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1. Project Overview

1.1 Project Description

The purpose of this project is to develop a smart vent system which comprises of a series of electronically-controlled and networked air vents designed for homes with central HVAC systems.
The objective of the project is to give homeowners more control over the heating & cooling systems in their homes, resulting in improvements to the systems' responsiveness and efficiency.

1.2 Problem Statement

The HVAC systems commonly found in North American homes make use of central air systems whereby a single heating/cooling unit distributes hot/cold air to the rest of the house via ducts and vents. Homeowners may set a temperature that the HVAC system should maintain the home at, and they may restrict airflow to certain parts of the home by manually closing air vents.
Due to these air vents requiring manual operation, they are typically just left open. That means HVAC systems need to heat/cool the entire house whenever they turn on. This results in an increase in energy expenditure (and increased costs), as well as a slower response time for desired areas of the home to reach the set temperature.

Our smart vents will allow for dynamic control of home heating/cooling via the restriction of airflow to undesired (i.e. temporarily unused) areas of the home. The product is expected to increase the efficiency of the heating/cooling and reduce costs to the homeowner.

1.3 Existing Technologies

A review of the current market space has shown that a few smart vent products are already available to the public, from companies such as Flair and Keen Home. These existing products appear to address the problems outlined above, however, the current cost of these systems is estimated to be $100+ per vent and another $50-$100 for thermostats in each room.

Thus our aim with this project is to expand the market competition of such products and attempt to achieve a lower-cost solution to increase the accessibility for the average homeowner.

2. Technical Summary

2.1 Project Requirements

For this project we intend to develop 2 or 3 functional smart vent units, a hub to connect them, and a basic smartphone app to allow easy user interfacing with the vents via the hub.

The system will ultimately satisfy the following list of requirements:

1. Each smart vent unit is capable of opening and closing to restrict airflow
2. Each smart vent sends intermediate temperature and humidity data back to the hub
3. The opening and closing of vents are controlled by the hub which runs a scheduler program that alters the vent states based on the time & day
4. The user is able to view a vent’s status (open/close, temp., and humidity) via a smartphone application which connects to the hub
5. The user may manually set vents to be opened/closed via the smartphone app
6. The user may view and modify the scheduler program (on the hub) via the smartphone app

Based on the requirements, each smart vent unit will require the following electronics:

- a temperature sensor,
- a humidity sensor,
- a motor,
- a microcontroller,
- a Bluetooth module, and
- a power source,

which will allow it to perform the necessary I/O operations and communication with a hub that is Bluetooth and Wifi enabled.

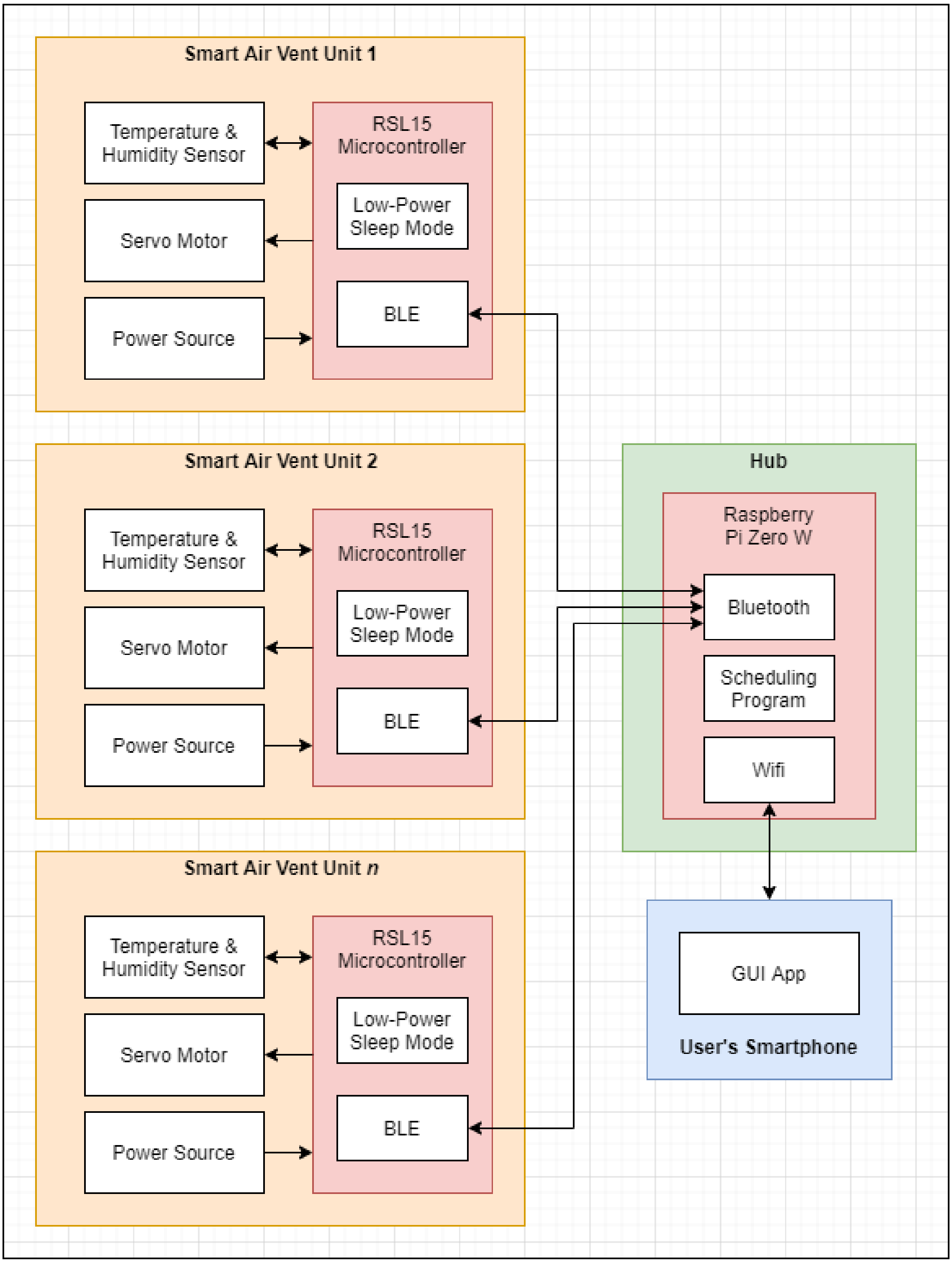
During development, we will also maintain the focus that the smart vent unit should minimize power consumption as much as possible. This means the units will use sleep modes and status changes of the vents will likely be limited to a 10-15 minute resolution.

