Carbon Control

ECE445: Project Proposal

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Team 32

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Introduction

Problem

Air quality for indoor spaces is critically important, and universally needed. Whether it is an office, a school, or a hospital, buildings where large amounts of people congregate need to be safe to occupy. A key component of the safety of an indoor environment is ventilation. If a space is under ventilated the safety of its occupants is compromised. Diseases could potentially spread more rapidly, and the cognition of those in the space could be negatively impacted. There are two components of bad ventilation that we would like to address. First, is that a room's ventilation may render it safe when there are small groups of people, but when large gatherings take place the room's ventilation is insufficient. Second, is that larger spaces, such as auditoriums or gymnasiums may be locally underventilated.

Indoor CO_2 concentrations can be used to assess ventilation quality. When humans exhale, CO_2 concentration in a space increases. Indoor Co2 concentration cannot be increased indefinitely because very high concentrations of the gas are considered unsafe. Public health agencies recommend against high CO_2 concentration indoors. It is therefore important to have adequate ventilation indoors, and the effectiveness of indoor ventilation can be gauged by the rate of decay of CO_2 concentration within it.

Solution

We propose building a scalable wireless sensing package that can monitor CO_2 concentrations and decay rates in a building, or any indoor space. We can calculate the CO_2 decay rate by measuring the time constant of concentration decay. Our device will be able to report analytics and monitor concentration in real-time. This device has two main use cases.

The first use is to track and monitor CO_2 concentration in real-time, and persons inside a room will be alerted if it is unsafe. An interesting use of the device is that it can help people know if an empty room is safe or not, depending on its CO_2 concentration. This is important because while people may think a room without people is safe, it may potentially carry pathogens (this is more likely if CO_2 concentration is high). We plan on scaling this system to multiple devices that can be placed throughout a room to detect local hot-zones. This device will inform occupants of a room's CO_2 levels by having a "traffic-light" LED system (red, yellow, green). If the concentration is extremely high there will be an audible alarm. This is useful because it will allow people who are in charge of the room (a professor, facilities personnel, an RSO, etc.) to take steps to reduce high concentration, such as opening windows, or activating an HVAC system.

The second component to our device will be the ability to assess the quality of ventilation for a building, or room within a building, by tracking the decay rate of CO_2. The device will use an occupancy sensor to determine whether or not a room is occupied. If the room is unoccupied, the decay rate will be calculated by using the CO_2 generated inside it when it was occupied. By being able to calculate the time-constant, or decay rate, over multiple instances, the device can track how ventilation in a space changes as a function of time. For instance, if the time constant over many weeks is increasing, we know that the ventilation is worsening. Our device will be WiFi enabled, and therefore connected to the internet. Data will be sent to a web interface where it can be used by facilities management to keep track of CO_2 levels and ventilation quality for a particular room/rooms in a building.

