**IoT Connected Devices**

Final Formal Proposal

C40: Courtney Connery, Noel Lopez, Clayton Armbrust,

Changyan Liu, Brandon Guerrero

**Sponsor**: Direct Supply

**Sponsor Advisor**: Kent Newbury

**Advisor**: Dr. Chandana Tamma

May 2017

**Table of Contents**

1. Executive Summary…………………………………………………………..3

2. Project Overview……………………………………………………………..3

3. Customer Needs………………………………………………………………3

4. Product Component Overview……………………………………………….7

5. Justification of Design……………………………………………………..…8

6. Experimental Verification……………………………………………………9

7. Issues and Standards…………………………………………………………20

8. Economic Analysis……………………………………………………..……21

9. Risk Assessment……………………………………………………………..23

10. Project Legacy……………………………………………………………...24

11. Conclusion………………………………………………………………….25

12. References………………………………………………………………….25

13. Appendix……………………………………………………………………26

1. **Executive Summary**

The purpose of this document is to present the final design of the IoT Connected Devices smart hub. The document encompasses the entirety of the project focusing mainly on final design decisions. An economic analysis and verification testing were done to show how the final design meets customer needs.

1. **Project** **Overview**

2.1 Objective Statement

The goal of this project was to develop a smart hub capable of collecting Bluetooth data from any medical device, regardless of the company brand. The smart hub would act as a central location for accessing patient data. Direct Supply sponsored the team and give them a budget of $500 to create such a hub for the elder care community. This hub could make health information more accessible for patients and healthcare professionals.

2.2 Background

The Internet of Things, or IoT, is a growing topic amongst technology companies and consumers. A basic definition of IoT is the connection of a Bluetooth or WiFi device to the Internet. The growth of IoT has resulted in the rise of smart hubs. Some of the most common are Google Home, Amazon Echo, and Samsung SmartThings. Smart hubs have just recently spread to the health tech industry. A majority of these health companies make hubs in the form of mobile applications solely for their own products, so consumers are left to buy devices from just that brand. This becomes an issue when a company does not manufacture a desired device. Consumers then must look to other companies for that device, and thus have a smart hub that does not collect all their data.

**3. Customer Needs**

3.1 Target Audience

Health care professionals and the elderly are our two main customers that would benefit from this device. It is necessary to address both groups since the smart hub will serve different purposes for each respective customer. For example, a health care professional may want the product to have simple connectivity features and a friendly user interface that allows for uploading and analyzing of the medical data. On the other hand, a senior citizen may want the device to be easy to interact with while having their medical data protected.

With the help of our sponsor, Direct Supply, the team gained access and insight into both customer subgroups. It was concluded that we had sufficient guidance and understanding of medical workers, but lacked some necessary information on the seniors themselves. The team decided to conduct a survey with the respondents being around 70+ years old. Throughout the document, we used the results from that survey and two other online surveys to make conclusions about the customer needs for seniors. These results are listed in Appendix A.

3.2 Breakdown of Customer Needs

The following charts and information split the previously identified customers into two different groups. The medical professional needs will be discussed, and the senior citizen needs will follow.

3.2.1 Medical Professional Needs

Table 3.1 provides a list of potential customer needs with their respective priority. Further discussion of these can be found in Appendix B.

|  |  |  |  |
| --- | --- | --- | --- |
| Need # | Customer Need | Importance (1-3, where 1 is lowest and 3 is highest) | Notes |
| **1A** | **Device Provides Connectivity to Medical Devices** | 3 | 1.0 |
| 2A | Connectivity to Blood Pressure Monitors | 3 | 1.0 |
| 3A | Connectivity to Heart Rate Monitors | 3 | 1.1 |
| 4A | Connectivity to Pulse Oximeter | 3 | 1.2 |
| 5A | Connectivity to Scale | 3 | 1.0 |
| 6A | Connectivity to Activity Trackers | 1 | 1.3 |
| **7A** | **Device Displays Useful Information** | 3 | 2.0 |
| 8A | Displays Raw Data in Real Time | 3 | 2.1 |
| 9A | Displays Trend Graphs | 2 | 2.2 |
| 10A | Displays Warnings | 3 | 2.3 |
| 11A | Displays General & Detailed Medical Data | 3 | 2.0, 2.2 |
| 12A | Displays Time, Temperature, etc | 1 | 2.4 |
| **13A** | **Sends Information** | 2 | 3.0 |
| 14A | Sends Warnings & Abnormalities to Medical Professionals | 3 | 3.1 |
| 15A | Sends Weekly or Monthly Logs of Recorded Data | 2 | 3.2 |
| 16A | Sends Information to Family | 1 | 3.3 |
| 17A | Social Media Sharing | 1 | 3.3 |

*Table 3.1* Summary Medical Professional Needs with Priority Rating

Analysis

Through our discussions with Direct Supply and our careful consideration, we believe that the medical professionals who use our device care about two main characteristics. First, the medical professionals want the smart hub to have connectivity to medical devices. Without this connectivity, our device is not useful and cannot provide any medical benefit. The second characteristic is the ability to analyze and visualize data through charts, graphs, etc. Examples of this include sending weekly updates on patient’s vitals or sending warning messages due to abnormalities in the medical data. This is just as important as the second characteristic because medical professionals need to be able to analyze the medical data in more innovative and effective ways.

3.2.2 Senior Citizen Needs

Table 3.2 provides a list of potential customer needs with their respective priority. Further discussion of these can be found in Appendix C.

|  |  |  |  |
| --- | --- | --- | --- |
| Need # | Customer Need | Importance (1-3, where 1 is lowest and 3 is highest) | Notes |
| 1B | Device Provides Easy User Interface | 3 | 1.0 |
| 2B | Provides Large Visuals and Text | 3 | 1.1 |
| 3B | Provides Audio Output Capability | 3 | 1.2 |
| 4B | Provides Extensive Manuals and Video Tutorials | 3 | 1.3 |
| 5B | Device Works with Minimal User Interaction | 3 | 2.0 |
| 6B | Updates Medical Information Automatically | 3 | 2.1 |
| 7B | Data Security & Data Representation | 3 | 3.0 |
| 8B | Displays Raw Data in Real Time | 3 | 3.1 |
| 9B | Displays Trend Graphs | 2 | 3.2 |
| 10B | Displays Warnings | 3 | 3.3 |
| 11B | Displays General Medical Data with Detailed Options | 2 | 3.0, 3.2 |
| 12B | Displays Time, Temperature, etc | 2 | 3.4 |
| 13B | Device Sends Useful Information | 3 | 4.0 |
| 14B | Sends Warnings or Abnormalities to Medical Professionals | 3 | 4.1 |
| 15B | Sends Weekly or Monthly Medical Logs of Recorded Data | 3 | 4.2 |
| 16B | Sends Information to Family | 3 | 4.2 |
| 17B | Social Media Sharing | 1 | 4.2 |
| 18B | Affordable & Performant | 3 | 4.3 |

*Table 3.2* Summary of Customer Needs for Senior Citizens with Priority Rating

Analysis

There are two needs that are pertinent to the senior citizens who will use and benefit from the device. The first focuses on their experience with the device and how easy they can operate it. Many people assume senior citizens are not technologically savvy and our survey confirms these results. However, it surprised our group that all the seniors in our survey believe or are at least open to the idea that technology devices could benefit their health. This implies that seniors could be interested in a device like ours. Even those that are not technologically savvy are not opposed to the notion that certain technology devices can improve their health. We concluded that our device must be very easy to operate in order to have a large percentage of seniors want to use it. We concluded further that females may be more interested in our device because of our survey which revealed that female participants take a more proactive approach to their health. Since this device is designed for an elderly person who watches their health on a daily or weekly basis, a female’s proactive approach to health may make them more interested than males. Also, it would be important to include extensive manuals and videos to help seniors understand their devices since their children may not always be able to troubleshoot their problems.

