IQRF Technology Based Carbon Dioxide Measurement System

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ABSTRACT: ***The paper focuses on designing and implementing a comprehensive monitoring system that enables long-term monitoring and visualization of selected environmental quantities, particularly in the interior of buildings, using modern SW instruments. For this case the measured quantities include concentration of CO2, temperature, humidity and ambient pressure. The device component of the sensor uses sensors from Figaro CDM7160, Bosch BME280, and Microchip MCP9802. The IQMESH network is based on the advanced wireless IQRF technology which allows the wireless monitoring system to cover vast areas. Measured data from individual measurement modules is sent to the native IQRF cloud storage using Raspberry Pi or via commercial Internet gateways. From there, it is transmitted via a script to a MySQL database running on the university site server, which can then be processed and visualized using the Grafana SW program.***

KEYWORDS: ***Carbon Dioxide Measurements, Humidity Measurements, Internet of Things, Multi Sensor Integration, Pressure Measurements, Sensor System, Temperature Measurements.***

INTRODUCTION

IQRF is a wireless packet-oriented radio frequency (RF) networking system used in sub-GHz ISM bands. It is intended for general use where wireless communication is required, either point-to-point or in complex networks, for example for telemetry, industrial control, building and city automation and the Internet of Things. Fully open design relies solely on one program unique to the user. Basic IQRF communication unit is a transceiver module (TR) that includes MCU with an integrated operating system (OS) that implements link layer and network layer that supports mesh networking using IQMESH protocol. The program software is writable in C language directly under OS. Unlike the solution stack used, e.g. by ZigBee, when in development, only the application software is compiled.

Historically the concentrations of indoor CO2 used to be lower than they are today. Wood was traditionally used for heating. Earlier, gas or oil heaters were used which also required an sufficient supply of air oxygen. Upon the introduction of electric heaters and central heating rooms, for economic reasons, are being slowly sealed. Today, technology (plastic windows, etc.) enables the development of an enclosed atmosphere in which natural ventilation has decreased by about 40 times according to: Vanus et al. (2016). Even though the rooms today are no longer heated by fire, certain sources of CO2 exist. The most important of all is man. Tobacco smoking is another major indoor source of CO2.

The carbon dioxide concentration has an impact on the air quality. The CO2 concentration for indoor spaces should be under 1000 ppm. If this focus is surpassed, mental capacity, attention deficit disorder, and with greater excess extreme headaches, malaise, etc. are diminished. Overcoming the 5000 ppm concentration poses significant health risks. The Ministerial Decree 361/2007 Coll. State the acceptable exposure limit (PEL) value of 5000 ppm for CO2. The maximum value of the maximum permissible concentration (HPC) a person can meet with per shift is 25000 ppm. Table 1 summarizes the impact of CO2 concentration on human health.

Table.1: Properties of CO_2 Concentration

CO_2 concentration (ppm)	Comment
40500	Blackout
25400	HPC
15900	Breathing difficulties
5000	PEL
2500 - 6000	Headache, Fatigue
1550 - 2100	Concentration disorders
900 - 1500	Stale air
1000 - 1100	Recommended for indoor environment
450 - 650	Ventilated room
300 - 450	Outdoor environment

Man requires oxygenated air for breathing, essential for the metabolic processing of substances. At rest, man inhales and exhales on average 16 times per minute, the normal resting inhalation has an air volume of 0.5 litres. The volume of the lung is 5 – 6 litres, depending on height, age and other factors. Oxygen (O2) is substituted for carbon dioxide (CO2) that is bound to hemoglobin in the blood that exists in the lungs in the air sacks. The Outdoor CO2 content is approx. Ppm 350 (0.035 per cent). Man-exhaled air has a concentration of CO2 of 35000-50000 ppm (approx. 3.5-5 percent). Table 2 summarizes man-made air intake, depending on the operation.

Table.2: Air Consumption by Man Depending on Activity

Activity	Air consumption ($l \cdot min^{-1}$)
Rest	9 – 10
Walk	17 – 24
Accelerated movement	26 – 35
Medium heavy work	35 – 45
Heavy work	43 – 53
Extreme load	56 – 120

LITERATURE REVIEW

This article discusses the use of IQRF technology to introduce wireless communication between control unit and remote computer. It provides a stable, effective, and secure base for the Internet of Things with the Node-RED programming tool. This paper demonstrates how a control system and an IQMESH network could be built quickly. Node-RED procedures are provided on how to send, receive data, using either the MQTT protocol or the request for Háp. The result is a prototype application that calculates physical temperature quantities, light intensity and potentiometer value. This paper deals with temperature measurement and concentration of toxic gasses at mining dumps Ema and Hedvika in Czech Republic's Ostravian region. These mining dumps are affected by endogenous fires which result in higher thermal activity and the production of toxic fume gasses such as carbon dioxide and carbon monoxide. Wireless sensor network implementation extends the current system model with cabling for data transmission from the sensor to the data concentrator. This necessity is determined by the need for impredictable conditions at a given location for the distribution of thermal fields or other phenomena[1]. This paper puts forward a wireless sensor networks based on TC35 module and the method of the signal transmitting. Through the application of wireless technology, the MCU could send the carbon diocide concentration data from the carbon diocide sensor which is based on the NDIR technology to the process module, and the system could achieve the distant measurement of the carbon diocide displayed on the LED. Compared with the wire monitor system, the wireless monitor system omits linking lines and has strong prospect of operation[2]. This research mainly deals with the replacement of the wired power transmission system for charging electric vehicles using an efficient method of wireless power transmission. The inductive power transfer system and the laser optic method for charging the electric vehicle battery are taken into account when