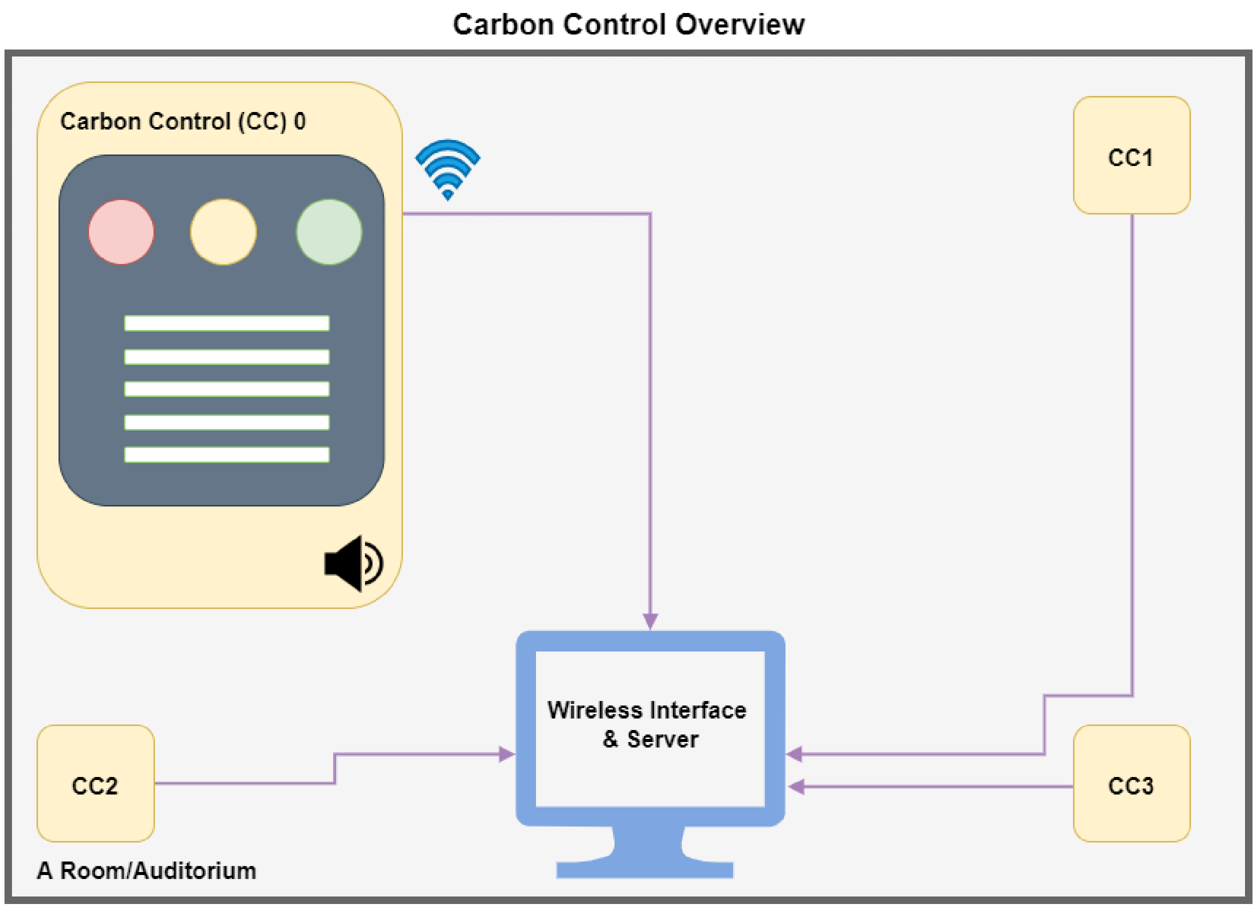

Figure 1: Visual Depiction of Carbon Control

Design

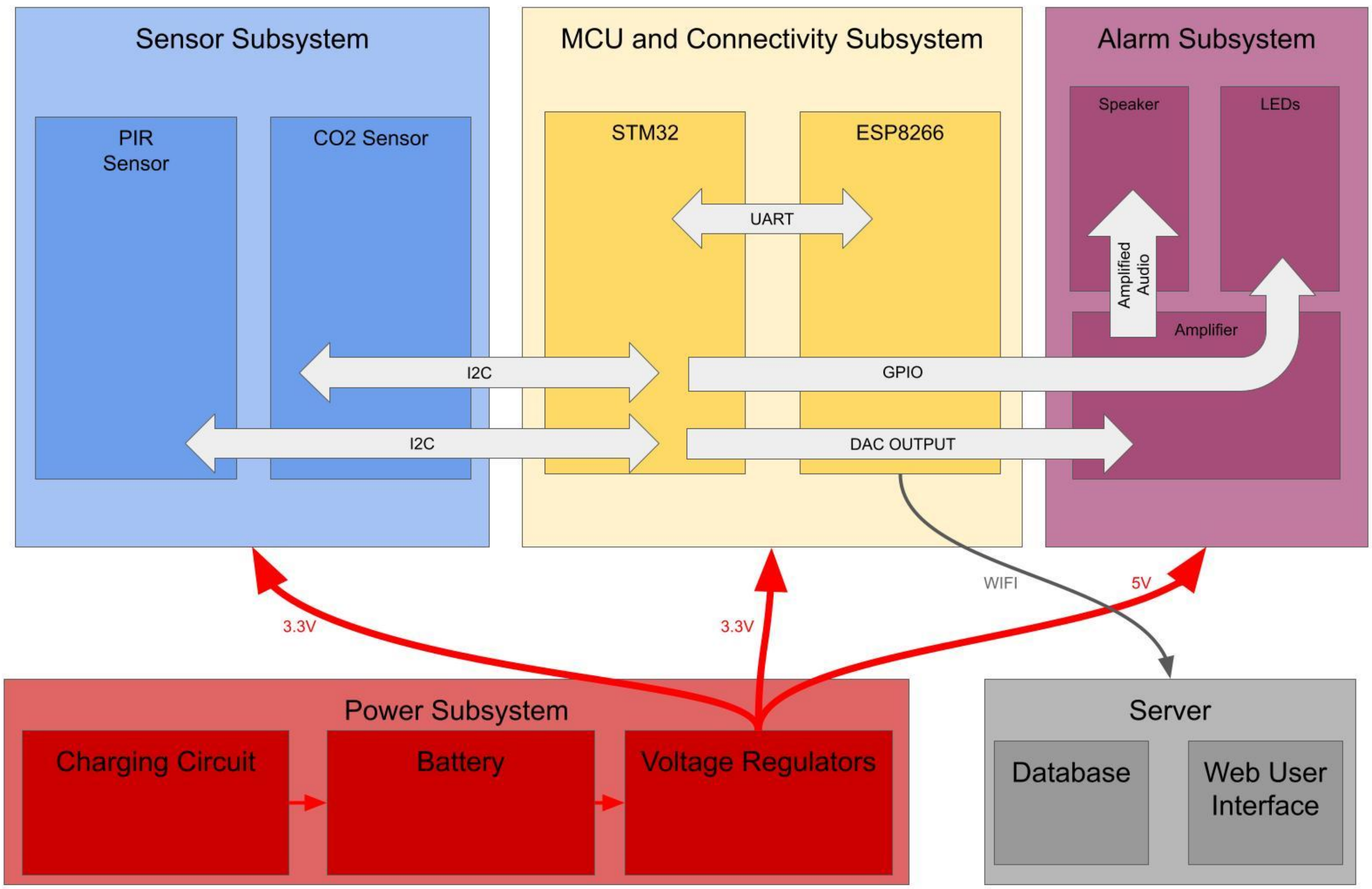

Figure 2: Block Diagram of the Design

High Level Requirements

We defined the following high level requirements for the implementation of our project. These requirements cover all subsystems and represent key elements of the functionality of our project.

1. Nodes must be able to upload their data to a server once every 10 minutes.
2. Nodes must be able to measure CO_2 levels in a room every ten minutes and sound an alarm if the reading is past a threshold.
3. Node must be able to operate on battery for a minimum of 8 hours and be rechargeable.

Subsystem Requirements

Power Delivery Subsystem Description & Requirements

The Power Delivery subsystem primary function is to supply two voltage rails, 3.3v and 5v, to downstream subsystems. The output rails are maintained by linear voltage regulators. The PD subsystem also enables the battery to be charged from an external power input. The PD subsystem is also expected to be able to maintain the supplied voltages at a 750mA current draw for the lower voltage rail and 250mA for the higher voltage rail.

1. The subsystem exposes a $3.3V \pm 0.1V$ power rail that can maintain its voltage within the specified tolerance with current draws $\leq$ 0.75A. The subsystem exposes a $5.0V \pm 0.1V$ power rail that can maintain its voltage within the specified tolerance with current draws $\leq$ 0.25A.
2. The subsystem can be battery powered for $\geq$ 8 hours, under standard operating conditions.

Sensor Subsystem

The Sensor Subsystem will consist of two devices, and it is designed to gather data on a room's CO_2 concentration and occupancy. First, there will be a PIR sensor to determine occupancy of an indoor space. The next sensor will be a Co_2 sensor that is used to calculate CO2 concentration levels in units of ppm. The requirements of the subsystems is that it must have sufficient CO2 concentration accuracy and a fast enough response time. We need to sense Co2 in a range of 400-10000 ppm with an accuracy of at least ± 100ppm. Additionally, the response time for the Co2 sensor must not be greater than 90 seconds.