The second need for senior citizens revolves around the data that the device will provide. Direct Supply reminded us of the importance of data security. While senior citizens might not understand technology thoroughly and how much data a device can collect, it is important for our product to have strong data security. Due to their lack of knowledge of technology, it is imperative that our group builds this device securely on their behalf. Also, the data on the smart hub must be easy for them to interpret. A main focus of this product is to allow seniors to have more insight into their health and comprehensible data makes that possible. The text must be large, the screen must be bright, and there should be minimal buttons. The family of the senior citizens may also want access to the data, so it is important for the device to have sharing mechanisms similar to those that medical professionals may want.

3.3 Target Specifications

Table 3.3 lists the target specifications for the IoT smart hub. These specifications were determined based off the customer needs.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Need # | Metrics | Units | Marginal Value | Ideal Value |
| 7A, 14A, 5B | Persons needed to operate | # of People | 4 | 2 |
| 5B | Lifespan for majority of systems | Years | 1-2 | 4-5 |
| 1A, 7A, 13A 6B, 13B | Power Source | Type | Connected to outlet power source at all times | Rechargeable Batteries & Power Source |
| 1B, 5B | Time to setup system | Minutes | <10 | <3-5 |
| 1B, 5B | Battery life per charge | Hours | 5 | 10 |
| 18B | Market Cost | US Dollars | $300-$400 | $150-$300 |
| 1A - 15A, 5B, 7B-15B | Data Storage Length | Months | 1 | 12 |
| 1B, 5B | Feedback Response | Type of Response | Audio/Visual | Tactile + Audio/Visual |
| 1B, 2B | Total device volume | Inches (HxWxD) | 10x7x0.2 | 8x5x0.3 |
| 1B, 2B | Component mass | Pounds | 2 | 1 |

*Table 3.3* Summary of Target Specifications

**4. Product Component Overview**

4.1 Component List

Tables 4.1 and 4.2 contain the list of software and hardware components necessary for the smart hub.

*Table 4.2* Hardware Components

|  |
| --- |
| **Software** |
| Raspbian OS |
| MagicMirror2 |
| BlueZ |
| Various Scripts/Programs |
| Local Database |

|  |
| --- |
| **Hardware** |
| Raspberry Pi 3(with preinstalled OS) |
| Raspberry Pi 7” Touchscreen Display |
| Case for Raspberry Pi 7” Display |

*Table 4.1* Software Components

4.2 Assembly Instructions

The assembly required for the smart hub is broken down into two categories—hardware and software. The hardware must be installed before software.

4.2.1 Hardware Instructions

1. Construct the LCD case and housing as written in the provided instructions from the manufacturer

2. Place Raspberry Pi in the holder on the casing for the LCD screen and plug it into the power slot

3. Connect a ribbon cable from the adapter board connected to the LCD screen to the DSI port on the Raspberry Pi

4. Plug in the LCD screen

5. Power on LCD and Raspberry Pi

4.2.2 Software Instructions

Each software component needs to be downloaded individually onto the Raspberry Pi, except for the Raspbian OS which comes preinstalled on a MicroSD card packaged with the microcontroller. Ideally, if the product were to be distributed, these software programs would be preinstalled on the device or come with a MicroSD card or web link directing to a download page.

**5. Justification of Design**

The final design is based on the decisions made during the concept generation phase. Previous concepts can be viewed in Appendix F.

5.1 Overview of Design

The smart hub is designed with a Raspberry Pi 3 and several open-source software programs. The Raspberry Pi is enclosed in a housing with a touchscreen LCD. To read data packets from a given medical device, an Expect script runs the program BlueZ on the Raspberry Pi. BlueZ is an open-source Bluetooth program that gives information on the nearby Bluetooth devices. The same Expect script then exports that data to a text file that is read in from an original Java program. This program decodes the hexadecimal values into base ten decimal values. Those values are then read into a JavaScript file that displays the information on the screen. MagicMirror2 is another open-source software program that acts as the application for the display, with the use of JavaScript files. The displayed information is sent to a database.

5.2 Design Components and Justification

5.2.1 Displaying Visual Data

The team was tasked with determining what software to use in order to manage and display the data from the medical devices onto the smart hub screen. The team had two main ideas to accomplish this goal. The first idea was to build our own program that could read and display data from each device in a clean and organized matter. The team later found an open-source software, MagicMirror², that did just that. We then had viable solutions to tackle our problem of displaying the customer’s data. On top of the MagicMirror² framework, the node.js and vis.js JavaScript frameworks were needed in order to display the device data on the screen. The MagicMirror² did not have a native implementation for graphing data and interacting with local files that stored the medical data, so those aforementioned frameworks aided with that.

Functional Characteristics and Technical Justification

As mentioned earlier, in order to display the visual data for our customer, the team chose to use MagicMirror². It allows users to add custom “modules” that are then compiled and displayed on the screen. The JavaScript modules are individual files that can be customized for a specific device. This would allow data to be displayed on the screen of the smart hub. It also has a built-in web server so there is no need to install a browser on our microcontroller and with new updates, the configuration of the program will not be lost. Overall, this proved to be the most time efficient solution for data display.

5.2.2 Microcontroller Selection

The microcontroller would act as the central place for devices to connect with. There are several microcontrollers in existence that could be viable solutions for our particular tasks. The team decided to look at three possible microcontrollers as candidates for the creation our product. The possible candidates for our project included the Raspberry Pi 3 Model B, Arduino, and PSoC. All three of these microcontrollers are relatively inexpensive and have a lot of online documentation for the team to reference.

Functional Characteristics and Technical Justification

For connecting and communicating to the IoT devices, the team chose to continue product development with the Raspberry Pi 3 Model B. We chose this microcontroller because not only is it economically viable, but it also has built in Bluetooth and Wi-Fi capabilities. The Raspberry Pi also has an extensive amount of online documentation for custom configurations and plenty of compatibility capabilities with other devices. Our team is also very familiar with Raspberry Pi microcontroller andfound that the Magic Mirror² program was built for the Raspberry Pi, making it an even more viable candidate for our product.

5.2.3 Data Collection

Data collection was the most important task that was focused on by the team. There were two main concepts that the team had to decide between to accomplish this task. The first being Screen Scraping or Data Scraping. With this technique, it would be possible to “scrape” data from a terminal or end user screen to be displayed on the product screen. The next method was to have Bluetooth connectivity with the IoT devices and interpret and display the data being communicated from the devices to our product.