Since our focus for this project is primarily on the smart vents, we will utilize a Raspberry Pi Zero W for our central hub which comes enabled with Bluetooth and Wifi.

The smartphone application will be written for Android devices with a priority on functionality and satisfying the above requirements. It will interface with the hub via Wifi connection on the owner’s home network.

2.2 Block Diagram

The following diagram outlines the components and interfaces within each smart vent and between the devices and a user's smartphone.



2.3 Cost Estimates

This section outlines the estimated cost of the prototype smart vent units.

Smart Vent Prototype Per Unit Cost			
No.	*Description*	*Part No.*	*Price*
1.	Vent Register	N/A	$12
2.	Microcontroller Development Board	RSL15-EVB	$127
3.	Temperature & Humidity Sensor Development Board	MIKROE-3436	$21
4.	Servo Motor (Linear Actuator Kit)	FS90	$9
5.	Power Supply (4AA Batteries + Holder)	N/A	$4
6.	Protoboard	MIKROE-767	$10
7.	Misc (Resistors, Capacitors, Buttons, etc.)	N/A	$5
	+ *Overhead (10%) and Tax (13%)*		×*1.24*
	Total		*$233*

* Prices may be inflated from regular amounts due to 2022 chip shortage

Hub Prototype Per Unit Cost			
No.	*Description*	*Part No.*	*Price*
1.	Raspberry Pi Zero W	N/A	$10
2.	16GB SD Card	N/A	$8
3.	Power Supply	N/A	$11
	+ *Overhead (10%) and Tax (13%)*		×*1.24*
	Total		*$36*

Given our interest in producing a lower-cost alternative to what is available on the market currently, we've also included a second estimate that replaces development boards with their core ICs. We note that these ICs come with a reduced part cost but with an increase in costs of manufacturing a custom PCB and additional circuitry (e.g. power regulation and clock).

Smart Vent Product Per Unit Cost

No.	*Description*	*Part No.*	*Price*
1.	Vent Register	N/A	$12
2.	Microcontroller SMD Chip	RSL15	$10
3.	Temperature & Humidity Sensor IC	HDC2080	$7
4.	Servo Motor	MS18	$3
5.	Power Supply (4AA Batteries + Holder)	N/A	$4
6.	Custom PCB	N/A	$15
7.	Misc (Resistors, Capacitors, Buttons, etc.)	N/A	$10
	+ *Overhead (10%) and Tax (13%)*		×*1.24*
	Total		*$76*

In the event that this product was to be manufactured at scale for the mass market, these prices would likely reduce further due to bulk pricing options.