defining an effective wireless power transmission method. Such methods are evaluated for different conditions by hardware implementation. Wireless power transfer is an emerging technology used to charge the battery through an air gap for the electric vehicles. This paper sets out a wireless network of sensors based on the nRF401 chip and the signal transmission system. Through the application of wireless technology, the MCU could send to the process module the carbon diocide concentration data from the carbon diocide sensor, which is based on the NDIR technology, and the device could achieve remote measurement of the carbon diocide displayed on the LED. Compared with the wire control system, the wireless control system omits linking lines and has strong prospect of use[3]. This article discusses the use of IQRF technology to introduce wireless communication between control unit and remote computer. It provides a stable, effective, and secure base for the Internet of Things with the Node-RED programming tool. This paper demonstrates how a control system and an IQMESH network could be built quickly. Node-RED procedures are provided on how to send, receive data, using either the MQTT protocol or the request for Háp. The result is a prototype application that calculates physical temperature quantities, light intensity and potentiometer value. The entire implementation runs on the Raspberry Pi platform and the IQRF technology which provides wireless communication within the IQMESH network[4]. This paper is about applying wireless inclination calculation of objects located at mining dumps. Inclination measurement uses a collection of sensors which include a gyroscope, an accelerometer and a magnetometer. AHRS algorithm processes measured data which, once applied, allows more accurate information on object rotation in the area compared to unprocessed accelerometer or gyroscope data. Chain of measurement consists of two parts[5]. This paper presents a model of wireless, distributed temperature measurement system based on the IQRF platform using IQMESH protocol, which makes it possible for most industrial applications to construct a small monitoring system with appropriate RF and metrological parameters. The system's key components are IQRF TR-52D transceiver modules and the Maxim DS18S20 1-Wire Analog Thermometer operating in parasitic control mode. Additionally, the paper includes findings from the model test carried out under industrial conditions, which demonstrates the efficiency of the system being built[6]. They compare and analyze street light control systems in this research paper, and compare them with their advantages and disadvantages. Street Light Control System, which runs an automated street light system, is a smart system, but not the simplest one. This machine can be set to function in automatic mode; it detects climatic condition and determines the street light's dimness and brightness. Such regulation will allow a fair seasonal variance change. Using monitor we can power the entire street lights. With the aid of sensors, the device detects climate change and is dim and bright depending on the climatic situation[7]. This paper presents the results of detailed data analysis from the first 122 wireless environmental pervasive sensors (motes) available commercially, built by Newcastle University and deployed in England. Emission, meteorology, and traffic measurements are used to analyze the nature of the physical and chemical processes that control traffic-related emission rates in urban areas. A review of the mote technology is provided after a brief overview on the health impacts associated with air quality[8].

METHOD

A measuring chain has been installed for monitoring air quality in the offices of the Department of Cybernetics and Biomedical Engineering, the central element of which is the wireless measuring node, hereinafter referred to as RMCD (Carbon Dioxide Room Measurement).

The constructed measuring chain is composed of wireless RMCD measuring nodes and a central unit. The quantities measured are: concentration of CO2, temperature, relative humidity, and the ambient air pressure. The sensors used have digital output with connectivity to the I2C bus. Measured information is sent via IQRF transceivers from these sensors (hereinafter IQRF NODE) see IQRF Tech.

- Sensor 1 – CO2 sensor - Figaro CDM7160
- Sensor 2 – Temperature, humidity, atm. pressure sensor - Bosch BME280
- Sensor 3 – Temperature sensor – Microchip MCP9802

Data transmission is based on IQMESH network contact based on the IQRF modules, see Hajovsky and Pies (2015). The network coordinator's IQRF module (IQRF COORD) is linked to Pi via the SPI bus; see

Bazydlo et al. (2015) and Calvo et al. (2016). The IQRF- Daemon program provides contact with the network coordinator. Data is transmitted via MQTT between IQRF- Daemon and Node-RED. In a Node-RED program the calculated data is translated to a readable form and stored in a MySQL database. The Grafana system is used for visualisation. Figure 1 shows the physical diagram of RMCD wireless measuring node.