Functional Characteristics and Technical Justification

The best approach was determined to be the general extraction of data from the Bluetooth device. The team researched this approach and found an open-source Bluetooth program, called BlueZ, that allows for data packets sent from a device to be viewed. This would give the team access to the device’s characteristics and attributes, including the health vitals recorded.

In comparison to data scraping, this approach of intercepting packets proved to be practical for its cost. Since BlueZ is open-source, the data can be intercepted for no cost. In contrast, most data scraping programs require payment of an annual fee of several hundred dollars. The cost was the major determining factor for this decision.

5.2.4 Data Storage

Data storage was another important feature to consider. The team had several ideas on how to do this. We could configure the Magic Mirror² platform to write the data being displayed. This would write to a csv file (which can be opened and edited in Excel) which would either be saved locally or emailed to the patient’s caretakers for later viewing. We could also have implemented the use of a database to store and manage the data with SQL programming to store the data in a cloud.

Functional Characteristics and Technical Justification

The team decided that a free local database would be the best solution. The team has worked with both SQL and Excel. Excel ended up taking the least amount of time to setup, and was thus chosen as the current means of storing data.

**6. Experimental Verification**

The following experimental verifications were done to test whether the smart hub currently meets the proposed target specifications listed in Table 3.3.The following sections outline a target specification and address how it was tested, the associated results, and whether this specification was met or not.

6.1 Device Connectivity

The purpose of this experimental procedure is to verify what devices were successfully connected to the smart hub. To look at the connectivity, it is necessary to break down the different stages the device goes through before it is fully connected and sharing data. These stages can be broken down as follows: First, the device must “connect” with the Raspberry Pi. Next, the device must “pair” with the Raspberry Pi, and finally the Raspberry Pi must be able to pick up and read the characteristic packets being sent from the device to the Pi.

6.1.1 Experimental Procedure

1. Run BlueZ via Raspberry Pi terminal

2. Search for the device and run “connect [dev]” command

3. Run “pair [dev]” command with device

4. Run “select-attribute [characteristic]” command

5. Run “notify-on” command

6. Observe the pass/fail messages

6.1.2 Equipment

Raspberry Pi, BlueZ, medical device

6.1.3 Results

The results are listed below in the Table 3.1-1. A common error was detected among the A&D devices which was identified as a failure to retrieve packets. Both devices that failed gave authentication failure errors. This is an issue that would likely be resolved if permission from the company to access their device data was acquired.

6.1.4 Conclusion

The smart hub meets the minimum requirements with device connectivity. One device is fully connected and paired, while two are unable to connect without permission from A&D. These are currently the only devices the team has access to.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Device** | **Connection to**  **Raspberry Pi via**  **Bluetooth** | **Paired via Bluetooth** | **Packet Retrieval** | **Comments** |
| Nonin Pulse Oximeter | Complete | Complete | Complete | Able to view heart rate and % of Oxygen in blood |
| A&D Medical  Deluxe Connected  Weight Scale | Complete | Complete | Incomplete | Will pair and connect but will not allow data attributes to be viewed |
| A&D Medical  Deluxe Blood  Pressure Monitor | Incomplete | Incomplete | Incomplete | Authentication error when trying to pair |

*Table 6.1* Summary of Device Connectivity Results

6.2 Receiving and Displaying Information

The entire smart hub is run using a shell script that calls an Expect script to extrapolate the Bluetooth medical data from the pulse oximeter, which is possible through BlueZ. The Expect Script uses screen scrapping algorithms to gather the information, but the specific medical information needs to be isolated and parsed. Next, the shell script calls a Java program that takes in the entire text file that the Expect script produces and then it exports the converted values to a text file for the display. After this, the shell script calls a JavaScript program that displays the medical data exported from the Java program.

6.2.1 Experimental Procedure

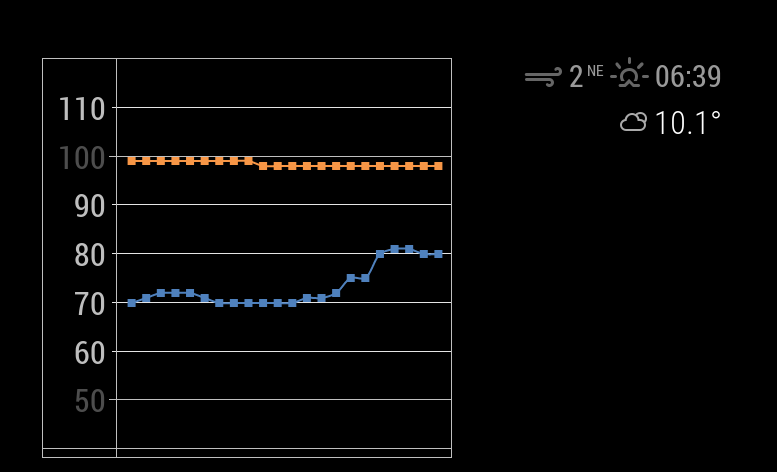
1. Run the smart hub program
2. Observe the information displayed on the user interface

6.2.2 Equipment

Raspberry Pi, BlueZ, Expect Script, Exporting Data Java Program, JavaScript program, Medical Devices, LCD screen

6.2.3 Results

A screenshot of the data displayed on the smart hub is shown below in Figure 6.2. The data points on the screen were compared with the values recorded in the text files to ensure they are truly the values that were recorded and exported to the text files.



*Figure 6.2* Screenshot of the IoT Smart Hub displaying recorded data

6.2.4 Conclusion

By comparing the data points on the screen and the values recorded in the text files, we can verify that the correct measurements are being received and displayed on the MagicMirror2 program from the BlueZ program and text files. With this confirmation, the team verifies that this need is met.

6.3 Useful Information

When a device is connected and in use, a graph is displayed, plotting the data points of the vitals coming from the device. This graph is specific to the Nonin pulse oximeter, and is how we utilize the data in a useful way.

6.3.1 Experimental Procedure

1. Power on smart hub
2. Connect pulse oximeter to the smart hub.
3. Collect data.
4. Examine the data displayed on the smart hub

6.3.2 Equipment

Raspberry Pi, BlueZ, Expect Script, Exporting Data Java Program, JavaScript program, Medical Devices, LCD screen

6.3.3 Results

When the device is connected and in use, the data from the pulse oximeter is plotted on the graph. The graph plots the heart rate and the percentage of oxygen in the blood.

6.3.4 Conclusion

This target specification was met for one device, but could easily be expanded upon if more devices were able to connect.

6.4 User Interaction

The goal for user interaction is to keep it minimal. A caregiver and elderly patient are the ideal users, so it is important that this is something they can both intuitively use.

6.4.1 Experimental Procedure

Have someone not familiar with the equipment walk through the steps of working with the smart hub. The goal will be to gauge the subject’s reaction and thoughts.

1. Subject: turn on the smart hub
2. Subject: turn on medical device
3. Subject: view results
4. Team: record subject’s reaction and observation of the hub

6.4.2 Equipment

Raspberry Pi, Bluez, Expect Script, Exporting Data Java Program, JavaScript program, Medical Devices, LCD screen

6.4.3 Results

The team had a 2 people unfamiliar with the product do a test run. These users both around 20 years of age and do not represent the customer base, but gave the team some feedback regarding the device. The users needed to be walked through the steps of using the hub, since it is not significantly user friendly in its current state. All users were able to successfully run the program and see their vitals from the pulse oximeter. The feedback mainly consisted of a desire for an easier way to start the program. This is something that we will take in consideration and pass on to the legacy team, if applicable.