2.4 Timeline

The following table contains a brief breakdown of the work to be completed from September 5th to December 16th, 2022, including the major deliverables required.

Week — Date	*Focus*	*Description*	*Deliverables*	*Due Date*
1 — Sept. 5th	Project Definition	- form a group - brainstorm & propose a viable capstone project idea	Project & Group Selection Document	Sept. 7th
2 — Sept. 12th	Project Planning	- infer major components required for the project - develop a project plan describing the solution, requirements, timeline, etc.	Parts Request Form	Sept. 15th
			Project Design Document	Sept. 18th
3 — Sept. 19th	Software Framework Development	- plan the MCU software details - plan the hub software details - plan the mobile app details		
	Schematic Design	- create a schematic diagram that plans out all pinouts and additional components		
4 — Sept. 26th	Software Framework Development (cont.)	- develop the base of each MCU module	Initial Software	Sept. 27th
5 — Oct. 3rd	Software Framework	- develop the base of the hub		

	Development (cont.)	software (via Python) - develop the base of the mobile app		
6 — Oct. 10th	Hardware Assembly	- begin assembling acquired hardware		
	Mechanical Prototyping	- figure out the vent open/close mechanism using the servo		
7 — Oct. 17th	Hardware-Software Integration	- begin integrating available hardware with software and fix any identifiable bugs	Low-Level Software	Oct. 18th
8 — Oct. 24th	Residual Development	- continue with the HW/SW development and integration - add any missing features		
9 — Oct. 31st	Project Testing	- isolated testing of each component - fix any issues that arise		
10 — Nov. 7th	Project Testing (cont.)	- system-level testing - verify that the vents-hub-app interfaces work reliably	SW-HW Integration	Nov. 8th
11 — Nov. 14th	Documentation	- begin the project report & posterboard - prepare for the project demo & presentation		
12 — Nov. 21st	Documentation (cont.)	- continue with final project documentation & deliverables		
13 — Nov. 28th	*Reserved Overflow*			
14 — Dec. 5th	*Reserved Overflow*			
15 — Dec. 12th	Deliver Results	- submit & present final deliverables	Project Completion	Dec. 13th
			Formal Project Report	Dec. 15th
			Project Posterboard	TBD
			Project Demo	TBD
			Project Presentation	TBD

2.5 Future Developments

The scope of this project is limited to the details outlined in the project overview and requirements sections above. This is due to the constraint of 15 weeks to complete this capstone project to a functional prototype of our idea.
As with any project, there is always more that can be done and further refinements that can be made. We list here some of those ideas that were considered during the brainstorming and initial planning of this project but were ultimately cut.

1. Designing a custom vent register — this would allow the circuitry to be better integrated into the whole unit and would allow the opening/closing of the vents to be optimized to minimize power consumption and maximize airflow control (perhaps even with partial airflow settings).
2. Replacing the AA power supply with Li-ion — moving the system to a rechargeable battery type (and potentially lower profile) would open up the option to include a battery charging feature which would reduce e-waste and provide more convenience to the user. It also opens the possibility of including a small solar cell to recharge the batteries passively.
3. Adding more sensors — the addition of more air condition sensors, such as CO, CO2, and pressure/airflow, would give the users more stats that could alert them to issues in their home and empower the automatic system to take more control in maintaining ideal conditions.
4. Removing the hub — for the project prototype, we required a central hub that our smart vents could reliably connect to that would ease the development of an automated vent control program; however, most users and homes are already equipped with smartphones and smart home devices which could take on the tasks handled by the dedicated hub. This would reduce costs to the users and reduce the bloat of smart home devices (and ultimately e-waste).

3. Team Overview

3.1 Development By

Zephyr

3.2 Team Description

The Zephyr team is composed of 3 students enrolled in the Embedded Systems Development program at Conestoga College. They are responsible for the outlined project, from planning and development to working with the onsemi sponsors, ensuring all project requirements are met.

3.3 Team Members & Roles

1. Name: Pierino Zindel
   Email: pzindel2270@conestogac.on.ca
   Role: Team Lead & Developer
   Responsibilities:
   - Project planning & progress tracking via Jira
   - Consulting with industry sponsor onsemi
   - Software & hardware development

2. Name: James (Thai An) Le
   Email: tle0475@conestogac.on.ca
   Role: Mechanical Designer & Developer
   Responsibilities:
   - Mechanical hardware prototyping
   - Software & hardware development

3. Name: Arshdeep Singh
   Email: asingh8644@conestogac.on.ca
   Role: Recorder & Developer
   Responsibilities:
   - Maintaining project documentation & meeting minutes
   - Software & hardware development