Home Air Monitor

October 24, 2014

Dr. Andrew Rawicz
School of Engineering Science
Simon Fraser University
Burnaby, BC
V5A 1S6

Re: ENSC 440 Design Specification for Home Air Monitor (H.A.M)

Dear Dr. Rawicz,

Please accept the following design specification document for our Home Air Monitor project. Our goal is to create a cost efficient way to monitor dust and pollutant levels within a household space, and to provide alerts for users when air quality in an area becomes non ideal. This design will consist of a sensor and a WiFi capable processing system, communicating
with an Android mobile application to alert the user.

The purpose of this document is to provide details on all technical aspects that the monitoring system will have. This will assist us in the way we design our project, along with solving problems when they occur. This document includes diagrams to further explain design concepts, along with methods and procedures to test different components within the system.

Our team consists of three dedicated members that have joined to form the company *Clean Space.* We have Joanne Leong, Peterson Poon, and Elaine Chiang, all fourth year Engineering students at Simon Fraser University. Should you have any concerns about these functional specifications, please feel free to contact me at eychiang@sfu.ca.

Sincerely,

Elaine Chiang
Chief Executive Officer
Clean Space

Enclosure: Design Specification for Home Air Monitor

Home Air Monitor

A cleaner, healthier home

Project Team:

Elaine Chiang

Joanne Leong

Peterson Poon

Contact Person:

Elaine Chiang

(eychiang@sfu.ca)

Submitted To:

Dr. Andrew Rawicz

Steve Whitmore

School of Engineering Science

Simon Fraser University

Issued Date:

October 24, 2014

Revision:

1.2

Abstract

The objective of *Clean Space* is to create a device that allows users to take control of pollutant levels in their living space by monitoring air intake areas and thus, prevent pollutants from entering their home in the first place. This idea was developed after our personal experiences of having to clean out dusty areas such as furnaces, PC towers, and other filtration devices. Furthermore, all our group members have experienced the discomfort of indoor facilities that were dusty with poor ventilation, which motivated us to work on a project to improve indoor health and comfort as a whole.

In this document, we have put together our designs specifications for our system including electrical, software, and hardware components. HAM consists of a sensor that detects dust and pollutants within an enclosed space, which then alerts users when air quality in an area becomes non-ideal. This document will also focus on the technical details of the system components with justification for chosen parts and approaches to problems. It will also elaborate on the interaction between the hardware and software components, as well as provide a thorough test plan to ensure our success in this project.

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Glossary

HAM	Home Air Monitor
WiFi	Wireless Fidelity
ODS	Optical Dust Sensor
DMM	Digital Multi Meter
API	Application Programming Interface

1. Introduction

With amounts of pollution being released in the air increasing daily, certain measures must be taken to protect ourselves and our homes. For many of us, the majority of our lives are spent indoors in locations such as school, work, and homes. In these environments, poor ventilation, mold, dust, and pollution can all play a major role in our respiratory health and well-being. [1] At *Clean Space*, we aim to develop a system that helps homeowners take control of the cleanliness in their living space by monitoring less frequented areas that could permit unsafe levels of dust to collect.

Clean Space offers a unique monitoring solution that provides maximum customization and flexibility in that the system can oversee any area that a user selects. With WiFi capabilities and a compact design of the system, HAM can be placed in ventilation systems, attics, furnaces, and more. The design specifications for HAM, as proposed by *Clean Space* are described in this following document.

1.1 Scope of Project

All design specifications in this document will cover details and justification for the components used in HAM including a particle sensor, Arduino YUN microcontroller, wireless communication, and an alerting mobile application. This design document will also support the previous *Functional Specification For the Home Air Monitor* document, by outlining the predetermined functional requirements. This document will include analysis of limits in individual component performance, hardware design justification, communication procedures, and integration functions of all parts. Finally, the document will supply a thorough component and system test plan for HAM.

1.2 Intended Audience

This design specification will be used by all group members of *Clean Space*. It will be referred to throughout our phases of development to ensure the final product meets the predefined technical requirements, and functions the way it was originally designed to. This document will provide justification for design decisions, and to serve as a basis for future modifications of this prototype after testing and finalization of the product.

1.3 Background

Asthma is one of many respiratory illnesses that can be triggered by dust, pollutants, pollen, and smoke. In 2013, Stat Canada reported that there were 2,363,010 Canadians that were affected by asthma. [2] While Vancouver may have better air quality than that of neighbouring cities, many illnesses are still being caused due to improper monitoring and care for our living space. Air quality is defined by the Fraser Health as “the state of air around us” and it is up to us to understand how the air quality, both indoors and out, can impact our lifestyles. [3]

Thus, the objective of *Clean Space* is to create a cost efficient way to monitor dust and pollutant levels within a household space, and to provide alerts for users when air quality in an area becomes non-ideal.

2. Complete System Overview

2.1 Prototype Model

Upon completion of the second development stage, a prototype that resembles Figure 1 should exist. HAM consists of two main subsystems, which includes the hardware component, and the software mobile application component as illustrated below.

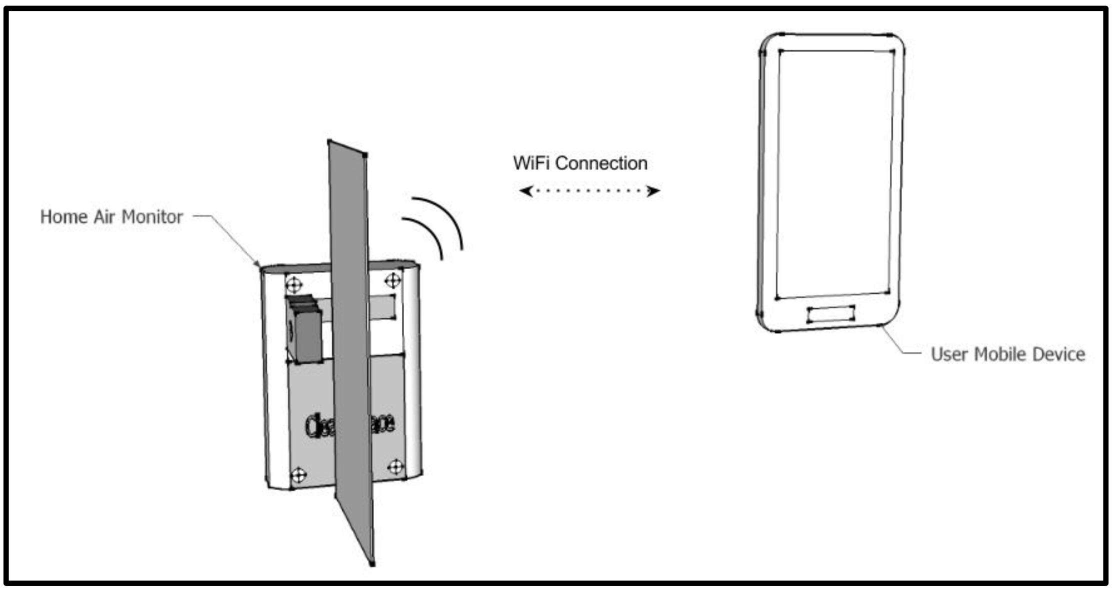

Figure 1: Complete Home Air Monitor system components

In Figure 2, the top and front view relative to a filtration system is displayed, which is the main target usage scenario that we are developing for. The prototype should be a compact system with a small extrusion to allow the sensor to collect data through free airflow.