6.4.4 Conclusion

This need is currently not met.

6.5 Real-Time Display

The purpose of this experiment is to test whether our various processes of gathering, processing, and displaying medical data is fast and efficient. This is important to our customers because synchronous data transfer and data visualization offers a transparent and pleasing customer experience.

6.5.1 Experimental Procedure

1. Connect Bluetooth Device(s) with the smart hub
2. Run MagicMirror2 program
3. Observe display

6.5.2 Equipment

Raspberry Pi, BlueZ, Expect Script, Java Program, Medical Devices, Pen and paper, Javascript File

6.5.3 Results

The data is recorded before it is displayed on the screen, so it is not considered real-time display. The data is shown shortly after the recording.

6.5.4 Conclusion

This need is not currently met.

6.6 Accuracy of Data

The objective of this experiment is to verify that the data being displayed on the smart hub reflects the measurements shown on any of the given IoT devices.

6.6.1 Experimental Procedure

1. Power on smart hub
2. Power on and prepare IoT device for connectivity
3. Run the Shell Script to execute the Expect Script that starts the connection and data recording from the BlueZ program
4. Start recording measurements from device manually as the Expect Script is being executed.
5. Stop manually recording once the Expect Script is finished executing
6. Compare the last 20 seconds of the manually recorded measurements with the measurements displayed on the smart hub
7. Repeat Steps 3-6 several times in order to obtain more measurements to analyze, compare and help reduce human error

6.6.2 Equipment

Raspberry Pi, BlueZ, Expect Script, output.txt , output\_ox.txt, Java Program, Medical Devices, Pen, Paper

6.6.3 Results

The data collected from each iteration (shown in the following table) were recorded using the proposed procedure and the Nonin Pulse Oximeter which records a patient heart rate and oxygen saturation. The accuracy for each iteration of recordings was dependent on the time that the Bluez program was executed and the time that the manual recordings took place.

The first iteration of data, shown in Table 3.7-1, show a very promising result in terms of accuracy. The oxygen saturation recordings between the manual readings and the program readings are 100% accurate. This is not much of a surprise since a person's oxygen saturation levels do not frequently fluctuate. Since a person’s heart rate can change more frequently we expected to have some fluctuation in the readings for both the manual and program recordings. The heart rate recordings only had mismatches for 3 of the 20 seconds that were recorded, giving us an accuracy of about 99.85% which is tolerable.

The second iteration of data, shown in Table 3.7-2, also shows some promising results. The oxygen saturation recordings between the manual readings and the program readings are again 100% accurate. For this iteration, the heart rate recordings had mismatches for 4 of the 20 seconds that were recorded, giving us an accuracy of about 99.80% which again is tolerable.

The third iteration of data, shown in Table 3.7-3, show results similar to the second iteration. The oxygen saturation recordings between the manual readings and the program readings are again 100% accurate. In this last iteration, the heart rate recordings had mismatches for 4 of the 20 seconds that were recorded, giving us an accuracy of about 99.80% which again is tolerable.

6.6.4 Conclusion

With three different iterations of data recording, it is apparent how accurate the readings can be for a given device and how consistent the accuracy is for a given device. The oxygen saturation had 100% accuracy within all three iterations. This is expected since those measurements tend to stay static for a person. Although the heart rate had a few mismatches within each iteration, the overall accuracy did not drop below 99% which can be considered tolerable. A possible reason for the inaccuracies within the heart rate readings could be a syncing issue between the manual recordings and the program recordings. This would be caused by human error since we could not tell for certain when the program began to record the data. The BlueZ program has a few instructions to be executed before it starts recording so it is possible that we were just not recording at the same exact second that the program started recording. Regardless of timing issues, the team knows that the hexadecimal values read from BlueZ match the decimal values exported to the .txt files because simple unit conversions of the numbers will not affect the true values that were recorded and exported. Even with the human error, the data matches with a high enough accuracy and meets the need.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **1st Iteration** | |  | |
| Time (seconds) | Manual Recordings | | Output.txt Recording | |
|  | Heart Rate (BPM) | Oxygen Saturation (%) | Heart Rate (BPM) | Oxygen Saturation (%) |
| 1 | 72 | 97 | 71 | 97 |
| 2 | 71 | 97 | 71 | 97 |
| 3 | 72 | 97 | 72 | 97 |
| 4 | 72 | 97 | 72 | 97 |
| 5 | 72 | 97 | 72 | 97 |
| 6 | 72 | 97 | 72 | 97 |
| 7 | 72 | 97 | 72 | 97 |
| 8 | 72 | 97 | 74 | 97 |
| 9 | 74 | 97 | 74 | 97 |
| 10 | 74 | 97 | 74 | 97 |
| 11 | 74 | 97 | 74 | 97 |
| 12 | 74 | 97 | 74 | 97 |
| 13 | 74 | 97 | 74 | 97 |
| 14 | 74 | 98 | 73 | 98 |
| 15 | 73 | 98 | 73 | 98 |
| 16 | 73 | 98 | 73 | 98 |
| 17 | 74 | 98 | 74 | 98 |
| 18 | 75 | 98 | 75 | 98 |
| 19 | 75 | 98 | 75 | 98 |
| 20 | 75 | 98 | 75 | 98 |

*Table 6.2* Summary of Accuracy of Results 1st Iteration

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **2nd Iteration** | |  | |
| Time (seconds) | Manual Recordings | | Output.txt Recording | |
|  | Heart Rate (BPM) | Oxygen Saturation (%) | Heart Rate (BPM) | Oxygen Saturation (%) |
| 1 | 75 | 97 | 76 | 97 |
| 2 | 76 | 97 | 76 | 97 |
| 3 | 76 | 97 | 76 | 97 |
| 4 | 75 | 97 | 75 | 97 |
| 5 | 75 | 97 | 75 | 97 |
| 6 | 75 | 97 | 76 | 97 |
| 7 | 76 | 97 | 76 | 97 |
| 8 | 78 | 97 | 76 | 97 |
| 9 | 78 | 97 | 78 | 97 |
| 10 | 78 | 97 | 78 | 97 |
| 11 | 78 | 97 | 78 | 97 |
| 12 | 78 | 97 | 78 | 97 |
| 13 | 77 | 97 | 77 | 97 |
| 14 | 78 | 97 | 77 | 97 |
| 15 | 76 | 98 | 76 | 98 |
| 16 | 76 | 98 | 76 | 98 |
| 17 | 76 | 98 | 76 | 98 |
| 18 | 75 | 98 | 75 | 98 |
| 19 | 75 | 98 | 75 | 98 |
| 20 | 75 | 98 | 75 | 98 |

