Modular Wi-Fi Sensor Node for Indoor Environmental Sensing Applications

Philipp Bolte (bolte.philipp@fh-swf.de)
Dr. Ulf Witkowski (witkowski.ulf@fh-swf.de)

Department of Electronics and Circuit Technology,
South Westphalia University of Applied Sciences

Fachhochschule Südwestfalen
University of Applied Sciences

ALLSENSORS 2021

IARIA

July 18 to July 22, 2021 - Nice, France

Authors

Philipp Bolte is research assistant at the Department of Electronics and Circuit Technology of the South Westphalia University of Applied Sciences since 2016. He received his master's degree in systems engineering in 2017. Currently, he is working on his PhD research with focus on industrial IoT sensor nodes.

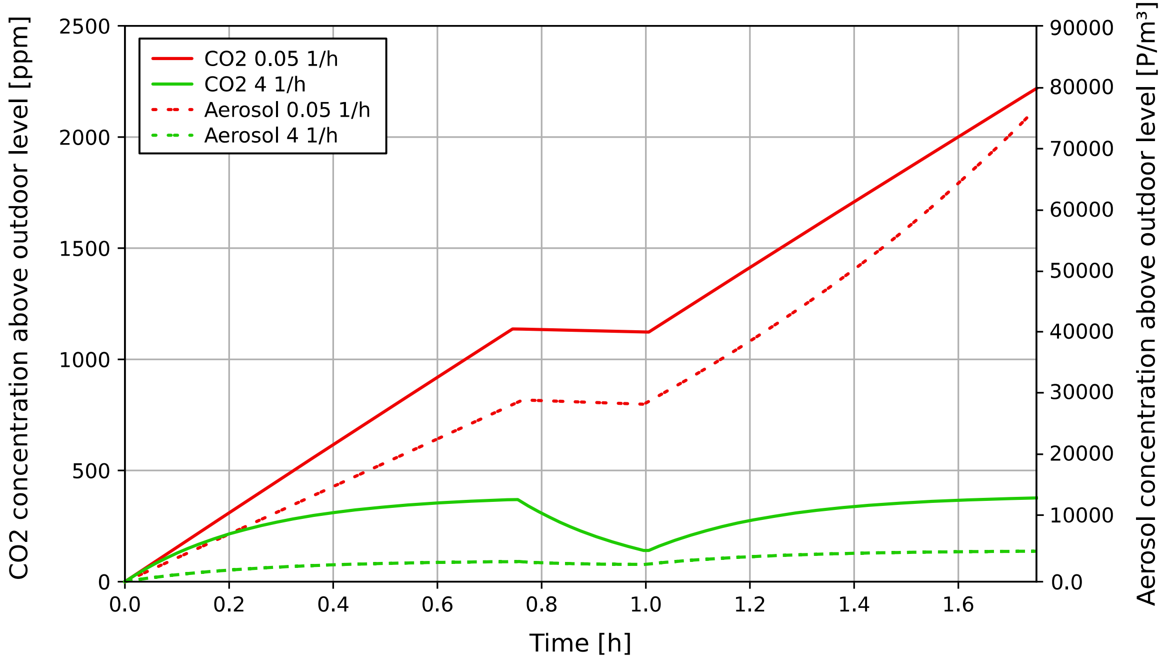
Dr. Ulf Witkowski heads the Electronics and Circuit Technology research group at the South Westphalia University of Applied Sciences in Soest, Germany. He has been an active researcher for about 20 years in the area of wireless networking, sensor networks, cognitive systems, and mini- robotics. He has established his research group at the South Westphalia University as a professor in 2009. His research areas include wireless communication involving mobile ad-hoc networking, radio-based node localization, sensor networks, and embedded systems. He received the diploma degree in electrical engineering in 1995 from the Technical University of Hamburg-Harburg, Germany and in 2003 the Dr.-Ing. degree from the University of Paderborn. U. Witkowski has published more than 80 scientific articles.