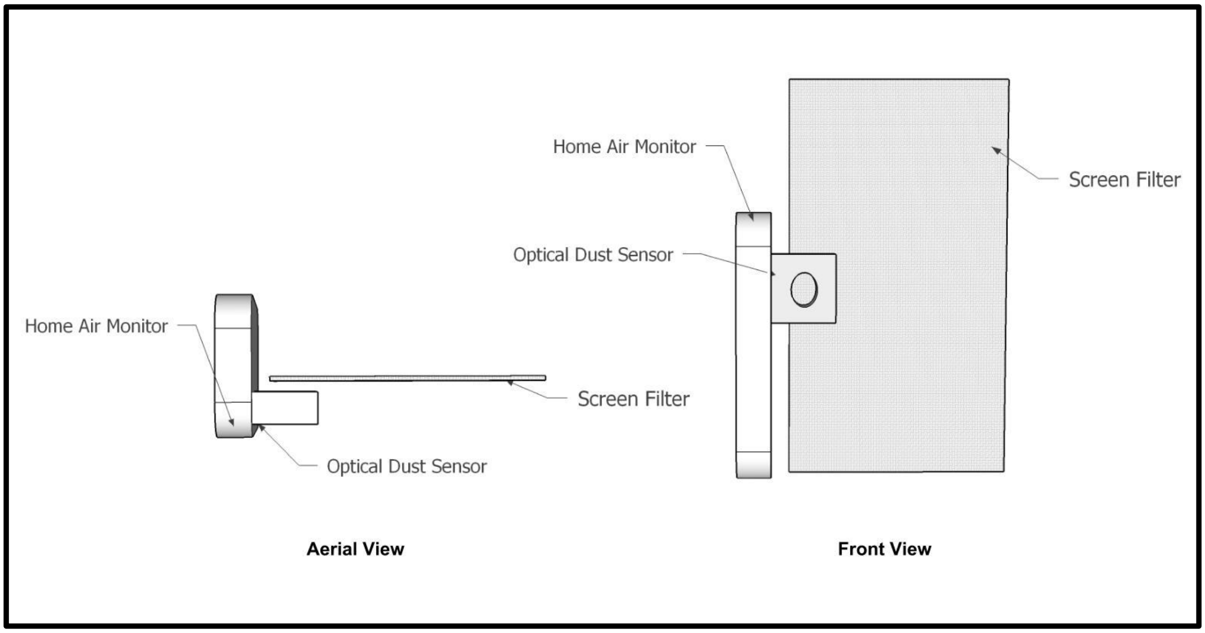

Figure 2: Aerial and front view of HAM with reference to filter.

Our entire hardware system including the dust sensor, battery, microcontroller, and circuitry will be packaged into a compact container, with consideration to electrical contact requirements. Since the microcontroller has WiFi capabilities, the phone will be able to receive data from the sensor, provided the microcontroller and mobile phone are on the same network. The software system consists of an Android mobile application that will communicate with the hardware system to alert the user and display pertaining data.

2.2 System Block Diagram and Flowchart

The designed inputs and outputs of the HAM system are outlined in Figure 3. As displayed below, the Arduino YUN will be the processing microcontroller that controls and conducts necessary calculations. For the prototype, we will start with using one sensor connected to the microcontroller, but will design the overall system so that it can also be compatible with multiple sensor inputs.

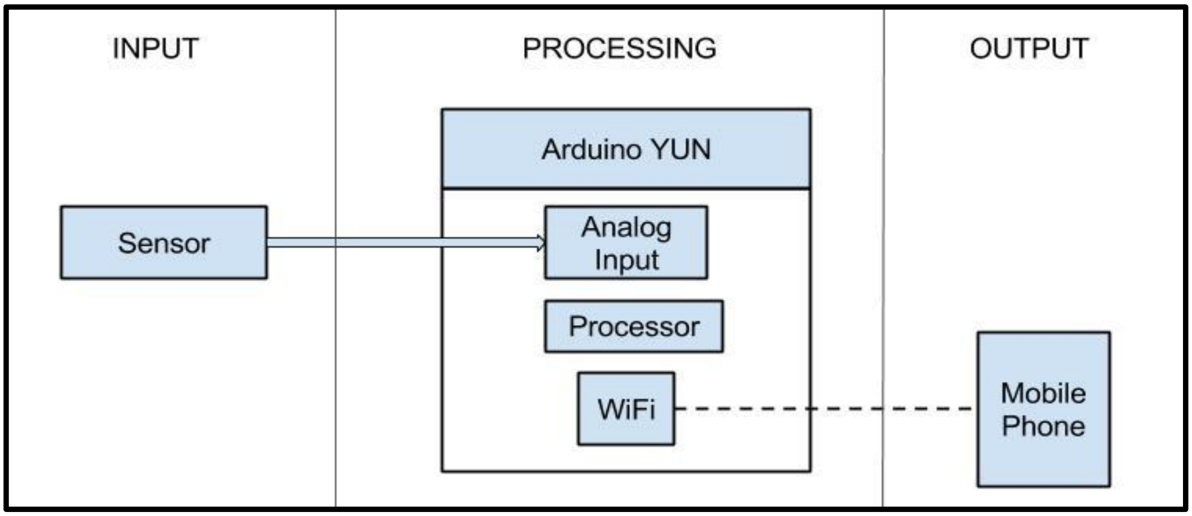

Figure 3: High level system block diagram for HAM

The flowchart diagram in Figure 4 on the next page will further elaborate on how the block diagram translates into the functionality of HAM. It will also show how the software system will process certain inputs to produce various output results. As the hardware system collects data and passes it to the software aspect, a comparison is made for a preset threshold level. This threshold is still yet to be determined, and will be resolved once testing with our researched values begin.

