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HomeMe
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Abstract

The Amazon Alexa has changed the landscape for smart home technology and how people go about their daily lives. With the invention and improvements of the Amazon Alexa and compatible smart home devices, there is still something missing. That is where the HomeMe system comes into play. The problem with the current smart home device controllers, such as the Amazon Alexa with smart home hub, is these smart home device controllers offer little functionality in how smart home devices are turned on or activated. The two common ways that smart home devices can be enabled is through verbal queues, manual activation via a switch or some sort of power source, or by going into a companion smartphone app. For how brilliant these devices are and how much they improve daily, there is little attention paid to the activation.

The HomeMe system puts together many known and useful technologies in the hope to create a hands free activation and deactivation of smart home devices. The design of the system uses three main hardware components, the bluetooth beacons, an android smartphone, and the Amazon Alexa with smart home hub. The purpose of using bluetooth beacons is to seamlessly track the smartphone's location throughout the space the HomeMe system is set up in. Once the phone's location is tracked the phone is able to activate or deactivate the smart devices affiliated with the phones current position. The smartphone then reports the room that it is in to the Amazon Alexa, and the Alexa activates the smart devices. These hardware pieces are tied together using three different pieces of software for communication between them. The first piece of software is the programming of the bluetooth beacons. The beacons are programmed to be on a wake and sleep interval, after the beacons wake, they search for the phone's unique bluetooth id, and if found they measure and report an RSSI (Received Signal Strength Indicator) value. This RSSI value is then taken in by the phone app to determine which beacon is closest to the phone in order to determine the room. Once the phone app has determined the room, it sends the room information over to the HomeMe Amazon Alexa skill. The HomeMe skill will activate the Alexa command and the room's smart devices will be activated.

The HomeMe system as a whole has not yet been implemented. The HomeMe system has been implemented up to the point where the bluetooth beacon connection is made with the smartphone. The system is looking to be completed by the end of the following semester.

1. Introduction

1.1 Problem Statement and Context

The smart home industry has developed and continues to grow every year. Smart home devices are a part of the ever expanding IoT industry that has come to take over a huge portion of the consumer electronics market. The IoT industry is flooding the market with devices and "is on pace to grow to over $3 trillion annually by 2026"(Insider). With the development of many new smart home and IoT devices, smart home device controllers will be an essential part of the

industry. The HomeMe system is trying to work in conjunction with current smart home device controllers to solve the problems of those smart home device controllers.

The HomeMe system is hoping to solve many small but noticeable shortcomings of modern day smart home IoT devices. The most apparent of those shortcomings is the inability to change the current state of the smart devices without a physical process, whether than is voice actuation or going into a phone app to change the state of the device. The next issue with current smart home device controller's is the inability to switch or manipulate smart home devices given a user's location. For example, if the user of the smart home device controller is upstairs, the current state of the smart lights on the floor below or the room next door should be powered off. Finally the most unique function that a lot of current smart device controllers cannot implement is changing or manipulating smart device states based on the time of day.

Understanding the issues of modern day smart home device controllers, led to the idea for the development of the HomeMe system. The problems affiliated with smart home device controllers can be solved using a series of bluetooth beacons to track the user's position in the home, and an android smartphone app to set up the system and manage the routines for the smart devices.

1.2 Requirement Analysis

In order to create a smart home device controller system, there are many requirements that need to be in place to develop a successful system. To start the system has to meet some requirements that the consumer would like. To create a system that a consumer would like to have installed in their home, the system can not be unreasonably priced. As the system does not include any smart devices, smart device controllers, but is merely an add on to increase functionality of an existing device. Most home automation devices, in which the HomeMe could fit into cost from 271 dollars to 1,485 dollars (HomeAdvisor). Since the HomeMe is not a fully capable home automation system and features limited functionality and devices, the system should be on the lower end of the range. The HomeMe systems parts in total should not cost more than 100 dollars total in order to keep the end product pricing lower. With the development of a lower cost home automation device, comes the installation of the system. The installation of the system needs to be easy in order to keep costs low by not having to hire a professional to install the system adding cost to the system. Given the cost of the system and goal of the system, HomeMe needs to be accurate. The accuracy of the system should be able to identify the location of the user's phone to within a meter. A meter is a good requirement to have on system functionality, because the system has to identify rooms which are generally larger than a couple square meters. Another requirement of the system is that it needs to be power efficient. Power efficiency is more appealing for customers of the system and allows for greater usability of the system. The final requirement is the HomeMe system to be easy to conceal or aesthetically pleasing. If the system is bulky and sticks out, less and less people would like to put the system in their home. If the system is easy to conceal or aesthetically pleasing the system would not be an eyesore.

