, tiny size, digital 4-in-1 sensor for air quality, humidity, pressure and temperature measurement, based on proven sensing principles, a user can monitor some important parameters of living or working environment.

This station is intended to be implemented in the cabin of the vehicle to improve the sense of the travel comfort, because the climate parameters in the interior of the vehicle can be controlled by built actuators.

A key advantage of proposed solution is wireless communication which requires only a Web browser to be installed on the client side.

Keywords: Web, weather station, client-server, NodeMCU, BME680, WiFi.

INTRODUCTION

A weather station is a facility, on land or sea, with sensors and equipment for measuring atmospheric conditions including: temperature, atmospheric pressure, humidity, wind speed, wind direction, and precipitation amounts. The application of modern digital sensors or sensor's modules in the weather stations [1] has a number of advantages such as: compact design, small dimensions, pre-calibrated sensors with known measurement error limits, low power consumption, etc.

Weather stations are very important for industrial processes control, warehouses, and of course in the private sector, such as in a house to determine interior and exterior climate and humidity within the walls (weather stations for air speed, temperature, humidity, pressure, etc.) [2], [3].

Modern cars, for example, have sensors for measuring outdoor temperature and for cabin temperature regulation. However, manufacturers still do not install additional climate sensors such as air humidity sensors, atmospheric pressure sensors or air quality sensors for both outdoor and indoor application. Monitoring and control of the mentioned climate parameters in the interior of the vehicle may be of importance of a more comfortable driving feeling and thereby greater safety of driving.

The solution proposed in this paper was installed in the car and tested under driving conditions. Thanks to existing actuators built into the car, the driver could control some of the important local environmental parameters such as temperature, relative humidity and air quality. By ventilating the car cabin or by blocking the air supply, the user can affects to the local air quality and even the local air pressure.

SUBSYSTEMS

Complete weather station was implemented using only two inexpensive subsystems: NodeMCU development platform [7], and the sensor's module CJMCU-680 [5].

NodeMCU is one of the many open source IoT's, based on the well-known ESP8266EX WiFi SoC (System on Chip), the product of Espressif Systems [4]. The platform was created shortly after the appearance of the ESP8266EX WiFi SoC on the market at the end of 2013, precisely, in October 2014.

ESP8266EX SoC integrates 32-bit microcontroller unit (MCU) Tensilica's L106 Diamond, which has extremely low power consumption with a maximum clock speed of up to 160 MHz. In addition to the MCU, compact design integrates the hardware TCP/IP stack for adding WiFi functionality, SRAM (50 kB) and ROM memories and standard digital peripheral interfaces, RTCs, antenna switches, RF electronics, power amplifiers, low noise amplifiers, filters and power management modules - all in one small housing.

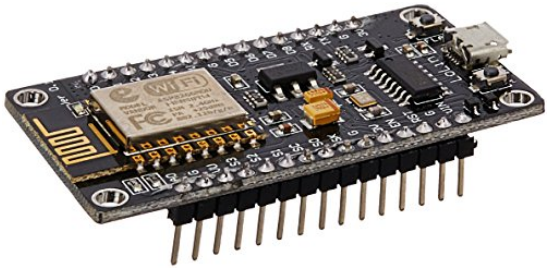

Fig. 1. *The NodeMCU development platform.*

The NodeMCU development platform, shown in Figure 1, is primarily intended for the development of IoT applications, but it can also be used as a general purpose 32-bit MCU development kit. Beside the ESP8266EX SoC, this platform consists of an integrated USB to TTL UART converter - CH340G, fixed voltage regulator from 5 V to 3V3, micro USB port and few passive components. QSPI (*Quick SPI*) flash programming memory is added as an external unit, also. Two buttons on the top side of the development module, reset and flash, serve for module configuration to the programming mode or for reset. The 12 I/O lines of this platform are available to the user.

The ESP8266 i.e. NodeMCU can operate in two modes: AP - access point mode and STA - station mode. AP mode enables creation of own network and connection with other devices (e.g. mobile phone). STA mode allows the ESP8266 to connect to a local wireless router (WLAN). So, an important feature of the ESP8266 is that it can operate as a client or as an access point or even both.

A second subsystem used in this paper is Sensor's module CJMCU-680, actually a new Bosch's compact digital 4-in-1 sensor for air quality, relative humidity, atmospheric pressure and temperature measurement, based on proven sensing principles. The layout of CJMCU-680 module with BME680 sensor [5] on the printed board is shown in Figure 2.