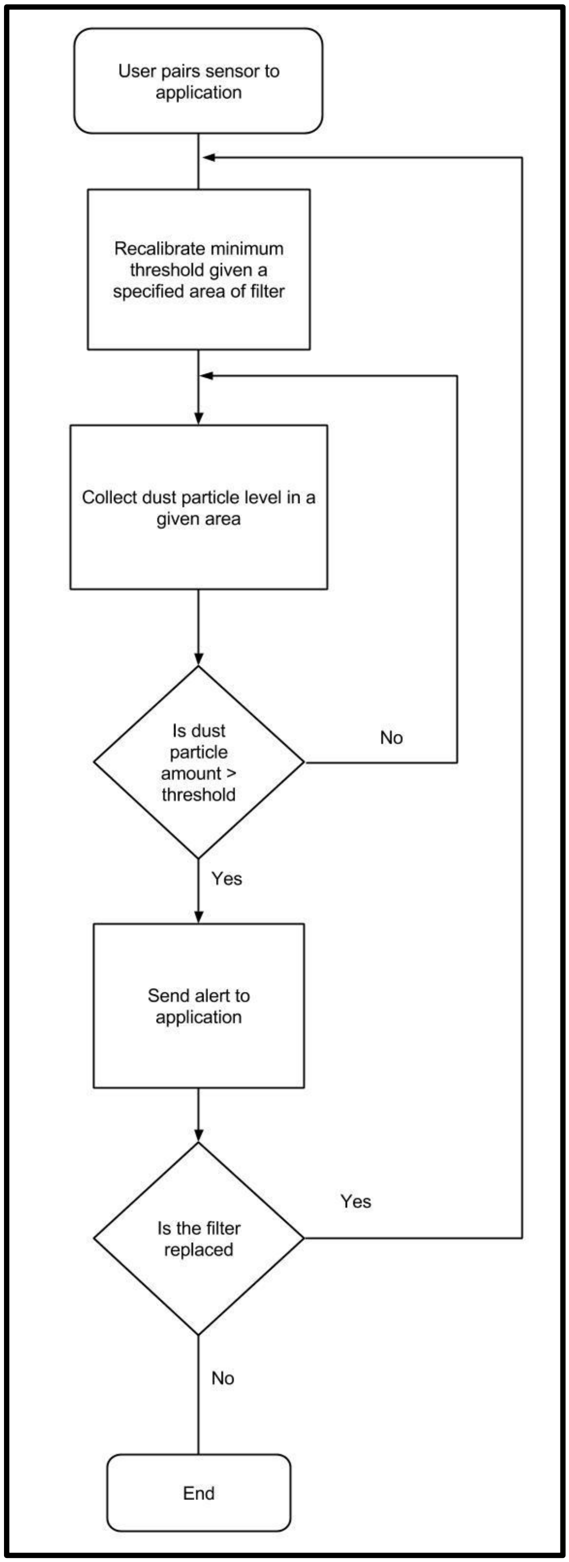

Figure 4: Flowchart to demonstrate functionality of HAM

3. Hardware System Specifications

3.1 Components

The components used for the Home Air Monitor will consist of a single Arduino Yun microcontroller, a Sharp ODS, an external battery, and a clear enclosure casing to hold all components. The Arduino will be a stock unit with no modifications to the hardware and will be connected to a Sharp ODS. The components used are displayed in Figure 5 with the sites of each connection colour coded. The ODS will connect to the Arduino via the digital and analog pins. The external battery will be connected to the Arduino through the micro-USB port colored blue.

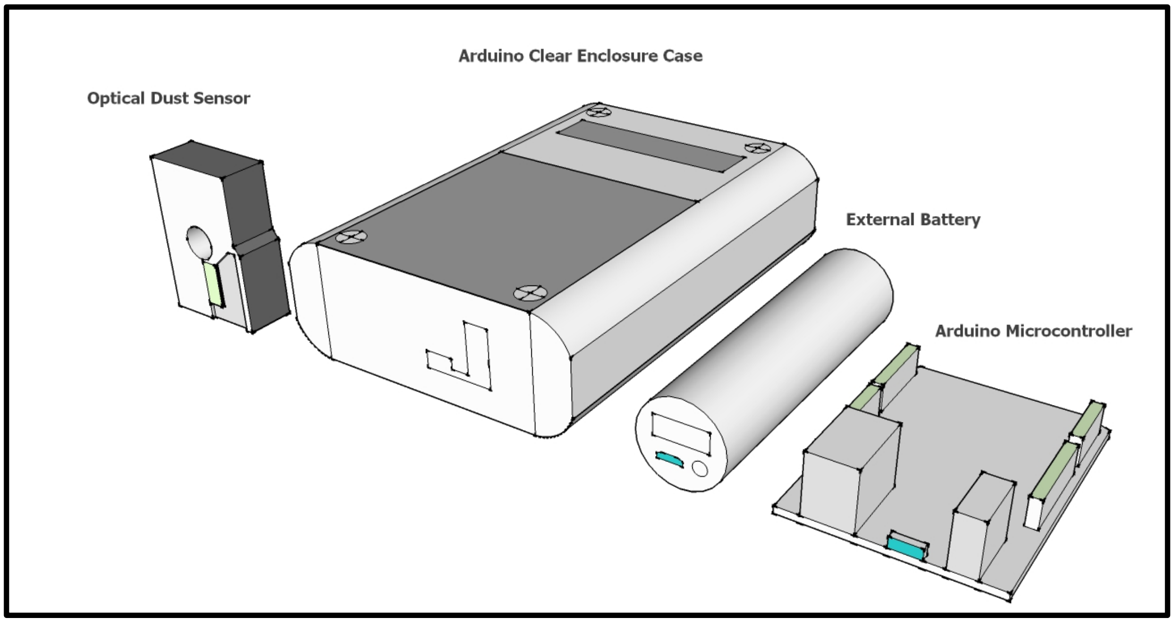

Figure 5: Components in the Home Air Monitor

In Figure 6, the conceptual casing of the home air monitor is shown along with the orientation of each component. The Arduino and the battery will be placed inside the casing and will be connected with the micro-USB cable. The micro-USB cable will then power the Arduino and the ODS of HAM. On the side panel where the battery is positioned, a USB port will allow the user to recharge the device when the battery is low. The optical sensor will be mounted on the surface of the casing and will be wired to the PCB through the case opening. The HAM will be assembled securely using non-conducting adhesive and will have dimensions shown in Figure 7.

