DOI 10.5162/SMSI2021/D10.2

Feasibility Study for Safe Workplaces through automation and digitalization technology with redesigned Smart Sensors and LoRaWAN Monitoring System

Sergej Johann[1], Carlo Tiebe[1], Harald Kohlhoff[1], Matthias Bartholmai[1]
[1] Bundesanstalt für Materialforschung und -prüfung, Unter den Eichen 87, 12205 Berlin, Germany
Sergej.Johann@bam.de, Carlo.Tiebe@bam.de, Harald.Kohlhoff@bam.de,
Matthias.Bartholmai@bam.de

Summary:
This project addresses the application of safe and healthy workplaces in offices, chemical laboratories and other workplaces where indoor air quality plays an important role. The LoRaWAN (Long Range Wide Area Network) is used as a communication interface to make sensor data globally accessible. The objectives of the project are to create a sensor node and an online and offline system that collects the data from the sensor nodes and stores it on a local server, in a cloud, and also locally on the node to prevent communication failures. An important point in this project is the development of the sensor nodes and the placement of these in the premises, thus no development work is involved in building the infrastructure.

Keywords: smart sensors, air quality monitoring, LoRaWAN, VOC, multisensor system

Idea

The idea of the project is to create a safe and healthy workplace for safe and unimpaired work. The implementation is based on the current technology LoRaWAN [1], which allows to cover a large area with a range of up to 15 km under optimal conditions and a calculated range from the link budget of even 800 km [2]. Regarding occupational safety, important air quality parameters should be detected and measured to avoid endangering people. In the office, in the laboratory, etc. limits for hazardous volatile gases must be observed [3,4,5]. The proposed sensor network with the low power sensor nodes should continuously record all necessary data and issue a warning if the limit value is exceeded.

Implementation

The concept envisages the development of several sensor nodes and their equipment with different sensors to determine indoor air quality. Sensors for measuring the following parameters are implemented as a basis: volatile organic compounds (VOC), temperature, humidity and pressure. The network can be operated in two ways to make the collected data available. Online via a cloud and via the associated network infrastructure, that is provided in cooperation project partners and is implemented as the primary solution. A local computer is configured as a server and provided with a user interface.

Figure 1 shows the overall concept of how the network should look like. A room under investigation (office or laboratory) is equipped with sensor nodes, each sensor node contains several sensors to determine the parameters for room air quality measurement. The first step is to collect experiences and measured values to be able to make a statement about the requirements. The red marked communication paths and components are currently being implemented.

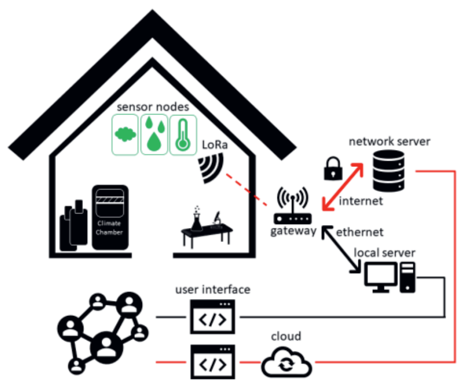

Fig. 1. Implementation of the System Network.

To keep the sensor node as simple as possible some components were removed from the predesign (GPS, Multisensorport and IC). The system is powered by a 4800 mAh rechargeable battery. It can be recharged via wired power supply or an external power source. A powerful

but energy saving ESP32 microcontroller controls all the peripherals and offers the possibility to connect to the local WiFi or Bluetooth network. A LoRa module provides the interface between the sensor accounts and the network. A commercially available 4in1 environmental sensor was used for the sensor node (BME680 from Bosch). The acquired measurement values are stored on the local SD card before being sent to the network to still record the measurement data in case of network problems.
Figure 2 shows the first prototype which is inserted into a housing that allows air access to the sensor, providing good ventilation.

