IoT Modular Thermo-System

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Project Narrative:

Living in Florida has its difficulties, one of them being temperature/climate control in the home. The motivation of this project is the trouble which arises when a home does not distribute cooling between rooms evenly and this results in imbalances in the temperature between rooms. Oftentimes you try to set the thermostat to a certain temperature and what occurs is not what you were expecting. Certain rooms will simply not reach the temperature desired by the user as a result of the current limitations of modern HVAC systems. Many rooms have different temperatures and this creates a variability in climate from what the user may have been expecting. Modern AC systems are quite basic in their design. They typically cool on full blast until the desired temperature is reached and then turn off. The AC system continually performs this routine throughout the day in order to maintain the desired temperature. However this method of cooling and heating isn't comprehensive and typically doesn't heat every room to the desired temperature. In addition to this, certain users may have different temperature needs than others and one of our goals is to allow for different temperature zones between different rooms.

We are looking to alleviate this problem by creating an IoT system which controls the heating and cooling of independent rooms. One of the goals associated with this project is to develop an accurate independent temperature controlling technology which is relatively easy to use and can be controlled via a smartphone or computer application (Fig. 1.2, 1.4) & (Table 1.1, Specification 6). Certain rooms are too hot for their respective individuals while others are much too cold. Our product will make it easy to control the temperature in an individual's respective room without the need for physically going to the thermostat to alter the temperature and affect others in the household. Our product will also make it more comfortable for each individual as they can tailor the temperature to their needs.

A typical thermostat is also only controlled from one spot in the home, our approach will automatically control the central AC to reach the desired temperatures set by the user for each room. This will allow for the individuals to control temperatures to their liking assuming they are connected to the internet. The application interface will allow for the convenience of changing the temperature of any room remotely, resulting in improved portability as opposed to manually changing the temperature via the central thermostat (Table 1.1, Specifications 5 & 7). Our product will also be battery powered and relatively small in size in order to avoid routing many cables through walls. The specific details associated with these features are displayed in (Table 1.1, Specifications 1-4).

There are other products which provide similar benefits such as the Keen and Flair smart vents however these products are extremely expensive and typically poorly reviewed. Each smart-vent from these manufacturers also costs anywhere from $80-$135 per vent depending on the dimensions of the vent in question. This isn't including the price of the “Flair Puck” which is an additional $119 and must be placed in every room requiring a smart vent. This results in an astronomical cost in order to integrate the smart vent system in an average home. Our product will also require the installation of specially made vents and thermostats but targeting a much lower price point. Additionally neither of the current competitors do not provide a product to actually control the central AC unit.

The Smart Air Flow project is not meant to be a device targeted towards the high-end market but rather a system which can be provided to the average household. This product will be easily attached to vents with IoT system integration and allow for wireless connectivity between devices and an online database (Fig. 1.3). One of the goals of our project is to show that achieving a level of independent climate control shouldn’t be extremely expensive.

Each room or zone will have a temperature sensor along with a microcontroller that connects back to a main mcu which determines whether or not a room is hot or cold. This process will be automated via the microcontrollers communicating and sending the information to the main microcontroller (Fig. 1.3 - 1.4). Essentially each room will have its own climate based on the input specifications of the user.

The project roles will be assigned based on the strengths of each team member. Muhamad and Yoseph will be responsible for the mobile application and software development associated with the project. The central hub and embedded design of the main microcontroller will be under the control of Joseph and Muhamad. Finally the Valves, Sensors, and PCB design will be managed by Vinh and Joseph. These roles are consistent with strengths associated with each team member. The breakdown of project roles and assignments can be found in (Fig. 1.5). We have also weighed our options in terms of cost, usage, and features in a House of Quality diagram (Fig. 1.1). In addition to this we've researched the costs associated with the required components and have mapped out planned milestones (Tables 1.2 & 1.3).

Our group will be demonstrating and testing the project in a small-scale representation in place of a full-scale implementation in a real home as it is simply not feasible given the expected presentation environment. A small-scale representation will simply provide a proof of concept of what could possibly be achieved in a full-scale model. Our model will consist of two seperate rooms divided by a wall and will be interconnected with ducts leading to each room. Each duct will be fitted with a custom vent which will open and close depending on the temperature specified by the user.