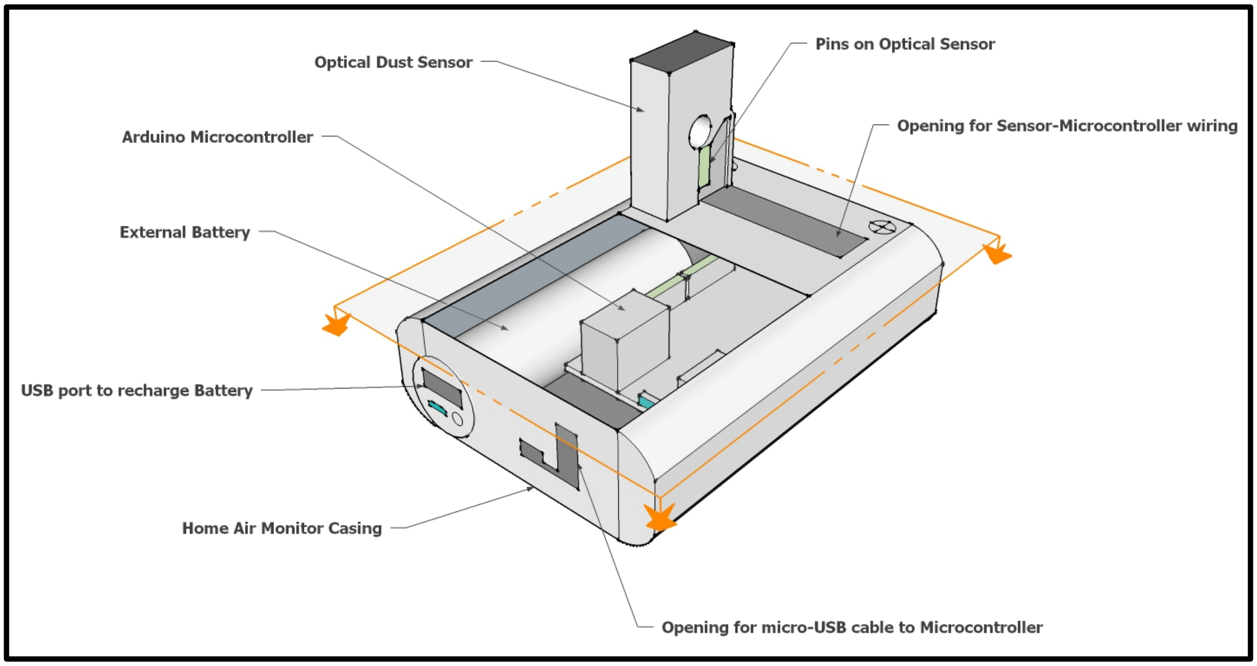

Figure 6: Section View of the Home Air Monitor

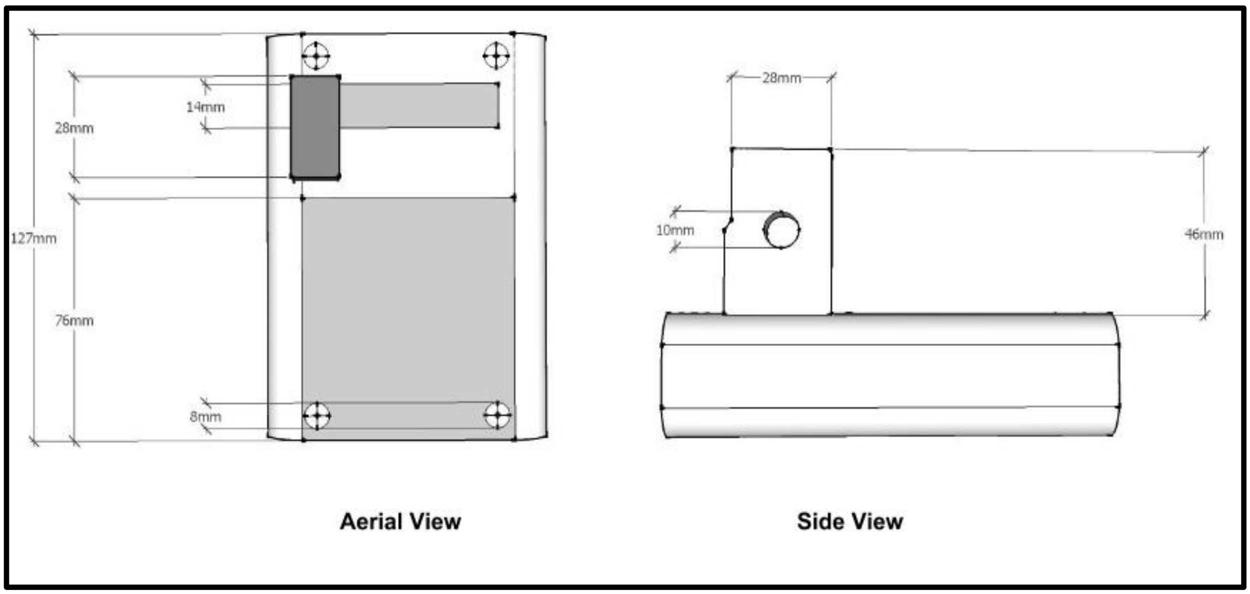

Figure 7: Dimensions of the Home Air Monitor

3.2 Circuitry and Connections

To connect the Arduino and ODS together, a PCB will be used to connect ports, as well as hold the necessary resistor and capacitor. The PCB will be made from scratch using a copper board etched with the circuitry shown in Figure 7. The circuitry used in the PCB requires the use of a 150 ohm resistor and a 220 microfarad capacitor based off of the specification found in the ODS datasheet [5].