Agenda

- Motivation
- Sensor Node Architecture
- Application 1: Air Quality Display
- Application 2: Spatial CO2 Concentration
- Conclusions

Motivation

Aerosol concentration correlates with CO2 concentration:

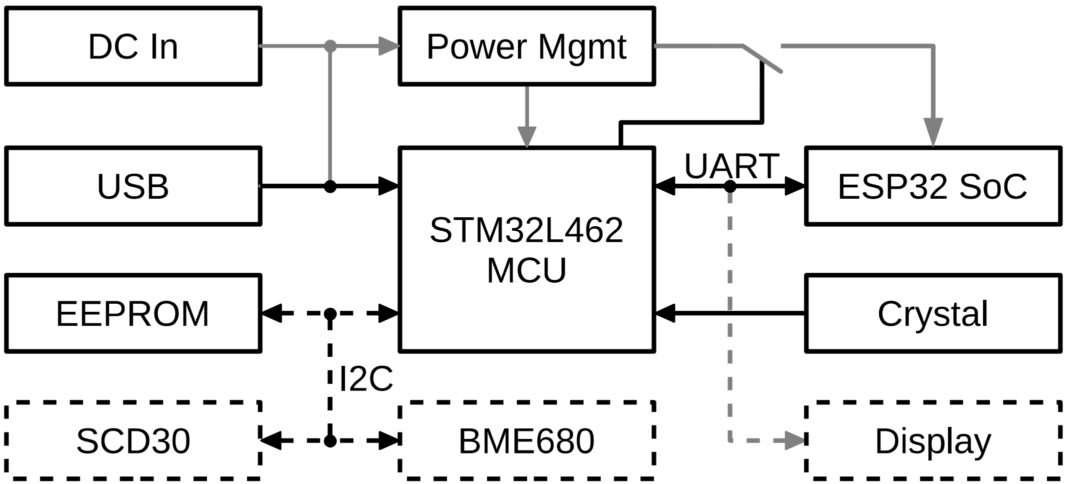


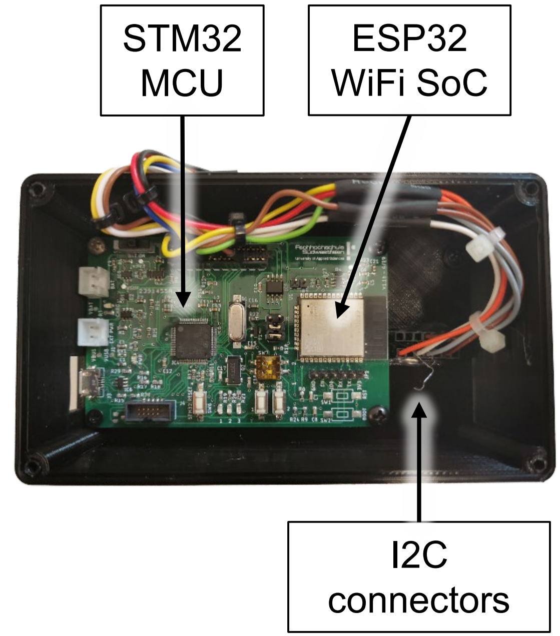
Two persons (one infected): Critical particle inhalation is reached…
… after 30 minutes for good ventilation (1000 ppm CO_2)
… after 15 minutes for bad ventilation (2000 ppm CO_2)

Increased infection risc especially in poor ventilated rooms

Source: A. Hartmann, M. Riegel,
Risk assessment of aerosols loaded with virus based on CO2-concentration

Sensor Node Architecture





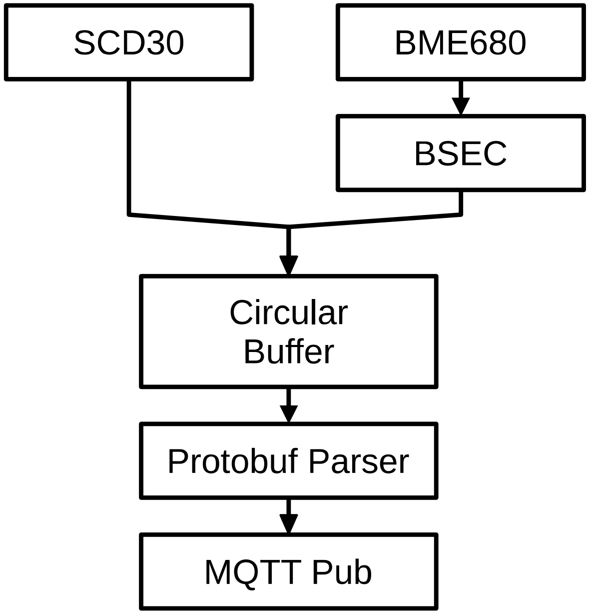
IoTyze Wi-Fi Module:

- STM32 main processor for data processing and MQTT client
- ESP32 SoC as Wi-Fi modem with TCP/IP stack

Plus external components:

- SCD30 sensor (***CO2***, temperature, relative humidity)
- BME680 sensor (***VOC***, pressure, temperature, relative humidity)
- 4.3“ TFT display

