# Open-source wireless sensor system for indoor air quality monitoring

**Overview**

We spend most of our lives indoors, but most of us lack the tools to assess the quality of the air we breathe in those environments. Personal tools are available, albeit expensive, and must be inconveniently carried with us along with all the other tools of our daily lives. Instead, we want to make it easy to instrument buildings, continuously monitor the indoor environment, and report data back to us. We can make it easy by making cheap, reliable devices that don't need recharging for a long time. Three features of indoor air are expected to be monitored: 2.5 μm particle count or PM2.5, carbon dioxide ($CO_2$) concentration, and ventilation air speed.

Regarding $CO_2$, "Statistically significant decrements occurred in cognitive performance (decision making, problem resolution) starting at 1000 ppm (Satish et al., 2012)" [1]. It is also a good proxy for ventilation; high $CO_2$ levels mean the room is poorly ventilated, which increases the risk of passing airborne diseases such as COVID. After I finish Zoom meeting in a closed room at home, the $CO_2$ level is often over 1200!

Regarding PM2.5, the WHO recommends an upper limit of 5 ug/m3 (microgram per cubic meter) average annually and 15 ug/m3 average over a 24 hour period [2]. As this project document is being written, the outdoor air in Portland is over 30 ug/m3!

An air speed sensor, or anemometer, can help us calculate how much air is flowing into or out of a room and help understand why $CO_2$ is high. The system should report an invalid value (e.g., not zero because zero airflow is a valid value) if the anemometer is not connected.

The system will be based on components past capstone teams have successfully incorporated such as the TI MSP430 (including super low-power sleep modes). In this iteration, we will aim to replace the closed-source proprietary SmartMesh IP wireless system with the OpenWSN open-source wireless networking system.

**Project Goals**

Produce a fully wireless sensor data logger incorporating as many open-source components as possible and able to be produced at a very low cost. A particular goal of this project is very low power performance: sensors, communication system, and the microcontroller should be in as low a power state as possible when not in use such that batteries need to be changed, at most, annually. (The lifetime of a smoke detector would be even better!)

Data should be temporarily logged locally and wirelessly communicated to base station(s) as appropriate. A stretch goal includes visualization dashboard to present the logged data graphically for at-a-glance use. The device should be mechanically integrated into as small a form-factor as is practical and contained in a robust housing appropriate for indoor environments.

We anticipate the project consisting of three phases:

Phase 1: Select, implement, and assess performance of, sensors. In particular this includes energy consumption characterization, and investigation of whether sensors can be put into deep sleep mode between use. If their deep sleep mode is deemed not low-power enough, we will investigate whether they are tolerant to total power disconnect (via, e.g., MOSFET switches) when not in use. In other words, does it save enough energy to totally disconnect the sensors?

Phase 2: Make it wireless. Incorporate sensor implementations into a complete system that periodically wakes up, takes measurements, transmits them wirelessly, and goes back to sleep. This phase will include overall system energy profiling to determine how much battery power will be required for at least 1 year of operation.

Phase 3: Respond. We want the system to automatically respond to high particle count by designing, for example, an IR filter controller to hijack the remote control of a consumer air purifier and turn it on when PM2.5 is above a certain threshold. Another option is to control the box fan inside a Corsi-Rosenthal box air purifier, including fan speed.

**Deliverables**

Complete documentation
Summary project report in the style of an academic paper
Bill of materials
System schematic & functional diagram
Design files for any custom mechanical components or PCBs
Source code
Operation guide
Demonstration hardware

**Skills Emphasized**

Circuit design, electronics, embedded systems, wireless networking, PCB design, mechanical design, 3D printing.

**References**

[1] https://www.sciencedirect.com/science/article/pii/S0160412018312807
[2] https://www.who.int/publications/i/item/9789240034228, Table 0.1