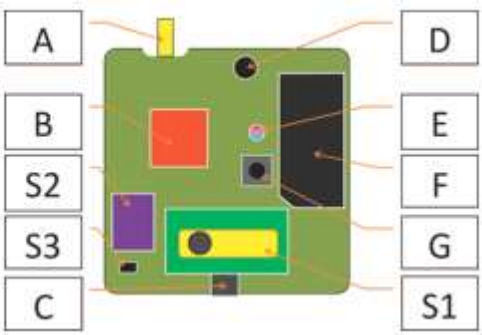

Fig.1: Physical Diagram of RMCD Wireless Measuring Node

Where A indicates the SMA antenna connector, B is the IQRF transceiver, C is the micro USB connector for charging, D is the piezo siren indicating CO2 concentration above 5000 ppm. E is an RGB LED in three colours, the definition of which is in table 3. Module F is a step-up converter that raises the voltage of the Li-Pol battery backup to 5 V. G shows the user button which can be used to signal the concentration of CO2 when running the RMCD on the battery. S1 shows the carbon dioxide concentration sensor set in Figaro CDM7160. S2 shall show the temperature, relative humidity and atmospheric pressure sensor of the Bosch BME 280. S3 shows Microchip MCP 9802 Temperature Sensor.

The number of quantities calculated can be modified as needed. For most instances, use of the full version is expected. A version may be chosen according to the current measurement criterion, if necessary. The selection is rendered by writing to the EEPROM a constant, which is part of the IQRF transceiver. The variant information is stored as part of the DPA packet within HWPID.

The digital sensor module CDM7160 is of NDIR (Non- Dispersive Infra-Red) form. It operates on the theory of reducing strength of certain infrared light wavelengths absorbed in the air by the CO2 molecules. The air flows into the sensor, obviously. The light source is an IR LED. A filter with a wavelength of 4.3 μm in front of the detector gives the selectivity of the IR spectrum. The IR Detector senses the decrease in pressure. The FIGARO CDM7160 sensor uses a detector as a reference, which measures only 3.8 μm of reference wavelength. Concentration is determined according to intensity differences. That limits the impact of absorption of light and emissions.

Node-RED:

Node-RED is a visualization and graphical programming tool created by IBM in 2013. Node-RED has belonged to the JS Foundation community portfolio since 2016 which deals with JavaScript and open-source project development. The key reason for that was MQTT's fast IoT connection and visualization. The basic elements are "Nodes," which are basically artifacts (in the context of object-oriented programming) managing the peripherals, protocols, and other functions. Programming takes place via a Web browser (remote and locally). This is where "flows" are formed and run in parallel. Use the node feature to build your own code, where you can write a JavaScript programe. Using messages, the data is transferred between the nodes; the message may be organized.

The Node-RED environment also allows display of the results. The node-red-dashboard pallet is used for this purpose, which contains the basic elements for the visualisation of data. The (dashboard) screen is accessible. To combine similar elements into groups, elements can be grouped into tabs and in those groups. The assignment to groups takes place directly in the properties of the unit. You can build your own user-functions and nodes.

Mosquitto:

MOSQUITTO is a protocol for the forwarding of messages via a central node between IoT devices (M2 M). Very frequently, the service provider (MQTT Broker) uses the 1883 port over which data is transmitted to and from another device within the LAN or through the Internet. The components that are connected to this server are publishers-P and subscribers-S, usually clients. This server serves as a buffer for messages. Every message must be assigned a Topic by the publisher according to which the user requests a server message. This subject can have several format rates. At the specified level the character "#" selects all the topics. In general, both a subscriber and a publisher may be an object at the same time. It is about the message queue system. The Network Layer is used as the TCP protocol. The message content is not standardized but in the current protocol version the message size is limited to 256 MB.

Grafana:

For the visualization of the calculated data an application was generated in the Grafana software framework. The courses are shown for the time interval chosen and the last calculated value. The alarm state values were set when a message about exceeding one of the parameters calculated is received. The calculated data may be shown as the time course of the individual environmental variables in the Grafana context. Measured data were subsequently exported from this area which was then analyzed and evaluated.

CONCLUSION

The developed and implemented comprehensive monitoring system is intended to track the quality of indoor air, primarily in the Cybernetics and Biomedical Engineering Department's classrooms and laboratories, VŠB-TU Ostrava. This may also be used in other school, office or household facilities.

A provision for the collection and archiving of recorded data is also part of the monitoring framework. Using a Node-RED program, data is processed. Processed data is stored in a database called MySQL. The atmosphere at Grafana was used to represent the calculated values. Visualizations were produced of the time courses and the real values.

Measured values are measured during the time when people are supposed to stay in a given room. Based on these principles it was possible to assess which part of the occupation time people are spending in an unacceptable setting. It is possible to suggest improvements or modifications of ventilation system in the rooms based on the established evidence. Based on these improvements, students and employees may improve their work environment.

Based on experience with the generated monitoring system's pilot service, it is possible to design its next version, which will be expanded by other sensors and functionality

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