Data Flow

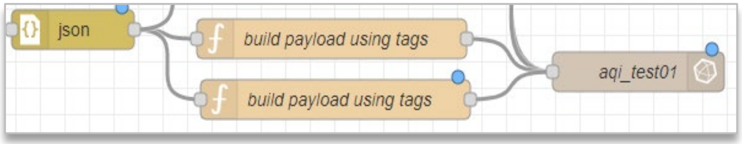


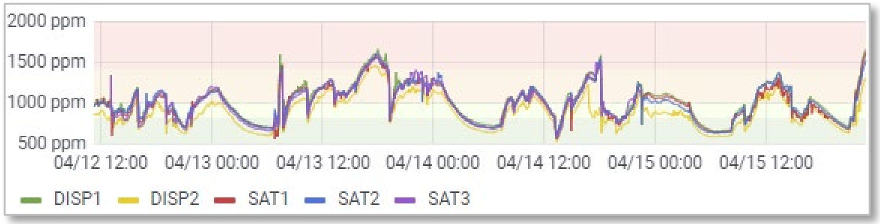
Internal:

- One or both sensors can be connected
- Sampling rate SCD30: 2 s
- Sampling rate BME680: 3 s
- BSEC sensor fusion estimates:
  - ***CO2 equivalent***
  - Index Air Quality (IAQ)
- Protocol Buffers for payload encoding
- Transmission of collected data each 60 seconds

External:

- Mosquitto MQTT Server as transport protocol
- Node-RED data processing
- InfluxDB as time-series database
- Grafana for web-based visualization





Application 1: Air Quality Display

Local display:

- Display of measurements
- Air quality indication according to DIN EN 13779
- Acoustical alert on critical CO² concentration

Application 1: Air Quality Display

Online display:

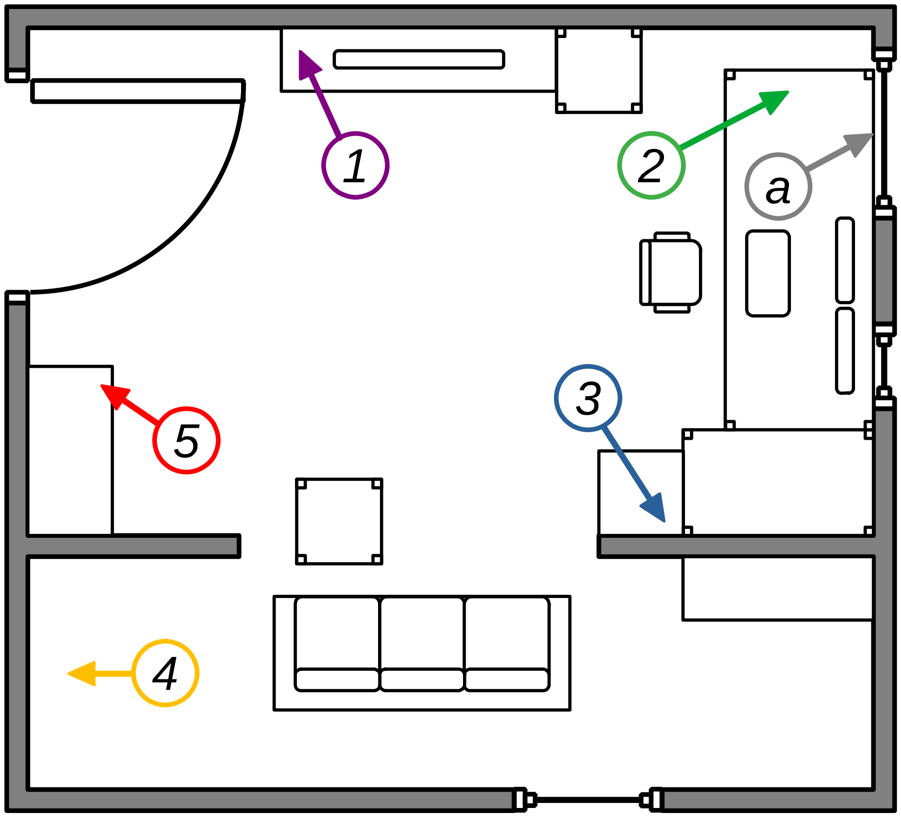
- Too *high* CO2 estimation in presence of other VOCs (e.g., paint, garbage)
- Too *low* CO2 estimation for other sources of CO2 except human breathing

Application 2: Spatial CO2 Concentration

Fachhochschule Südwestfalen
University of Applied Sciences

Experimental setup:

Installation of 5 SN in a height of 1.5m in home office environment



Application 2: Spatial CO2 Concentration

Temporal sequence:

CO^2 ~1500 ppm

First measurements

Opening door and window *a*

30 seconds

Second measurements

Closing door and window *a*

5 minutes

Final measurements

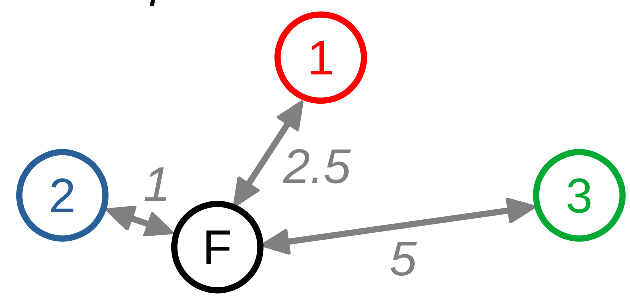
Application 2: Spatial CO2 Concentration

Spatial Interpolation for sparse, irregular data points:

Inverse Distance Weighting

$$F(x,y) = \begin{cases} \dfrac{\sum_{k=1}^{N} \left(\frac{1}{d_k}\right)^{\mu} f_k}{\sum_{k=1}^{N} \left(\frac{1}{d_k}\right)^{\mu}} & \text{if all } d_k \neq 0 \\ f_k(d_k = 0) & \text{if any } d_k = 0 \end{cases}$$

Example:



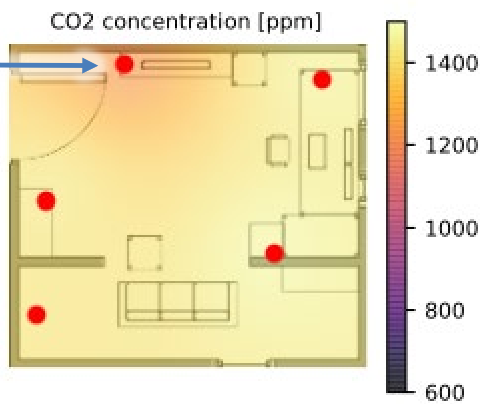
F = Estimation for coordinate x, y
N = Number of samples
d_k = Distance between estimation and sample k
μ = Power
f_k = Value of sample k

$$F = \frac{\frac{2}{1} + \frac{1}{2.5} + \frac{3}{5}}{\frac{1}{1} + \frac{1}{2.5} + \frac{2}{5}} = 2.625$$

Interpolated values in range of sample points

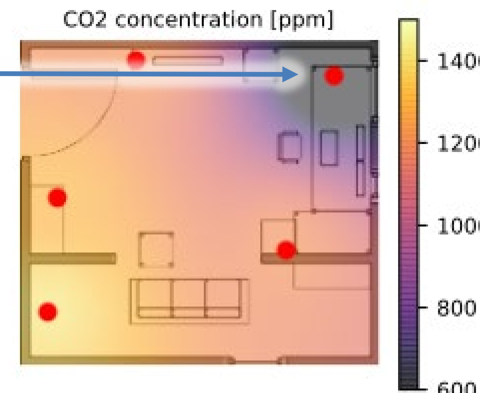
Application 2: Spatial CO2 Concentration

Results:



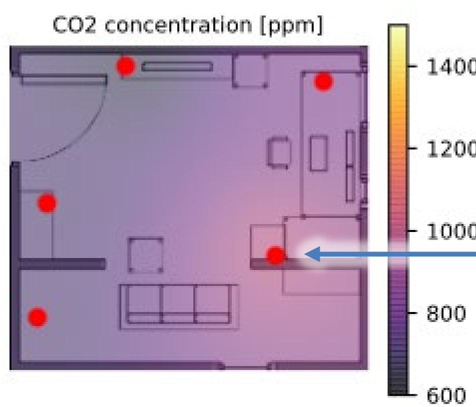
before airing

concentration drop near window



after 30s airing

slightly lower concentration near the door



increased concentration near workspace

after 5 min. with closed door and window

Fachhochschule Südwestfalen
University of Applied Sciences

Conclusions

- Sensor node with local display supports the ventilating habits
- VOC sensors with sensor fusion can be a cheap alternative to NDIR CO_2 sensors
- CO_2 estimation is usually too high in case of additional VOC (e.g. paint, garbage)

- No uniform distribution of CO_2 inside occupied space
- A drop in CO_2 concentration is first observed at the windows when airing
- Increased CO_2 concentration near workspaces shortly after airing was stopped
- Optimal position of a single sensor is near the workspaces in distance to windows

Future work:

- Measurements in crowded lecture rooms when possible
- Evaluate adjusted IDW (AIDW) to account for shielding effects
- Comparison of other interpolation techniques (etc. RBF, Kriging)
- Development of a planning tool for placement of sensors with real-time visualization