The Sensor Subsystem will interact with the MCU Subsystem, by sending it the sensor readings, in order to calculate the Co2 decay rate time constant. It is connected in the following manner:

1. The CO2 sensor will connect directly to the MCU and interface with it through the I2C Bus.
2. The PIR sensor will also use an I2C interface with the MCU by way of a direct connection.

The Sensor Subsystem will be supplied 3.3V via the voltage rail in the Power Delivery Subsystem.

MCU and Connectivity Subsystem

The microcontroller and connectivity subsystem (MCU Subsystem) is designed to poll our sensor subsystem for data and transmit the results to a web server. The sensors will be on an I2C bus, and the microcontroller will maintain the bus and it will receive data from the sensor through the bus. The microcontroller will then send the data to the ESP8266 over UART. The ES8266 (WIFI module) will then post the data to a web-hosted server. The MCU will also output audio to our amplifier. This amplifier will drive our speaker to produce the audible alarm pins. We plan to use GPIO pins to drive the LEDs output.

1. The WIFI module will be able to make post requests to a wireless server.
2. The MCU module will be able to output a sound signal over its DAC.
3. The MCU will be able to establish and maintain a bus over I2C.
4. The MCU module will be able to control a set of LEDs.

Server Subsystem

The server subsystem consists of a web-hosted server that maintains a database for data collection and storage. As well as a web accessible user interface that a user can access to see historical CO2 levels, room occupancy history, and calculated air exchange rates. The server will be hosted on a commercially available hosting service.

The subsystem has the following requirements:

1. The subsystem can update the database with data from an incoming POST request.
2. The subsystem can display historical data on a graphical user interface.
3. The subsystem will compute and display calculated air exchange rates.

Alarm Subsystem

The alarm subsystem consists of an amplifier which receives audio signals from the microcontroller and outputs an amplified sound signal on the speaker when the CO2 concentration reaches a certain point. We also have an LED system whose different colors tell us the severity of the CO2 levels controlled by the GPIO pins on the microcontroller.

The subsystem has the following requirements:

1. The alarm system should be able to receive and amplify the sound signal from the microcontroller and output it on the speaker
2. The alarm system should also light the correct LEDs symbolizing the level of CO2 using GPIO pins on the microcontroller.

Tolerance Analysis

Our project hinges on our sensor package being able to accurately record changes in the environment. In particular, we require a fast response time in our CO_2 sensor to be able to record the transient CO_2 concentration. Data collected by Allen et al., shows classroom CO_2 concentrations can surge by more than 400% in under 5 minutes and their data shows that the decay to background concentrations can occur in under 30 minutes. This necessitates that our CO_2 sensor can respond in the necessary time, particularly considering that it's enclosure may slow down the changes by being itself poorly ventilated.

Safety and Ethics

There are some safety issues that may be encountered during the course of this project. First, working with atmospheric gasses like CO_2 could include exposure to high levels of the gas for prolonged periods of time during the testing phase of this project. This could be prevented by having multiple people monitor and update the potentially exposed party. If the test involves using sources of carbon dioxide like dry ice proper safety equipment should be used to handle the chemical in a secure manner and in the proper location in the lab. Another safety concern would be the electrical hazard. We will be wearing protective equipment when utilizing the electrical test equipment, as needed, when we are present in the lab. Other safety issues may arise during the mechanical assembly for our project. Proper safety precautions will be followed and safety equipment worn while working with equipment capable of injury, particularly sharp objects. Another potential issue relating to safety could be in our device's alarm. We will isolate its testing to prevent confusion and unnecessary panic that could ensue if it were to be sounded in public.

In addition to the aforementioned safety concerns there are some ethical considerations to be made. Data privacy regarding the number of people in a room is important and will be safeguarded, so as to comply with the ACM's codes of privacy (1.6) and security (2.9). We will also ensure that this project complies with the ACM's policy on fairness and descrimination (1.4) by giving an unbiased reading, irrespective of anyone who may be occupying a room. To conform to the IEEE code of ethics (1.1), this project should make improvements on the existing infrastructure, and results from the project will be handled fairly and openly so as to not harm anyone if its implementation is erroneous.

References

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