Requirements and Specifications:

- **Central Thermostat Hub**
  - **Specifications**
    - MCU: ATmega328P
    - Power: 24V AC the central HVAC system provides
    - Display: Color Backlit LCD
    - Communication: WiFi & LoRa (SX1276)
    - Relays: Omron G6SK-2F-H relays
  - **Requirements**
    - Receives temperature updates from the distributed thermostats
    - Send commands to the zone dampers to close or open
    - Track temperatures of each room and decide on which vents to open and close in order to achieve the temperature target for each room/zone
    - Temperature zone targets may be updated through the web application
    - Distributed thermostats may also update the temperature zone target for their room
    - Controls the central HVAC system via relays.
    - Configured with an IoT technology provider like AWS.

- **Distributed Thermostat**
  - **Specifications**
    - MCU: SAMD21 Cortex
    - Power: 3.7 Li-Po rechargeable battery
    - Display: E-Paper display (Pervasive Displays E2154CS091)
    - Communication: LoRa (SX1276)
    - Temperature Sensor:
  - **Requirements**
    - Connects to the central hub wirelessly to report back the current temperature
    - Have buttons to change the target temperature of the zone and report back to the hub

- **Distributed Vent Dampeners**
  - **Specifications**
    - MCU: SAMD21 Cortex
    - Power: 9v Battery
    - Display: N/A
    - Communication: LoRa (SX1276)
    - Servo: SG92R Micro servo
  - **Requirements**
    - Be able to use a servo to open and close the vent to control airflow when the central hub sends the command to do so.

- **Thermoelectric cooler**
  - **Specifications**
    - Power: 12v DC power supply
    - Peltier Module: TEC1-12706
    - Cooler: AMD Wraith Stealth & 50x50 mm copper heatsink and blower fan
  - **Requirements**
    - Be able to cool an enclosed space down to 70 °F
    - Be able to warm an enclosed space up to 100 °F

- **Website/Mobile app**
  - **Specifications**
    - IoT integration tool: AWS IoT
    - Mobile app: MongoDB, Express, ReactNative, NodeJs
    - Hosted on AWS (gives mLab support for MongoDB)
  - **Requirements**
    - Communicates with the Central Thermostat Hub through IoT.
    - Allows you to control temperature in each room with a vent.
    - Receives temperature updates from the central thermostat hub.
    - Turn on/off a vent in a certain room completely.
    - Give names to each vent to represent rooms (ex: Bedroom 1)
    - Prioritize the mobile application, then the make web application if it seems fit.

Engineering Specifications

1	Central thermostat hub board size must be no bigger than 8cm x 4cm.
2*	Distributed board sizes must be no bigger than 4cm x 4cm
3	Each battery should be able to fit behind their designated distributed board.
4	The distributed boards must be run at least 1 month before recharging.
5	The distributed thermostat must check new data from sensors every 30 seconds and sleep between each check.
6*	The mobile app should fetch the most recent temperature information at least every minute.
7*	The vent valve has to open/close within two seconds of a temperature change request.

Table 1.1

*Specifications marked with * are key demonstrable specifications.*

House of Quality

Strong Positive Correlation	^^
Positive Correlation	^
Negative Correlation	v
Strong Negative Correlation	vv
Positive Polarity	+
Negative Polarity	-