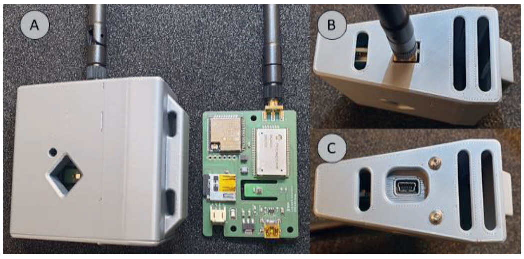

Fig. 2. Sensor node with 3D printed housing. A: side view, the sensor access and PCB. B: top view, C: bottom view.

Results

In a first publication with the conceptual design, the sensor (BME680) was successfully validated for stability with gas consisting of ethanol (C_2H_6O) and synthetic air at different molar fraction amounts 20, 40 ,80, 100, 200 and 300 µmol/mol with an uncertainty of about 4 % and an air flow rate of 1000 ml/min ±1 % [6]. Another test which lasted about 2 days started under real conditions. The sensor was installed in an office which was not used during this time. All raw values were stored locally on the SD card of the sensor node in with a sampling rate of 5 sec. and 1 sec. for the data processing. Figure 3 shows the signal course of the sensor parameters, temperature, relative humidity, pressure and the VOC signal Due to an individual mixing ratio of the air, the curves in Figure 3 are different from the calibration curve [6].

The signal curve shows a change of all signals over time. A trend can be seen where the values are moving into the stabilization. Environmental influences such as the changing temperature and humidity values in the room show a clear deflection of the VOC signal and cause a fluctuation. The temperature value is increased due to too frequent polling (approx. 25 % more often than recommended) due to self-heating. The end of the measurement was influenced with a direct human approximation. The change can be seen in the increase in relative humidity, temperature and the sudden change in the VOC value, which indicates that a gas source has approached the sensor.

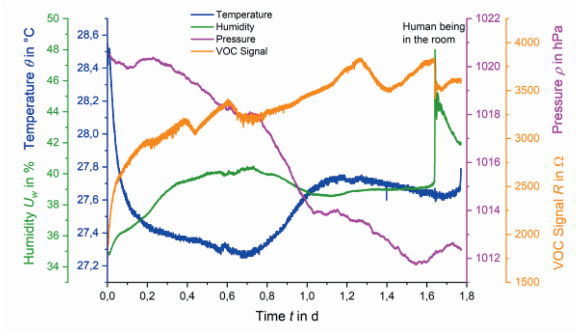

Fig. 3. Validation under real conditions. Acquired raw data from the BME680 multisensor at approx. 2 days.

Outlook

The selected sensor shows first promising results for indoor air quality measuring even under real operating conditions so that a rough statement about the activities in the room can be made. Further tests are in progress, e.g. to validate how robust and reliable the sensor nodes are. As well as that collect further knowledge. Another important aspect that should be investigated is the power management of the LoRaWAN, where the runtime of the system and the signal integrity until shutdown is examined.

References

[1] LoRa Alliance Inc., 2017, LoRaWAN Specification 1.1.

[2] https://smartmakers.io/lorawan-reichweite-teil-1-die-wichtigsten-faktoren-fuer-eine-gute-lorawan-funkreichweite/, 2020-11-20.

[3] Technical instructions for keeping the air clean - TA Luft (in German) https://www.bmu.de/fileadmin/Daten_BMU/Download_PDF/Luft/taluft.pdf, 2020-11-22.

[4] Directive (EU) 2016/2284 of the European Parliament and of the Council of 14 December 2016 on the reduction of national emissions of certain atmospheric pollutants, amending Directive 2003/35/EC and repealing Directive 2001/81/EC, http://data.europa.eu/eli/dir/2016/2284/oj, 2020-01-23.

[5] Arbeitsgemeinschaft ökologischer Forschungsinstitute e.V. (AGÖF), AGÖF-Orientierungswerte für flüchtige organische Verbindungen in der Raumluft Datenbank AGOEF-VOC-Orientierungswerte Stand: 2013-11-28, https://www.agoef.de/fileadmin/user_upload/dokumente/orientierungswerte/AGOEF-VOC-Orientierungswerte-2013-11-28.pdf

[6] Design and Implementation of Smart Multisensor Monitoring System for Safe Workplaces with LoRaWAN, SMSI2020 proceedings, 388 – 389.