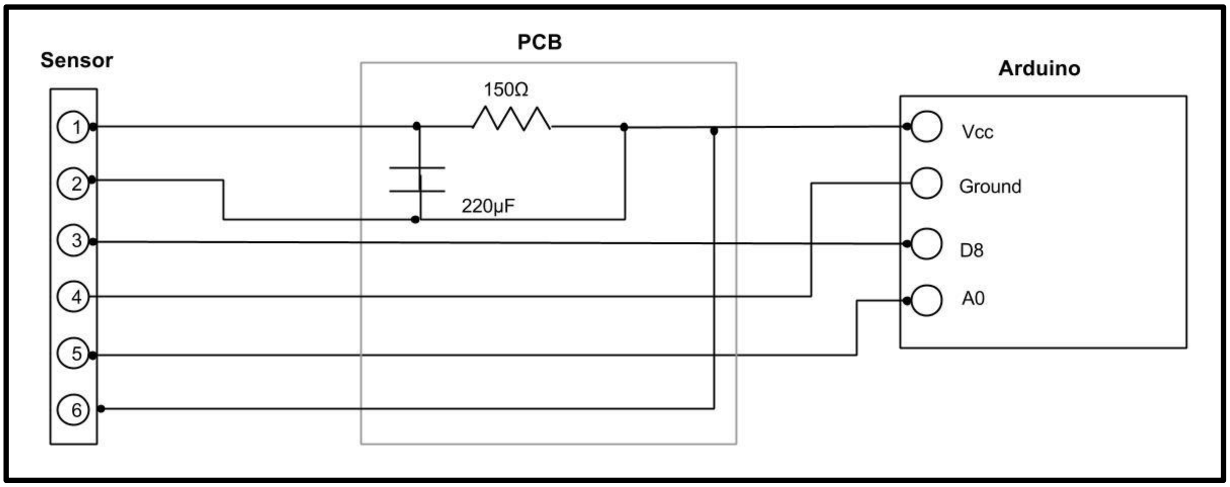

Figure 8: Proposed circuit connection between ODS and Arduino YUN

3.3 Performance Evaluation

In evaluating the performance of the ODS to meet operating requirements, the ODS will need to be able to remain functional for a long period of time given a 5V input voltage. The current used in the ODS will be limited to 11-20 mA as shown in Table 2.

4. Optical Dust Sensor Specifications

The sensor we chose to use for this project was the Sharp GP2Y1010AU0F ODS. This air quality sensor functions by using an infrared emitting diode, which detects the reflected light of dust in the air with a diagonally positioned phototransistor. From the documentation on this sensor, we can see that it is effective in detecting dust particles, as well as very fine particles such as cigarette smoke, and pollutants, which makes it a perfect fit for our purposes. [5] Figure 9 below shows the sensor from the top view and diagonal view. The particles pass through the large center hole, and are detected as they cross through the beam emitted by the light emitting diode.

Figure 9: Top and diagonal view of Sharp ODS [4]

4.1 Characteristics and Features

The ODS is a compact system that measures 46.0 x 30.0 X 17.6 mm in size. It also has a low current consumption, and can be powered with up to 7 VDC. These values, along with pertinent ratings are outlined below in Table 1: Absolute maximum ratings for Dust Sensor, and also in Table 2: Electro Optical characteristics for Dust Sensor. [5]

Table 1: Absolute Maximum Ratings for Dust Sensor at $T_a = 25\,{\circ}C$

Parameter	**Symbol**	**Rating**	**Unit**
Supply Voltage	V_{cc}	-0.3 to + 7	*V*
Input terminal voltage (Open drain drive input)	V_{LED}	-0.3 to V_{cc}	*V*
Operating temperature	T_{opt}	-10 to +65	$\circ C$
Soldering temperature	T_{sod}	-20 to +80	$\circ C$

*Table 2: Electro Optical characteristics for Dust Sensor at T_a = 25 ∘ **C** and V_{cc} = 5V:*

Parameter	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
Sensitivity	K	*1*2*3	0.35	0.5	0.65	V/(0.1mg/m^3)
Output voltage (No Dust)	V_{OC}	*2*3	0	0.9	1.5	V
Output voltage range	V_{OH}	*2*3 R_L $4.7%	3.4	-	-	V
LED terminal current	V_{LED}	*2 LED terminal voltage = 0	-	10	20	mA
Consumption current	I_{CC}	*2R_L = infinity	-	11	20	mA

*1 Sensitivity is specified by the amount of output voltage change when dust density changes by 0.1 mg/m^3.
*2 Input condition is followed as per data sheets
*3 Output sampling timing is followed as per data sheet

4.2 Motivation of Use

The Sharp ODS was chosen due to it's sleek design and consistency with our compact HAM concept. The sensitivity was high, allowing the sensor to monitor pollutants and smoke in addition to dust. Furthermore, the data sheet provided enough details that we knew it would be compatible with the Arduino as well. The cost of one sensor was approximately $12 CDN, which followed our requirements of creating a cost effective solution to a cleaner living space. This also allowed us to buy multiple sensors at a reasonable cost for testing purposes, and to prepare for future development stages where our system will be compatible with multiple sensors.

5. Wireless Communication

5.1 Background

A key aspect of HAM is the communication of the hardware component with a mobile application. Through research, we knew that a networked communication between the two needed to be created. To accomplish this in our system we set up the microcontroller with a TCP server so that it may send and receive data. On the application, a connection is made to the TCP server via the IP address of the Arduino. Using the REST call method of sending and receiving data via specific URLs, we are able to transmit and receive pin data between the microcontroller and mobile application, which is a built-in part of the Arduino. It uses an existing Arduino "Bridge" library to transmit information from the 32U4 processor, which is where the analog data is processed, to the Linino AR9331 processor where information that needs to be transmitted over WiFi is processed, as illustrated below in Figure 10.

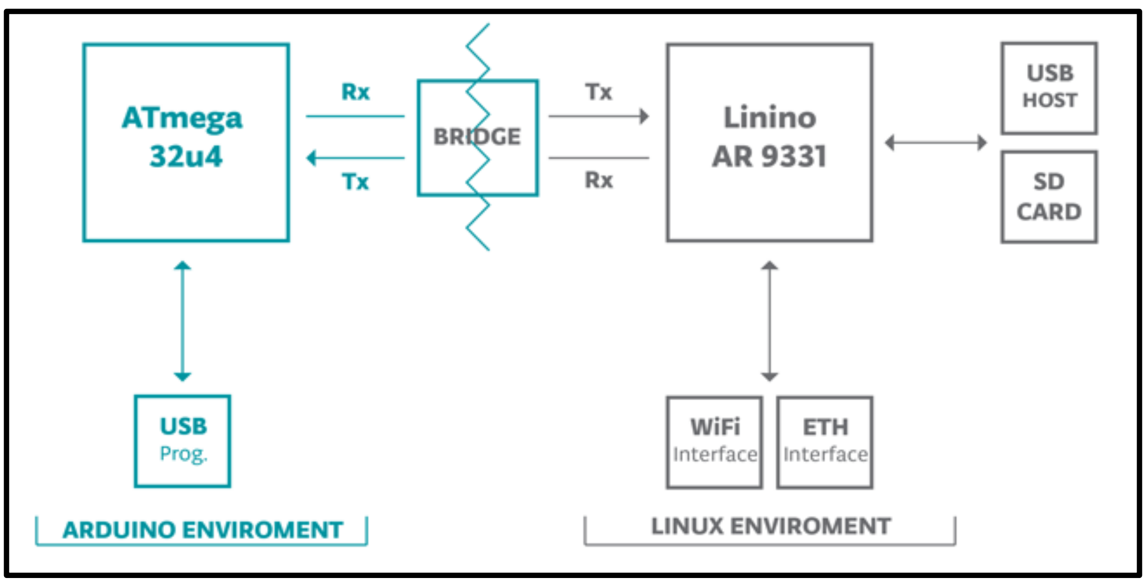

Figure 10: Diagram of Bridge Library communication

5.2 Motivations for this Method

We decided on this method of communication because it is the most convenient for what we want for our system. The transfer of information is direct and occurs in a recognized network. By using this method we are able to initiate data acquisition on the microcontroller from the mobile application end of the system. We are also periodically polling the sensor data so that it is not constantly queuing up data to send to the mobile application. This reduces the amount of time connection needs to be open, which conserves the battery of the hardware portion of the system.