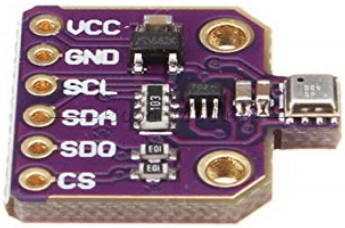

Fig. 2. *CJMCU-680 module with BME680 sensor on the printed board.*

The module supports the I^2C and SPI digital communication interfaces where it acts as a slave for both protocols.

The key feature of the Bosch's BME680 sensor [5] is its possibility to show air quality index (IAQ). BSEC (*Bosch Software Environmental Cluster*) software solution provides an IAQ index ranging from 0 to 500 which quantifies the quality of the air available in the surrounding area. In accordance with this software solution and its smart algorithm, the IAQ classification is formed and presented in Table 1.

IAQ index	Air quality
0-50	Good
51-100	Average
101-150	Little bad
151-200	Bad
201-300	Worse
301-500	Very bad

Table 1. *Indoor air quality classification.*

The gas sensor within the BME680 can detect a broad range of gases to measure indoor air quality. Gases that can be detected by the BME680 include: volatile organic compounds (VOC) from paints (such as formaldehyde), lacquers, paint strippers, cleaning, supplies, furnishings, office equipment, glues, adhesives, alcohol and other gases such as carbon monoxide and hydrogen, in the range of parts per billion (ppb).

For the gas measurement, the sensor integrates a heater. Parameters for this heater are defined by heater profiles. The sensor supports up to 10 such heater profiles, which

are numerated from 0 to 9. Each profile consists of a temperature set-point (the target temperature) and a heating duration. By default, only the heater profile 0 with 320 degrees Celsius as the target temperature and 150 ms heating duration is defined.

In accordance with manufacturer's specifications, the humidity sensor has operating range 0-100 % rH and absolute accuracy of ±3 % rH (20-80% rH). Operating temperature range of the temperature sensor is -40 to 85 ^{0}C with absolute accuracy of ±1 ^{0}C within 0-65 ^{0}C, while the pressure sensor has range from 300 to 1100 hPa with absolute accuracy of ±0.6 hPa.

The sensor also integrates an internal low pass IIR filter to reduce short-term changes in sensor output values caused by external disturbances. It effectively reduces the bandwidth of the sensor output values. The filter may optionally be used for pressure and temperature data that are subject to many short-term changes. With the IIR filter the resolution of pressure and temperature data increases to 20 bit. Humidity and gas inside the sensor does not fluctuate rapidly and does not require low pass filtering.

More details about the BME680 sensor may be found in [5].

WEATHER STATION DESIGN

Based on the previously described two subsystems, the compact design of the weather station has been created by direct connecting the NodeMCU platform with CJMCU-680 module, as in Figure 3. Communication between the NodeMCU platform and CJMCU-680 module is established via I^{2}C two wire interface. Powering of the station is provided via micro USB port of the NodeMCU.

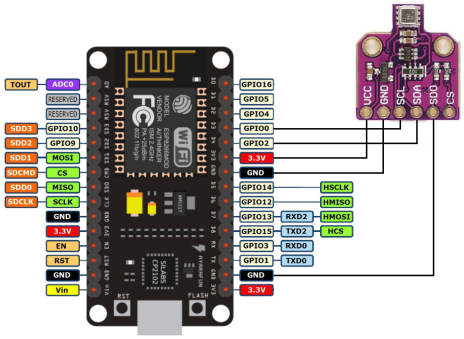

Fig. 3. *Weather station hardware.*

The NodeMCU development board acts as web server and an WiFi hot spot (access point). Weather station website can be accessed remotely from a web browser of any local PC or mobile handheld device using local WiFi network of the server and by pointing to the server's IP address. Wi-Fi technology is selected to be the network infrastructure that connects server and the clients.

NODEMCU PROGRAMMING

As mentioned above, the BME680 sensor is intended to be used together with Bosch Sensortec software environmental cluster (BSEC) solution [6] and BME680 sensor API to achieve its full potential. The BSEC software is characterized by intelligent algorithms which enable monitoring of indoor air quality using the BME680. Moreover, the software algorithms provide the temperature and humidity compensation, baseline as well as long-term drift correction of the gas sensor signal.