*Table 6.3* Summary of Accuracy of Results 2nd Iteration

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **3rd Iteration** | |  | |
| Time (seconds) | Manual Recordings | | Output.txt Recording | |
|  | Heart Rate (BPM) | Oxygen Saturation (%) | Heart Rate (BPM) | Oxygen Saturation (%) |
| 1 | 71 | 98 | 70 | 98 |
| 2 | 69 | 98 | 69 | 98 |
| 3 | 69 | 98 | 69 | 98 |
| 4 | 69 | 98 | 69 | 98 |
| 5 | 69 | 98 | 69 | 98 |
| 6 | 68 | 98 | 68 | 98 |
| 7 | 67 | 98 | 69 | 98 |
| 8 | 69 | 98 | 69 | 98 |
| 9 | 70 | 98 | 70 | 98 |
| 10 | 71 | 98 | 70 | 98 |
| 11 | 70 | 98 | 70 | 98 |
| 12 | 70 | 98 | 70 | 98 |
| 13 | 70 | 98 | 70 | 98 |
| 14 | 70 | 98 | 71 | 98 |
| 15 | 71 | 98 | 71 | 98 |
| 16 | 71 | 98 | 71 | 98 |
| 17 | 71 | 98 | 71 | 98 |
| 18 | 71 | 98 | 71 | 98 |
| 19 | 72 | 98 | 72 | 98 |
| 20 | 72 | 98 | 72 | 98 |

*Table 6.4* Summary of Accuracy of Results 3rd Iteration

6.7 Data Security

Data security is an extremely important concernt when it comes to IoT and medical devices. It’s worrisome to have personal information just floating around. While we truly understand the importance of security, measures to protect data were not implemented. The team did do research on protection of data, and believe that this is something a legacy team could further address.

One of the main issues is how the devices will constantly generate huge amounts of data, so the need for faster networks will also increase, large storage space will be needed (which most likely would be in the cloud), and finally more bandwidth will be needed to support the growing internet traffic. The current internet protocol (IPv4) also can’t handle the growth of the interconnected devices on the internet. A more stable protocol, such as IPv6, may need to be used. There also isn’t an open ecosystem to host the devices and make them interoperable such as other operating systems that are out right now (Microsoft Windows, Apple iOS, etc.). What we discovered is that vendors are creating private networks for interoperability among their own products but these are incompatible with others.

When it comes to security with IoT there are also several factors that we have to look at such as keeping the millions of devices updated with the latest firmware in order to be free of security bugs. With the large amount of data that the devices will generate, it will be increasingly difficult to identify suspicious traffic over the network. As for the internet protocols, even if IPv6 may be a more stable protocol and has been present for some time now, it’s not near being perfected for such tasks.

While there is no simple answer to solve all these issues, there are some actions that should be taken to overcome these obstacles. There must be an open ecosystem with standardized application programming interfaces that would allow for interoperability with a patching system. Devices must also be hardened with the best intention to protect against security exploits. Finally, the devices must be well protected on the connected networks (intranet and internet).

While the technology is still very young, we can still consider existing ecosystems and see which ones have the best features that would fit our needs. Some of the needs include scalability and the ability to isolate small and elusive devices on a separate network (with virtual local area networks) that is protected by firewalls or with some sort of screening router.

6.7.1 Experimental Procedure

1. Evaluate vulnerable entry points of the software
2. Attempt to “hack” into software and retrieve data

6.7.2 Equipment

Raspberry Pi, BlueZ, Expect Script, Exporting Data Java Program, JavaScript program, Medical Devices, LCD screen

6.7.3 Results

The desired result would be for the hub to be secure with no vulnerable access points. The expected result would be more along the lines of some vulnerable, sealable, access points.

6.7.4 Conclusion

This customer need is currently not met.

6.8 Information Sharing

The objective of this experiment is to verify that the smart hub can allow users to send their recorded data to pre-approved destinations such as to their doctors, caregivers, or relatives. This specification increases the saleability of the product by allowing the users to make less trips to the doctor and have less dependence on their caretakers for assistance

6.8.1 Experimental Procedure

Below would be the testing procedure if this customer need had been implemented:

1. Power on smart hub
2. Enter credentials for approved recipient of data
3. Allow data to be sent either by email or a cloud service or other form of data sharing platform
4. Give access to database or cloud where the data is stored or

6.8.2 Equipment

Raspberry Pi, BlueZ, JavaScript File, LCD Display, Cloud Service or Database

6.8.3 Results

A legacy team would need to implement a well-designed technique for transmitting and aggregating the data for others to analyze. Several techniques have been considered as possible solutions to this specific procedure. One of such is to allow the user to create a mailing list of approved recipients for the data. Those recipients would receive the data via email whenever the user directs the smart hub to send out the data. Another technique that the team has considered is to utilize a database from which multiple entities can access through remote access. Lastly, there is a technique which involves installing a cellular component to the smart hub to connect to a cloud service and store the data. Each process provides possible solutions to meet our customer’s needs but the advantages and drawbacks of each are still being considered to determine the best course of action.

6.8.4 Conclusion

This need has not been met.

6.9 Universality

One of the goals for the smart hub was for a diverse group of devices to be able to connect and share data with the hub. The way the hub is setup requires for the device to be manually set up by a software team. The procedure of grabbing device data involves examination of the packets being sent by a device. Partnership with the device companies would increase the ease of connecting certain devices because the

API’s, data information, and security information would (potentially) be accessible by the team. At this time, the team has not received any constructive or useful information from the device companies.

6.9.1 Experimental Procedure

1. Test multiple devices for connectivity, refer to the Device Connectivity procedure
2. Record if they pass or fail

6.9.2 Equipment

Raspberry Pi, BlueZ, Expect Script, Medical Devices

6.9.3 Results

The results are described in Table 6.5. The Nonin Pulse Oximeter is the only device that is fully implemented and integrated with the hub. Unfortunately, these are the only devices the team currently has access to.

6.9.4 Conclusion

This customer need has not been met. In order to be fulfilled, the implementation of data gathering would have to change, and permissions from device companies would need to be in place in order to gather data from those with security measures.

|  |  |  |
| --- | --- | --- |
| **Device** |  | **Connect and Share** |
| Nonin Pulse Oximeter | Yes |  |
| A&D Medical Deluxe Connected Weight Scale | No |  |
| A&D Medical Deluxe Blood Pressure Monitor | No |  |
| Bed Pad | No |  |

*Table 6.5* Summary of the Universality Testing

**7. Issues and Standards**

7.1 Applicable Standards

There are no official standards that are specific to this project. Although there are resources for reference on Bluetooth, IoT devices, database design, and cyber security, there are currently no IEEE or federal government issued standards to be followed in the creation of the smart hub. The most recent development in IoT standards is currently being drafted by IEEE-SA [1]. Even under the consideration that the smart hub may be categorized as a medical device, “the FDA allows devices to be marketed when there is a reasonable assurance that the benefits to patients outweigh the risks” when implementing cyber security [2]. For these reasons, the standards that this project followed were those set internally by the client and team.

7.2 Regulatory or Safety Issues

Since the smart hub is being developed for Direct Supply and will be intended for communication with medical devices, it may be possible for the product to be classified as a medical device. In this case, the smart hub would have to be regulated by the U.S. Food & Drug Administration [3]. There is little concern of having safety issues with the smart hub that would physically harm a customer because all the hardware implemented in the final design were already finished products that have gone through product development and commercial distribution. Each physical component of the smart hub was designed to work with the other components so the smart hub as a whole would only have safety issues that reflect those of the components implemented.