6. Mobile Application

The software aspect of HAM lies in the development of a mobile application that can alert users when an area falls below an ideal clean threshold, display specific details about connected optical sensors, and also provide control features such as changing the sensor name and adjusting the size of a sample area. If time should permit, more features will be added such as the ability to add new sensors to the microcontroller to monitor different areas, as well as camera and picture saving functionality so the user can remember where the system was installed. Figure 11 below represents the general navigation between different activities within the mobile application.

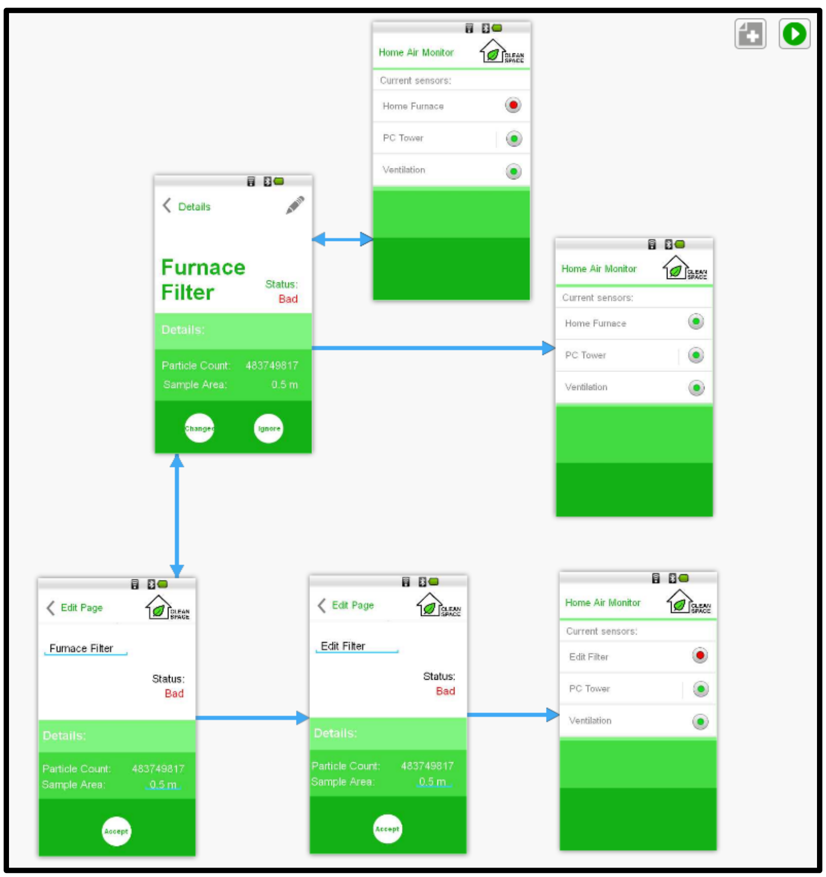

Figure 11: General navigation between Home, Details, and Edit page on mobile application

6.1 Background and Motivation

Mobile phones have become a staple in our society, and is often with the owner at all times. The purpose of our project was to provide alerts to a user about cleanliness in areas less frequented, so a clear solution was to provide these alerts on an interactive device that the user already utilizes. Creating a mobile application allows the user to have more control over the system, and also accentuates the flexibility and usability of our system. Furthermore, for our prototype we decided to use the Android development platform as it provided many customizing options and we were able to find sufficient documentation.

6.2 User Interface

Throughout the design of the user interface, cleanliness and simplicity were key factors that were considered. Having a minimal amount of pages to display the maximum information was achieved by thorough prototyping and research on common application design processes. With the flow chart diagram from Figure 4 in mind, the following designs have been created on Fluidui for displaying particle data and sensor statuses on the mobile application. [6] Our three main pages in this application include the Main page to display all sensors connected to the system, the Details page to show specific details of one sensor, and the Edit page to allow users to change certain fields about the sensors. In Figure 12, the navigation between the Main page and Details can be seen. Selecting a sensor, will open up the details page, and navigating back to the main page is also possible by clicking the up carat on the action bar.

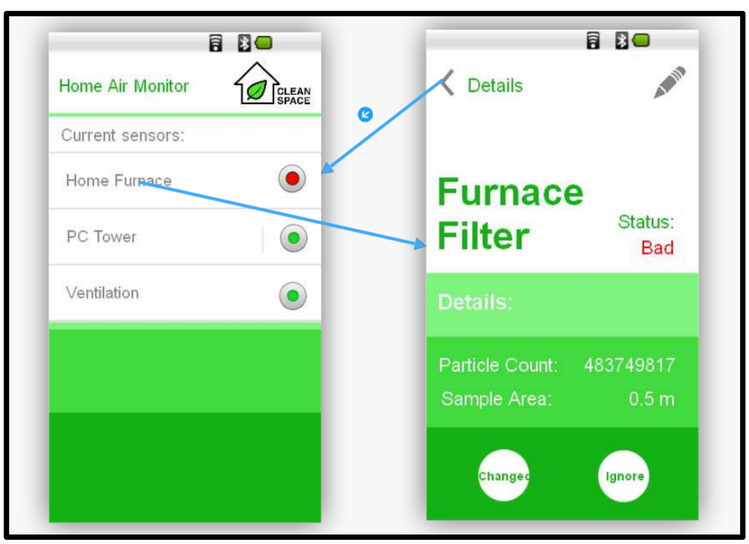

Figure 12: Navigation between Main page to Sensor Details page.

If the sensor data falls below the set threshold, the sensor status would appear in red, and it would also be listed in the details page as "Bad". In Figure 13, we can see that users then have the option of ignoring the warning, or mark the filter as "Changed", which would reset the sensor status to be green.