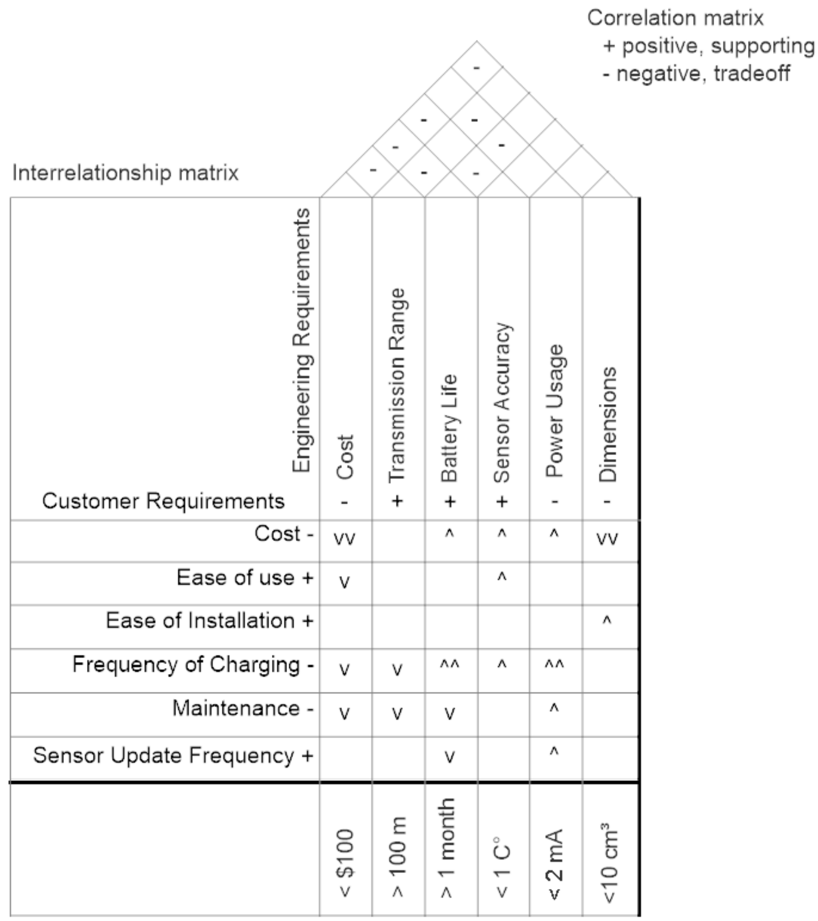

Figure 1.1

Block Diagrams and Illustrations:

General

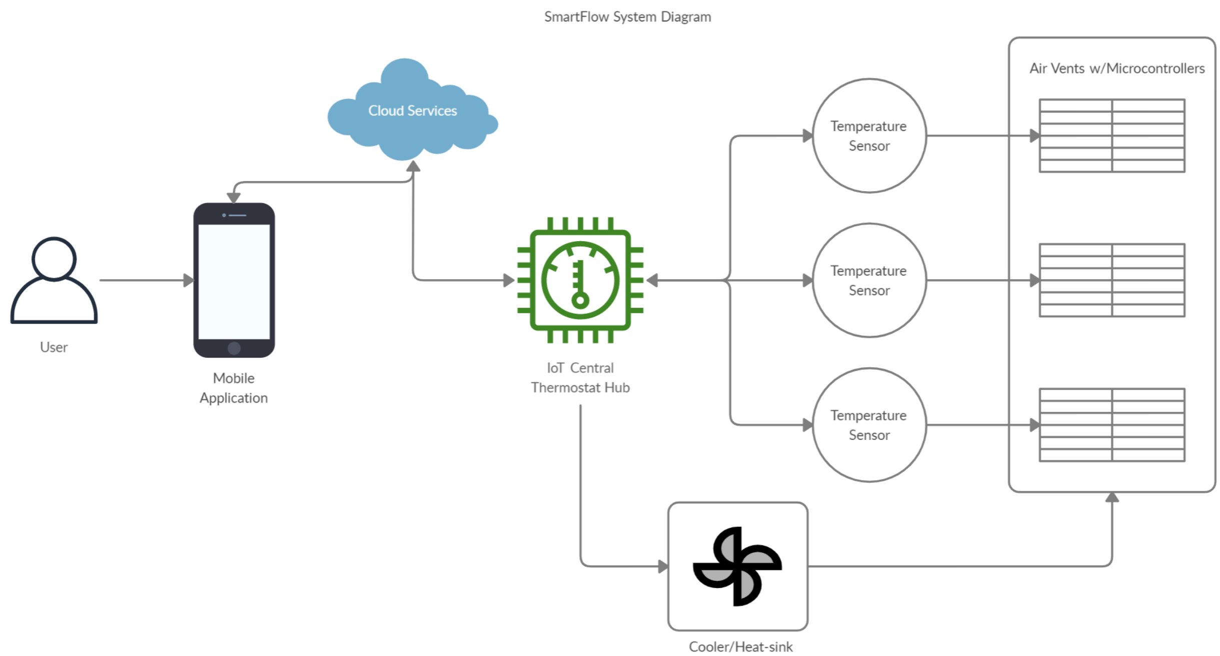

Figure 1.2

Hardware Block Diagram

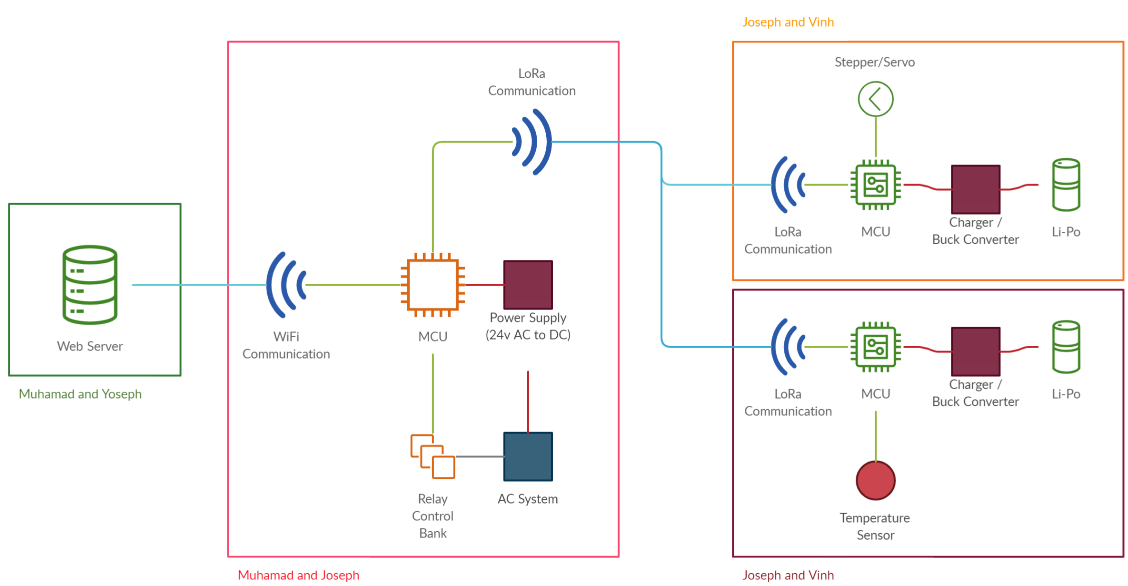

Figure 1.3

Software Flow

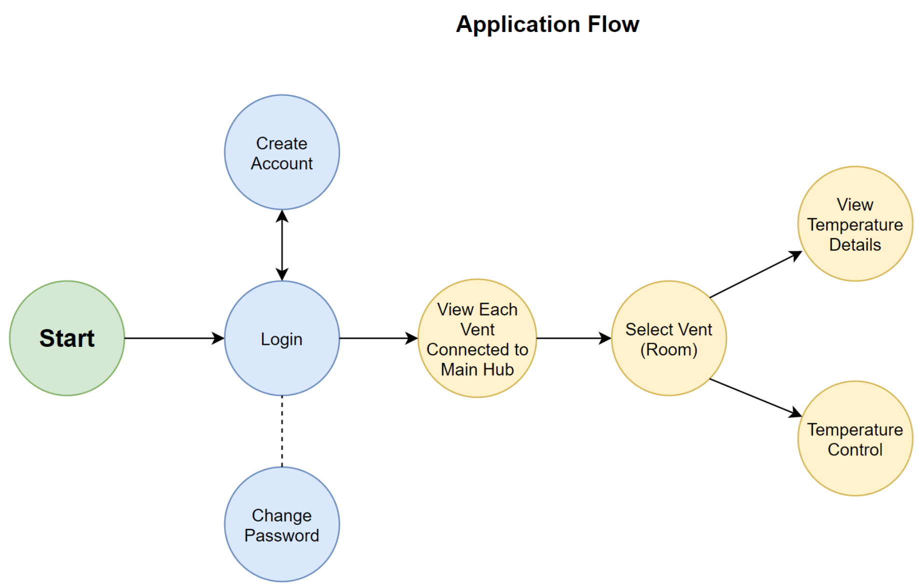

Figure 1.4

Group Roles Breakdown

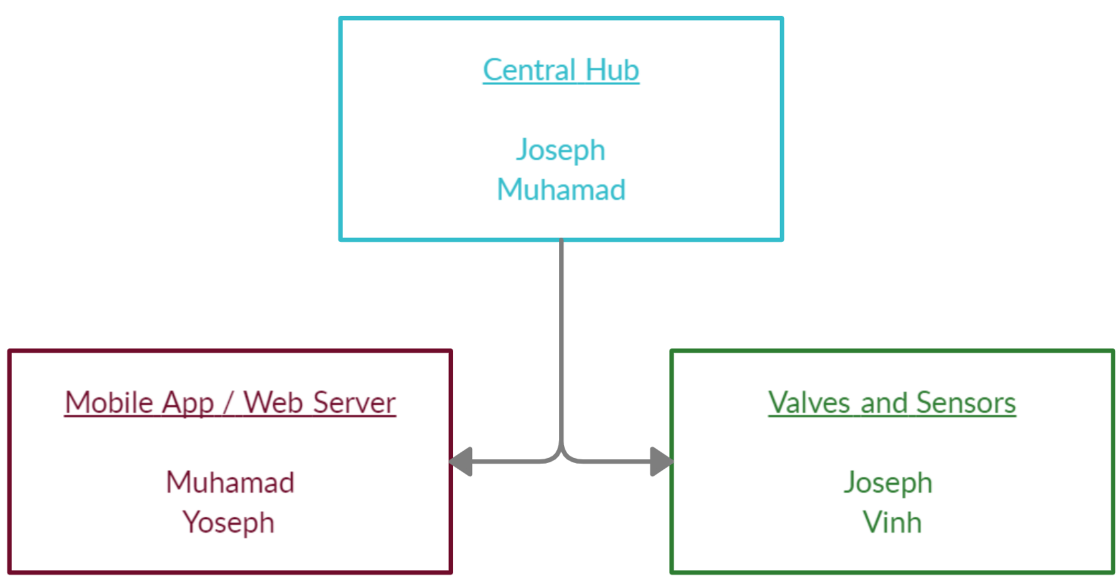

Figure 1.5

Budget and Financing:

The items included in our budget below include price estimates for parts in the final prototype as well as any development kits. Our project will be self-funded.

Project Financial Costs

Item	Quantity	Price Estimate
Temperature Sensor	3	$10
E-Paper display	3	$15
ATmega328P MCU	1	$2
SAMD21 Cortex MCU	6	$12
LCD Display	1	$5
Omron G6SK-2F-H relays	6	$25
Custom PCBs	7	$100
Servo	3	$9
LoRa Module	5	$30
WiFi Module	1	$8
Arduino Development Kits	3	$60
Thermo Electric Cooler	1	$70
Cloud Hosting Service	1	$10
Total	N/A	**~ $330**

Table 1.2

Project Milestones:

The milestones included below are the tasks that need to be completed and their associated date ranges to complete them. It also includes who will be responsible for each task.

Milestones

Number	Task	Start	End	Status	Responsible
1	**Ideas**	08/24/2020	08/28/2020	X	Everyone
2	**Project Selection**	08/31/2020	09/11/2020	X	Everyone
	Project Report				
3	Divide & Conquer	09/07/2020	10/02/2020		
4	Table of Contents	09/21/2020	10/23/2020		
5	First Draft	10/05/2020	11/13/2020		
6	Final Document	08/24/2020	12/08/2020		
	Research & Design				
7	Power management	09/21/2020	10/02/2020		
8	Hardware design	09/21/2020	10/16/2020		
9	Connection protocol	09/28/2020	10/16/2020		
10	Mobile app backend	10/12/2020	11/06/2020		
11	PCB schematic	10/12/2020	10/16/2020		
12	Main hub PCB layout	10/19/2020	10/23/2020		
13	End devices PCB layout	10/26/2020	11/06/2020		
14	Mobile app frontend	11/09/2020	11/27/2020		
16	Order and Test parts	10/19/2020	12/08/2020		

Table 1.3