7.3 Legal Issues

Any legal issues associated with the smart hub would more than likely come from interacting with companies about connectivity and security measures of their respective medical device(s). In order to gain access to that information it may be necessary—at minimum—to sign a Nondisclosure Agreement with said company. Since the team implemented custom code, scripts, and open source programs for the smart hub, it is not probable that any legal issues would arise from the software used in the design of the product.

**8. Economic Analysis**

8.1 Tangible Costs

8.1.1 Product Cost

Preliminary Bill of Materials

|  |  |  |
| --- | --- | --- |
| Component | Cost | Source |
| LoveRPI Raspberry Pi 3 Plug and Play Started Kit | $49.99 | [4] |
| Raspberry Pi 7" Touchscreen Display | $69.99 | [5] |
| Case for the Official Raspberry Pi 7" Touchscreen Display | $27.99 | [6] |
| Software Programs | $0.00 | Open-source or developed by the team |
| Excel (Database) | $0.00 | Local Database |
| **Total** | **$147.97** | |

*Table 8.1* Summary of Component Costs

Reoccurring Expenses

|  |  |
| --- | --- |
| Service | Cost Estimate (Hourly) |
| Developer | $30 x 5 developers\* |
| Maintenance | $30\*\* |
| Estimate Total | $200 |

*Table 8.2* Summary of Reoccurring Costs

\*Assuming the developer works a 5-hour week (same as current team)

\*\* Assuming a 5-hour monthly maintenance reoccurrence

Software Package and Licenses

No software packages or licenses are needed for this product because of the open-source code and the coding languages that this product uses.

Estimated Sales Forecast

Our estimated sales forecast for a year is 1000 units. This assumption will be used in other sections of this Economic Viability section.

Expected Production Process

Currently, the process will require a quick assembly, about 15 minutes, of the Raspberry Pi casing and LCD screen. The process will also require installation of software, which manually would take a few hours. As stated previously, the ideal process would include a software bundle with all the necessary programs, reducing the process time significantly.

Total Project Cost

The formula to calculate the estimate total:

Estimate Total = [(Component Cost \* Number of Units) + Service Cost]/1000 + Profit Margin

|  |  |
| --- | --- |
|  | Units |
| Component Cost | $147.97 |
| Service Cost | $40,800 annually |
| Number of Units Sold | 1000 annually |
| **Breakeven Price** | **$188.77 per unit** |
| Profit Margin | $50.00 per unit |
| **Estimated Total** | **$238.77** |

*Table 8.3* Breakdown of Product Cost

8.2 Tangible Benefits

8.2.1 Cost Savings

Our product’s market is very new and does not have any direct competitors. Since the IoT Market is growing fast and the medical field is a very profitable industry, we expect our product to have competitors very soon. It also would be fairly easy for Samsung to use their SmartThings platform and apply it to our market. SmartThings currently costs $100, but it does not have a display of any kind. This is how Samsung explains their product: “With the free SmartThings app, you can receive important notifications about what's happening at home, control your smart devices with a simple tap, and automate your home to react to your unique preferences”[7]. This is a compelling value proposition, but we believe that our product meets our customer needs at a low price. Our product is also the first of its kind, so that gives our smart hub a competitive advantage.

8.2.2 Added Value

The key difference between our smart hub and Samsung SmartThings is that ours comes with a LCD screen and casing for the Raspberry Pi. These are the main characteristics that factor into our more expensive price. Our product, when compared to Samsung SmartThings, is catered towards the Elder Care market. Our product has no intention to compete with Samsung in the IoT Home market and is specifically catered towards the medical field. This makes our product the only current viable solution in this market, since other competitors have put their focuses into the home. Therefore, our product is beneficial because it satisfies a need that has not been solved yet. This need, as mentioned before, is to utilize new advancements in medical devices to store, display, and analyze health data in one place. This benefits not only the patients who want to understand their health better, but also the health professionals so that they can analyze data more completely and quickly.

8.2.3 Financial Measures

Margin per Unit: $50.00

It is noteworthy that our product will require maintenance costs to update software and modules. While this expense becomes significant for 1,000 units sold, we would charge a service fee. This service fee would be priced to ensure that we would at least break even on each update; we could choose to make a small profit on each update as well.

Breakeven: Fixed Costs/Contribution Margin

Our recurring costs per year totals $40,800 so to breakeven on that, we must sell **816 units** per year. This is calculated by dividing our fixed costs by our margin per unit. To calculate fixed costs, we assume that we incur additional fixed costs besides our recurring costs. These fixed costs could include things like workshop operations and other unforeseen expenses.

**9. Risk Assessment**

9.1 Vulnerable Bluetooth Packets (Data Security)

The Bluetooth packets are free for anyone to see with a device and that is a huge risk especially dealing with medical devices.

**Mitigation**: A database would be the best option to securely have the information stored away with the patient's data.

9.2 Quality of Microcontroller

The smart hub relies heavily on the microcontroller and therefore the quality of it would have to be durable. Parts are constantly evolving and that means they may become more expensive the more durable them become.

**Mitigation**: Since parts are becoming more reliable as time goes by, it would be wise to only upgrade the microcontroller when wanting to connect new devices that aren't supported on the current hub.

9.3 Software Maintenance

With any software development, there are many changes that occur to files or the code itself while updating. Updating software is always a risk. There is always the potential of error.

**Mitigation**: The ideal plan would be to have a repository such as GitHub to make sure that the most updated version of the files and code are used.

9.4 Evolution of Technology

As time goes by, technology is constantly evolving.

**Mitigation:** This risk is inevitable. With proper maintenance and software updates, the product should remain as up to date as possible.

**10. Project Legacy**

While not all target specifications were met, the background knowledge gained has been extremely insightful. In general, there was a lot of investigative work to figure out what goes on “behind the scenes” with Bluetooth communication. The team was able to have a better understanding of how Bluetooth devices worked and how to read Bluetooth packets from the device that was connected. In terms of improvement, we would try to have the data that was gathered to be displayed on our hub in real-time, which was another one of the customer needs that was not able to be met. The biggest factor that played into not being able to have a prototype fully functioning was the limited amount of time and resources given. However, this is still a project that a group in the future would be able to pick up where the team left off and continue to make great strides in making a more complete prototype. The market for IoT for medical devices may be young, but it’s growing and will be relevant in years to come. The biggest aid a future group could have would be medical devices with the appropriate documentation so that the team could get through the security protocols and be able to work consistently with those certain devices.

One of the biggest challenges we faced was figuring out where to begin with the smart hub. As previously mentioned, the market for IoT medical devices is very new, and as a result there was a lack of references. The team often hit a wall when looking at different approaches. Right when it looked like something was figured out, another roadblock appeared and it was time to start from scratch again. The team came to the agreement to create the hub with a microcontroller and a medium sized LCD display comparable to a small tablet. The challenge then was getting the medical devices to connect to the hub, and with each device having its own security protocols, this made it all the more difficult to get them connected. The majority of the devices offered by the sponsor were not able to remain connected to the hub long enough to gather data from them. Fortunately, the pulse oximeter could connect and the team was able to read packets from it. The only difficult part was deciphering the packets coming through since they showed up in hexadecimal values. Like any project, with one accomplishment came another challenge, and that was trying to figure out how to display the data gathered from the pulse oximeter to the display on our hub. With the shell script written, the team was able to read the data, print it to a text file, and then finally display the results on the screen.