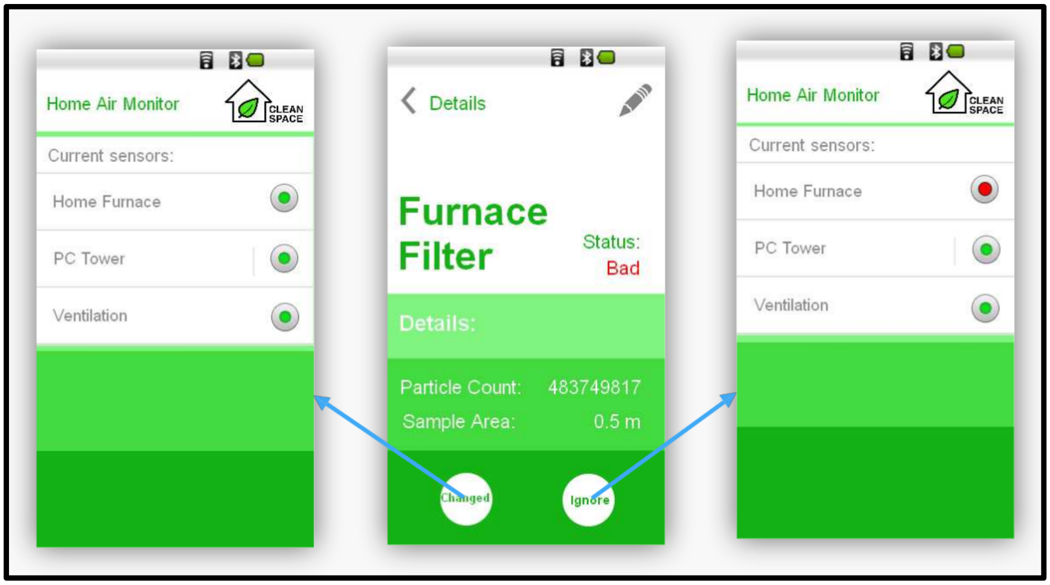

Figure 13: Effects of selecting "Ignore" or "Changed" on the Details page

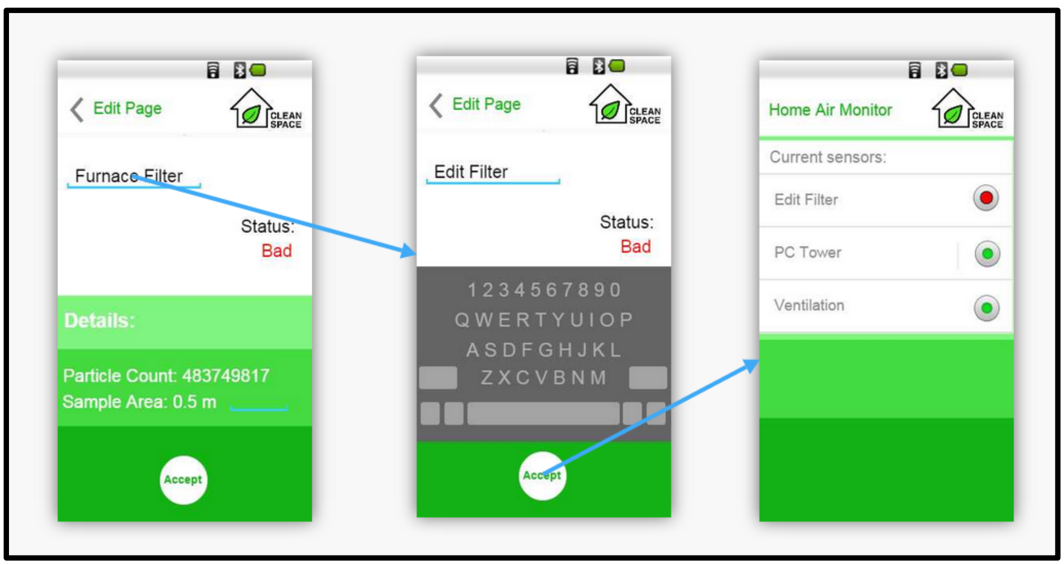

Figure 14: Edit page functionality and navigation

Finally, the Edit page can be reached by selecting the pencil icon on the Details page. This page will allow the user to only change the filter name, or the sample area that the sensor is in as seen in Figure 14. The filter status cannot be edited to avoid tampering with accurate reporting.

7. Microcontroller

The microcontroller used for the Home Air Monitor will be the Arduino Yun which is capable of transmitting a WiFi network. Table 3: AVR Arduino Microcontroller Specifications shows the specifications of the microcontroller and figure 10 further illustrates the schematic of the microcontroller. The HAM will be using a total of 4 pins from the Arduino a 5V VCC, one digital pin, one analog pin, and one pin for grounding.

Table 3: AVR Arduino Microcontroller Specifications [7]:

AVR Arduino Microcontroller	Values
Microcontroller	ATmega32u4
Operating Voltage	5V
Input Voltage	5V
Digital I/O Pins	20
PWM Channels	7
Analog Input Channels	12
Clock Speed	16MHz
Flash Memory	32 KB
SRAM	2.5 KB
EEPROM	1 KB

Table 4 outlines the specifications of the Linux microprocessor and the WiFi capabilities of the device. The ODS will be operated by the 3.3V generated by the Arduino and return data to the analog pins of the Arduino for processing. The WiFi used in the HAM will be using 802.11 b/g/n standards and will be able to communicate with a mobile application through the local WiFi network.

Table 4: Linux Microprocessor Specifications [7]:

Linux Microprocessor	Values
Processor	Atheros AR9331
Architecture	MIPS @400MHz
Operating Voltage	3.3V
Ethernet	IEEE 802.3 10/100Mbit/s
WiFi	IEEE 802.11 b/g/n
USB Type-A	2.0 Host
Card Reader	Micro-SD only
Flash Memory	16 MB
RAM	64 MB DDR2

8. Power Unit

The battery that we decided to use to power the microcontroller is the Anker Astro Mini. We selected it because of the size restriction of our system. The battery needs to fit within an enclosure that we have decided to use for our system. The Anker Astro Mini is a 3000 mAh battery, with enough voltage output to power the Arduino and sensor.

8.1 Characteristics and Features

The Anker Astro Mini is 3.5 x 0.9 x 0.9 inches and cylindrical, which is the appropriate size to fit within the chose enclosure of our system. It consists of Samsung Grade A cells and holds 3000 mAh, which is ideal for charging cell phones, as well as optimal for the power source of our system. As our system is relatively low power, the charge of the battery will be sufficient for our system.