Based on an intelligent algorithm, the BSEC provides an indoor air quality (IAQ) output. In principle, this output is an index that can have values between 0 and 500 with a resolution of 1 to indicate or quantify the quality of the air available in the surrounding area.

One of the leading and most popular software development environment for the various ESP8266 modules and development boards, including NodeMCU, is ESP8266 Core for the Arduino IDE [8]. Arduino IDE is a free software development environment that includes a rich set of libraries in the C/C++ language. Although programming in the Arduino IDE is not exactly the same as general programming in the C/C++ language, due to the usual differences in embedded software (limited memory and processor power), the programming base is the C/C++ language.

In this solution Arduino IDE was selected to be used. The application firmware, written in the Arduino IDE [8], contains inclusive libraries, a global variables declaration part, a setup() function for initialization and resources configuration which is executed only once, and loop() function that is cyclically executed. Owing to the BSEC libraries [6], which

control the BME680 sensor's operation, the code for firmware was written. This code also creates a Web server on the NodeMCU and configures the development board to an access point mode (AP). The Web server main page is on the root of SPIFFS (SPI Flash File System), Figure 4. Web server is on the default HTTP port 80. Though the file system is stored on the same flash chip as the firmware (sketch), programming a new sketch will not modify file system content. This allows using the file system to store sketches, configuration files, content for Web server or other necessary files. File system size depends on the SPI flash memory chip size and in our case is 4MB/1MB SPIFFS.

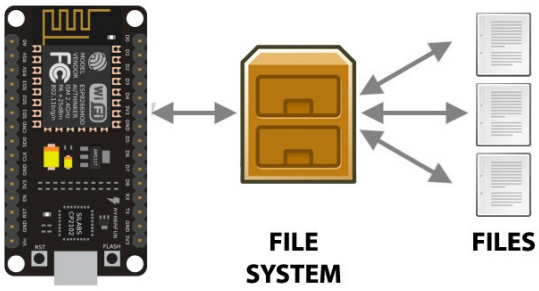

Fig. 4. *SPI flash file system on the NodeMCU.*

There are three subroutines that handle client requests:

- *server.begin()* to start the server,
- *server.handleClient()* to handle client request in main loop and
- *handleRoot()* called when a user enters the server IP address in a Web browser and presses the enter button.

When a client requests a web page from a web browser, by entering the server's IP address, the server's response is handled by subroutine *handleRoot()* at root location using a command *server.on("/", handleRoot)*.

HTML page together with javascript files which contain gauges are uploaded into the flash program memory.

As mentioned, uploading a new sketch into the flash program memory does not affect the file system and vice versa.

CLIENT WEB PAGE

Since the NodeMCU board was configured as an access point, any Wi-Fi device can try to connect to it. The correct Wi-Fi network is identified by the SSID that is set during configuration. The network may be protected with a password or may be open, if no password is set during configuration. SSID of our WiFi network is set during configuration to ELANTRA_AP with a password. The default IP address of the NodeMCU access point is 192.168.4.1.

By connecting the client on the access point network ELANTRA_AP and by entering the default IP address in any browser, the HTML Web page as in Figure 5 should be visible.

Fig. 5. *Client Web page of the online weather station on a multimedia screen in a cabin of a car.*

As can be seen in Figure 5, instant humidity, temperature and pressure values are presented on the round analog/digital gauges. There are three LCD displays of air quality below the gauges. First of them for IAQ index preview, second one for preview of IAQ accuracy (from 0 to 3) and third for scrolling the textual classification of air quality. Based on atmospheric pressure, the web server software calculates the pressure altitude above the sea level. On the Web page of the client station the instant altitude was also presented on the odometer gauge in MNV (meters of sea level altitude).

The online web-based weather station is installed in a car in order to allow users to monitor ambient conditions in the cabin of a car. The application serves also to monitor how different reactions of users in the case of air pollution impact on quality of air in the cabin of a car.

CONCLUSION

The solution proposed in this paper presents a simple and inexpensive Web based dedicated device for personal applications. It may be mounted in a house, car or in a laboratory environment. The device operates as a WiFi access point and as Web server of a weather

station, thus enabling monitoring of instant climate parameters on any near client device which has a Web browser. Maximum distance between the server and client is about 75m.

The opinion of the authors is that one of the most desirable applications of this device is in the car cabin. The results of testing the device in the car cabin show the full significance of the proposed solution for improving driving comfort and thereby safety enhancement.

ACKNOWLEDGEMENT

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