Aside from all the technical challenges the team met, one of the biggest general issues was working around each other’s schedule and respective school work. We resorted to meeting once a week during the fall semester in addition to meeting with our advisor every other Friday. During the spring semester, the team made the effort of meeting twice a week and on the weekends when necessary. Meeting up more than once a week alleviated the stress of trying to tackle all of the obstacles had we only met once a week per say. Meetings with our sponsor and advisor throughout the semester also served in settling any doubts and questions that the team had. There were times when team members could not meet together but everyone still did their share of work remotely even if they didn’t attend the meeting.

**11. Conclusion**

The goal of this project was to design a convenient, functional smart hub that allows for centralized visualization and storage of data from IoT medical devices of any brand with a deadline of May 2017 for the team’s sponsor, Direct Supply. The team met a good majority of target specifications, but there is still work to be done. The work done has created a framework for senior design teams to potentially work with in the future.

**12. References**

[1] "IEEE SA - P2413 - Standard For An Architectural Framework For The Internet Of Things (Iot)". *Standards.ieee.org*. N.p., 2017. Web. 4 May 2017.

[2] "Cybersecurity". *Fda.gov*. N.p., 2017. Web. 4 May 2017.

[3] "Overview Of Device Regulation". *Fda.gov*. N.p., 2017. Web. 4 May 2017.

[4] "Amazon.com: LoveRPi Raspberry Pi 3 Plug and Play Starter Kit: Electronics", *Amazon.com*, 2017. [Online]. Available: https://www.amazon.com/LoveRPi-Raspberry-Plug-Play-Starter/dp/B01IYBZEV6/ref=sr\_1\_9?s=electronics&ie=UTF8&qid=1481195416&sr=1-9&keywords=raspberry+pi+kit. [Accessed: 05- May- 2017].

[5] "Amazon.com: Raspberry Pi 7" Touchscreen Display: Electronics", *Amazon.com*, 2017. [Online]. Available: https://www.amazon.com/Raspberry-Pi-7-Touchscreen-Display/dp/B0153R2A9I/ref=sr\_1\_3?s=electronics&ie=UTF8&qid=1491938809&sr=1-3&keywords=raspberry%20pi%20screen. [Accessed: 05- May- 2017].

[6] "Amazon.com: Case for the Official Raspberry Pi 7" Touchscreen Display - Adjustable angle: Computers & Accessories", *Amazon.com*, 2017. [Online]. Available: https://www.amazon.com/Case-Official-Raspberry-Touchscreen-Display/dp/B01HV97F64/ref=pd\_bxgy\_147\_img\_2?\_encoding=UTF8&pd\_rd\_i=B01HV97F64&pd\_rd\_r=GVPVG4VWRS4F7F22DNRR&pd\_rd\_w=wTiod&pd\_rd\_wg=vjfVa&psc=1&refRID=GVPVG4VWRS4F7F22DNRR. [Accessed: 05- May- 2017].

[7]"SmartThings.", *SmartThings.com*, 2017. [Online]. Available: https://www.smartthings.com/. [Accessed: 05- May- 2017].

**13. Appendix**

**A. Customer Survey**

**A.1 Questions**

|  |
| --- |
| **Customer Needs Survey Questions**   1. Are you male or female? 2. Do you own either a smartphone or tablet? 3. On average, how many smart devices do you interact with daily? 4. On a scale from 1-10, how easy is it for you to manage all of your smart devices during your day? 5. On a scale from 1-10, how willing are you to learn how to use a smart product? 6. Please List the smart devices you use, if any, for monitoring aspects of your health. 7. Do your children or friends help you with technology issues? 8. Do you believe technology devices that constantly monitor your health are beneficial? 9. Do you take a reactive or proactive approach to your health? 10. How often do you visit your primary care doctor? |

**A.2**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Participant** | **Q1** | **Q2** | **Q3** | **Q4** | **Q5** | **Q6** | **Q7** | **Q8** | **Q9** | **Q10** |
| #1 | Male | No | 1-2 | 4 | 6 | N/A | Yes | I am not sure | Reactive | Once every few months |
| #2 | Female | Yes | 1-2 | 10 | 10 | iPhone | No | Yes | Proactive | N/A |
| #3 | Female | Yes | 1-2 | 10 | 10 | Android Phone | Yes | Yes | Proactive | Once every few months |
| #4 | Female | Yes | 1-2 | 3 | 6 | N/A | Yes | I am not sure | Reactive | Once every few months |
| #5 | Female | No | 1-2 | 1 | 1 | N/A | Yes | I am not sure | Proactive | Once every few months |
| #6 | Female | Yes | 1-2 | N/A | N/A | N/A | Yes | Yes | Reactive | Once every few months |
| #7 | Female | Yes | 3-5 | 8 | 10 | iPad, Computer | Yes | Yes | Proactive | Once every few months |
| #8 | Female | Yes | 1-2 | 4 | 4 | N/A | Yes | I am sure | Proactive | Once every few months |
| #9 | Female | Yes | 1-2 | 8 | 8 | N/A | Yes | Yes | Proactive | Once every few months |
| #10 | Male | No | N/A | N/A | 1 | N/A | Yes | Yes | Reactive | Once every few months |
| #11 | Male | Yes | 3-5 | 7 | 8 | FitBit | No | I am not sure | Reactive | Once or twice a month |

**B. Notes on Customer Needs for Medical Professionals**

|  |  |
| --- | --- |
| **Note** | **Comments** |
| 1.0 | As mentioned in the Chart Analysis, it is vital that our smart hub provides connectivity to medical devices or else it is not useful at all. Our industry sponsor gave us recommendations on what devices would be useful for our smart Hub to connect to. |
| 1.1 | Heart Rate Monitors would be useful for patients who are under constant supervision due to severe medical conditions. Many Activity Trackers such as FitBits track heart rate, so there is a possible need to get data from those devices as well. |
| 1.2 | Blood oxidation levels measured by a Pulse Oximeter is important to measure since it leads to a variety of elderly diseases. |
| 1.3 | Activity trackers are limited in the useful data that they can provide, but are still important since many consumers use them daily. Their adoption allows for a more consistent data flow, which could be useful to professionals, but is not necessary. |
| 2.0 | Displaying useful information on the smart hub is important so medical professionals will actually use and rely on the Hub. This allows them to see medical data in one central place that is convenient for them. |
| 2.1 | Raw data on the smart hub is important for medical professionals so that they can see multiple medical readings simultaneously one on device. |
| 2.2 | The ability to translate data into graphs is important for the device so medical professionals can quickly interpret medical readings. |
| 2.3 | Displaying warnings on the device is useful for medical professionals so they can differentiate meaningful data from useless data and look further into the meaningful and troublesome data. |
| 2.4 | Displaying non-medical information is not a need for the medical professional, but is a need for the senior citizen. |
| 3.0 | The smart hub will be in a patient’s room, so there is not a strong need for medical professionals to have the data outside of that room. One feature that could be useful is sending updated medical vitals to different doctors and medical professionals that work with the senior citizen. |
| 3.1 | As mentioned before, displaying warnings is very vital for medical professionals that work with senior citizens. If the medical professional is not there, there should be a way to send them the warnings so that they know there is an issue. Email or text updates could be possible implementations for this feature. |
| 3.2 | Weekly or monthly logs of information would be useful for a medical professional to have, but that could be complicated and not an immediate need. |
| 3.3 | The medical professional does not concern themselves with the sharing of this data since it is the senior’s choice. |