9. System Test Plan

9.1 Unit Test plans for each component

Sensor

- Test functionality by providing sensor with a stable voltage of 5V-7V, see if sensor is able to turn on, use DMM to test if voltage applied is in required range.
- Connect six sensor wires to PCB as documented in data sheet, ensure all wires have a good connection.

Microcontroller Testing:

- Supply a stable voltage of 5V through microcontroller using an external power adapter, use DMM to test if voltage applied is in required range.
- Test functionality of ground and 5V output pins on microcontroller with DMM.
- Confirm analog A0 pin and digital D8 pin are working by sending High and Low signals to each. (These will be the ones used by the sensor)
- Confirm that the two pins are able to output a 5 V voltage, and a maximum of 40 mA when stable.
- Verify WiFi capability of microcontroller by demonstrating connection to Arduino program through WiFi.
- Ensure written code on the Arduino Software Program for HAM is clean and concise. Compile and load time should be less than 30 seconds.

Communication

- Ensure WiFi network that the microcontroller and mobile device will be connected to is stable and open.
- Add microcontroller and mobile device to the network separately; ensure that communication is possible.
- Test server setup on microcontroller by running Arduino Bridge setup code in the Arduino IDE and checking for data on a specific Arduino pin denoted in Arduino code using terminal software such as telnet or Hyperterminal.
- Test network communication on mobile application by calling REST style URL calls to a specific pin to get data

Mobile Application

- Ensure written code on Android ADT can compile and be loaded onto devices with API 19 or higher.
- Mobile application should not take up large amounts of memory on mobile device.

- Mobile application should be able to launch and close without leaving any background processes.
- All pages on mobile application should flow logically with clear navigation buttons. User should not have difficulty reaching the three main pages which are the Main, Edit, and Details page.
- Clean Space logo can be seen in place of default Android app logo.

9.2 Integrated Test Plans

Upon completion of testing the individual components, the integrated test plan will be executed in a room temperature environment to simulate a normal living space.

The first part of the integrated test will involve just the sensor and microcontroller. Testing just these two components will ensure that the sensor is accurately returning the results needed for further calculations to the microcontroller. Here, we will be able to experiment with the sensor sensitivity, as well as calculate the threshold for an ideal living space.

The second part of the integrated test will involve the communication between the microcontroller and our mobile application. Testing the two way communication between the server and sockets is crucial since we want to allow the user to control the system from their mobile device.

Finally, the full system will be tested in a test tunnel similar to Figure 15. A furnace filter screen will be placed in the middle of the open tunnel to simulate a household filtration system. Air will flow freely through the tunnel, and HAM will be placed on the side of the tunnel that should contained filtered air. On the software side, when the returned data passes the threshold, an alert should be sent to the mobile application. The user should then be able to interact with HAM by informing the system when a filter has been changed. Throughout the testing process, several filter screens will be used, all with varying levels of dirtiness. This will provide a realistic simulation of a filter screen at various points of its usage life.

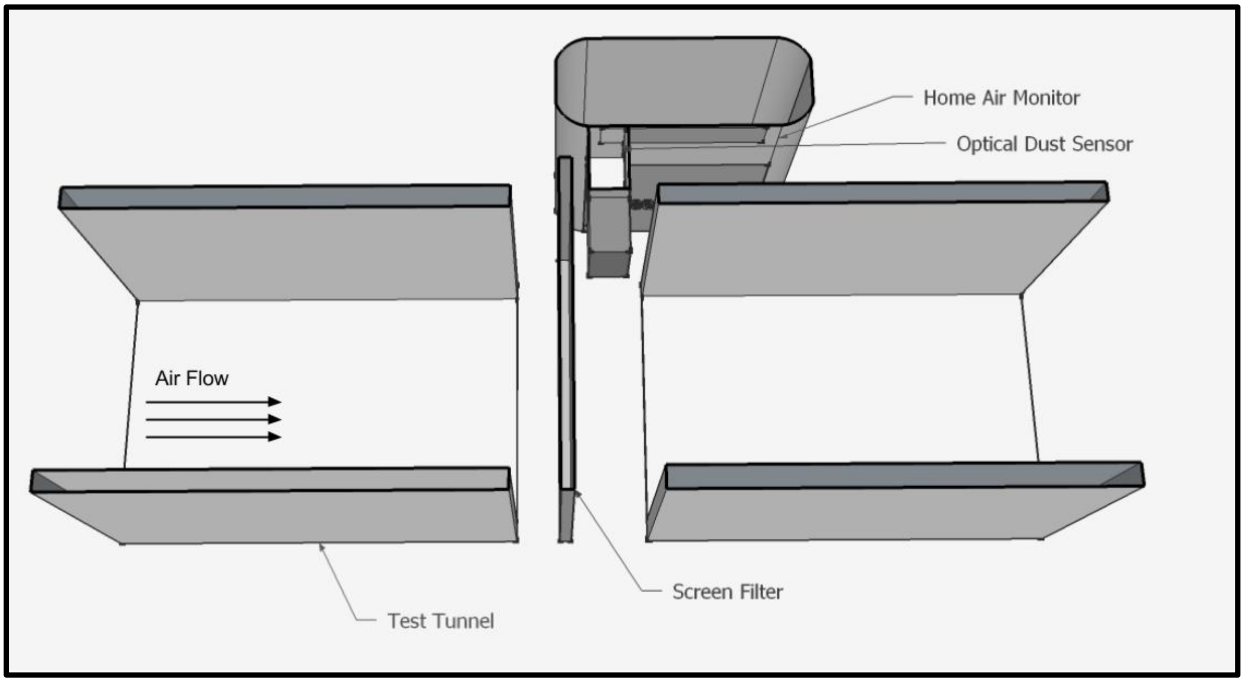

Figure 15: Test tunnel for fully integrated testing

10. Conclusion

The design choices outlined in our design specification will help *Clean Space* bring a portable, easy-to-use system to homes to help monitor pollutant levels. Among the existing alternatives to improving air quality at home such as air purifiers, HAM will provide a more economical and proactive approach to improve the air we come into contact with on a day-to-day basis.

Our decisions to use an Arduino Yun, Sharp ODS, and mobile application take into account affordability, convenience and portability. The design specifications in this document include specific details of each component, their compatibility, along with justification for why they were chosen. *Clean Space* is dedicated to helping people achieve healthier homes and is excited to demonstrate the benefits of our Home Air Monitor system.

11. References

[1] Health Canada, (2009). *Environmental and Workplace Health - Asthma*. [Online] Available: http://www.hc-sc.gc.ca/ewh-semt/air/in/qual/asthm-eng.php

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