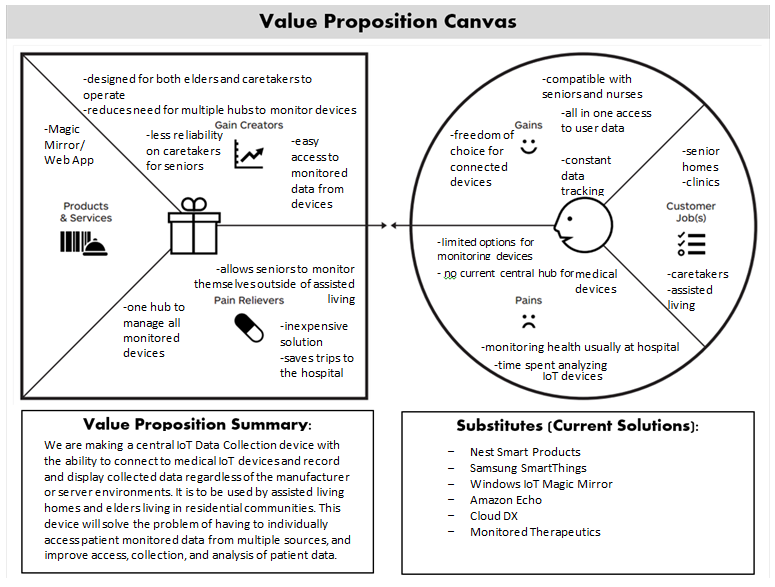
**C. Notes on Customer Needs of Senior Citizens**

|  |  |
| --- | --- |
| **Note** | **Comment** |
| 1.0 | As mentioned in the analysis section, having an easy and responsive user-interface is important for senior citizens due to their general lack of technology exposure. |
| 1.1 | Large text and visuals are important to seniors because it makes the device easier to use since their vision may be worse than those that are younger than them. |
| 1.2 | Audio output is a great feature for seniors who may have impaired vision. |
| 1.3 | Seniors will inevitably encounter issues with the device, so it is important to have resources for them (or their children) to troubleshoot their issue. |
| 2.0 | Relating to the easy user-experience, the device must update its medical data without the senior interacting with the device. Other features such as sending information and displaying warnings must require minimal effort. |
| 2.1 | The smart hub must automatically update the data without requiring any work from the senior. |
| 3.0 | As mentioned in the analysis section, data security is very important even though seniors may not realize it. Also, displaying relevant data is integral to the senior citizens who want to examine their health. |
| 3.1 | Real-time data synchronization will be important so that seniors can visualize their results after tests or vital measurements have been taken. |
| 3.2 | Graphs provide an easy and illustrative way for seniors to comprehend medical data, but could make the smart hub more complicated for them. |
| 3.3 | Displaying health warnings and concerns is important to seniors so that they can notify health professionals and resolve the issues. |
| 3.4 | Since this device will ideally be located in a central location, seniors may find it useful that the device can display general information like time, weather, etc. |
| 4.0 | Sending useful medical information to people is important to seniors so that they can be reassured that family members and doctors are informed about their health. This function should be easy or automated so seniors do not have to learn how to do this on the device. |
| 4.1 | Automatically sending warnings is important to seniors so they know that family members and medical professionals receive the information without manually sending it themselves. |
| 4.2 | Similarly to Note 4.1, seniors value a device that will automatically send weekly or monthly reports to those that they want to share it with. Most likely, they will not want to share this data with people outside of their family or medical caretakers. |
| 4.3 | The device needs to be affordable since many seniors do not know if it is necessary or not. While being affordable, the device needs to be performant and easy to use so that seniors will actually interact with the device. |

**D. Competitive Quantitative Performance**

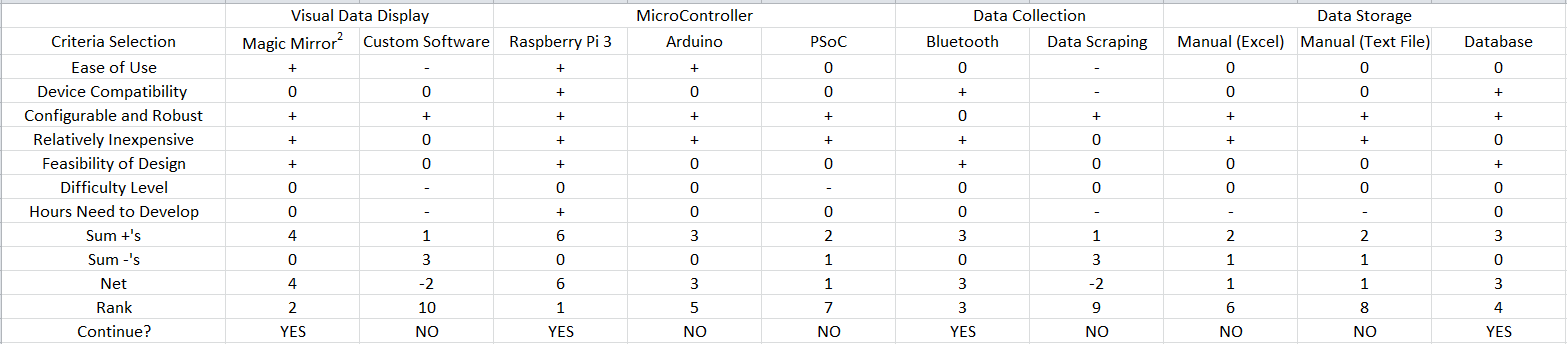
|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Competitor** | **Price** | **# of Connected Devices** | **Special Features** | **Market** |
| Nest | Varies by product (Thermostat $249) | 3 (The number of Nest Products) | Automatic Updates, Simple User-Interface | General Public |
| Samsung SmartThings | $96.03 (2nd generation) | 100+ | Mass Connectivity Options | General Public |
| Amazon Echo | $49.99 - $179.99 | 100+ | Mass Connectivity Options + Alexa Voice | General Public |
| Windows Azure IoT Hub | $50 -$500 per month | Numerous | Works with Multiple Platforms, Open-Source | Smart Homes |
| Windows IoT Magic Mirror | TBD | TBD | Facial Recognition, Windows 10 Compatible, Completely Open-Source | General Public |
| Cloud DX | $500-$600 for complete kit | ~10 | They build their own medical sensors that are connected in a mobile app.. | General Public |
| Google Home | $129 - 179.89 | Numerous | Voice-activated speaker powered by the Google Assistant. | General Public |
| Apple HomeKit | Varies by Device (software included on products) | 100+ | Pre-installed on iOS 10 | General Public |

**E. Value Proposition Canvas**



**F. Concept Screening and Scoring**

**F.1 Screening Matrix**



**F.2 Scoring Matrix**