To produce a system that meets all of the requirements of the consumer, there has to be some required products that HomeMe will not supply but will need to function. In order to produce the best functionality at the lowest cost, the HomeMe is smart home device limited. The HomeMe requires an Amazon Alexa with the smart home device hub. This allows the HomeMe system to only have to communicate with the Amazon Alexa. What all limiting the smart devices to Alexa compatible devices entails is not having to put in more time and labor into programming multiple smart device programs and interfacing the smart devices with the smart device controllers. Another requirement that will allow the time and labor to be lowered is limiting the smartphone to android. Using only the android platform allows for not having to account for programming on different operating systems and the complications associated with that.

List of Requirements

Consumer

- Low Cost
- Easy Installation
- Accurate
- Power Efficient
- Aesthetically Pleasing

Producer

- Amazon Alexa with Smart Home Hub
- Amazon Alexa Compatible Smart Devices
- Android Smartphone

Use Cases

There are many requirements for the system and the functionality of the system. In order to say that the system is working it has to perform given a one room, one smart device, one Alexa, one phone, one bluetooth beacon system. Figure 1, illustrates the set up of a system that the HomeMe is required to work for. Figure 2, represents the first use case of the system. The first use case is for the user to enter the room with the smartphone on them, and activate the smart device in the room. The second use case is illustrated by figure 3. Figure 3, shows that the user exits the room with the smartphone and the device that is currently activated becomes deactivated. The final use case is shown in figure 4. The final use case is a time of day function, this time of day function changes the current state of the smart device given that the user has not exited the room.

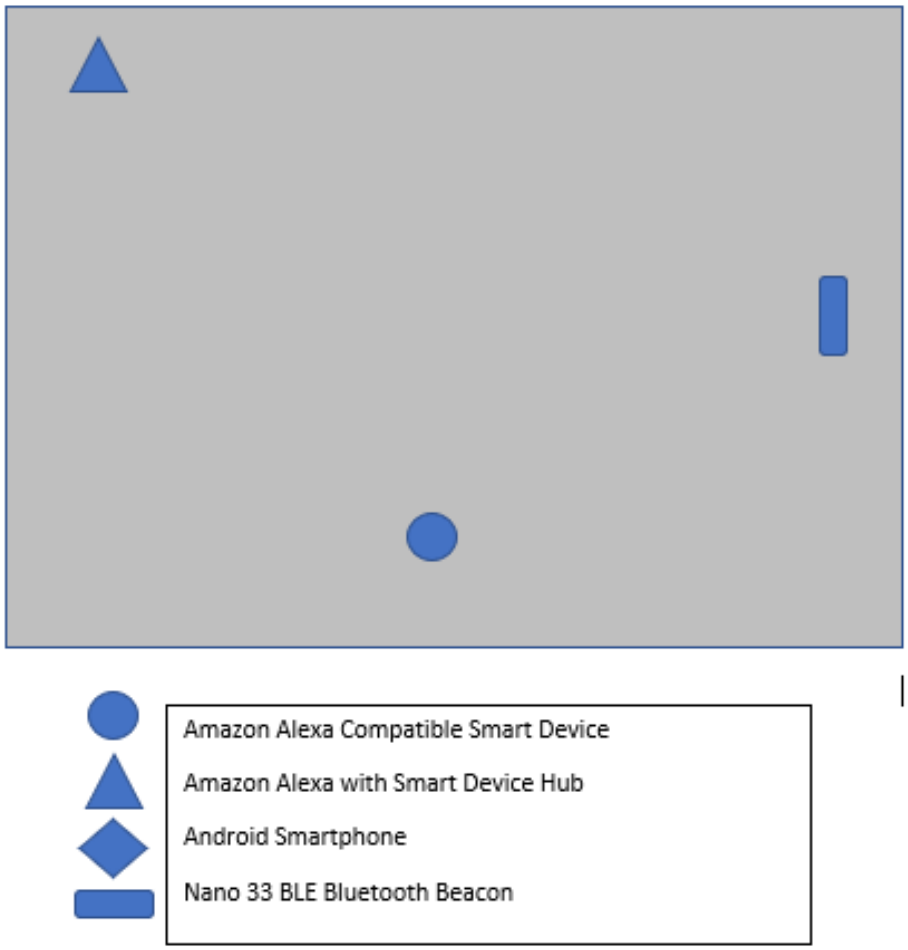

Figure 1: Model of a room with the HomeMe system installed (devices are randomly placed, should have no effect on functionality of this system)

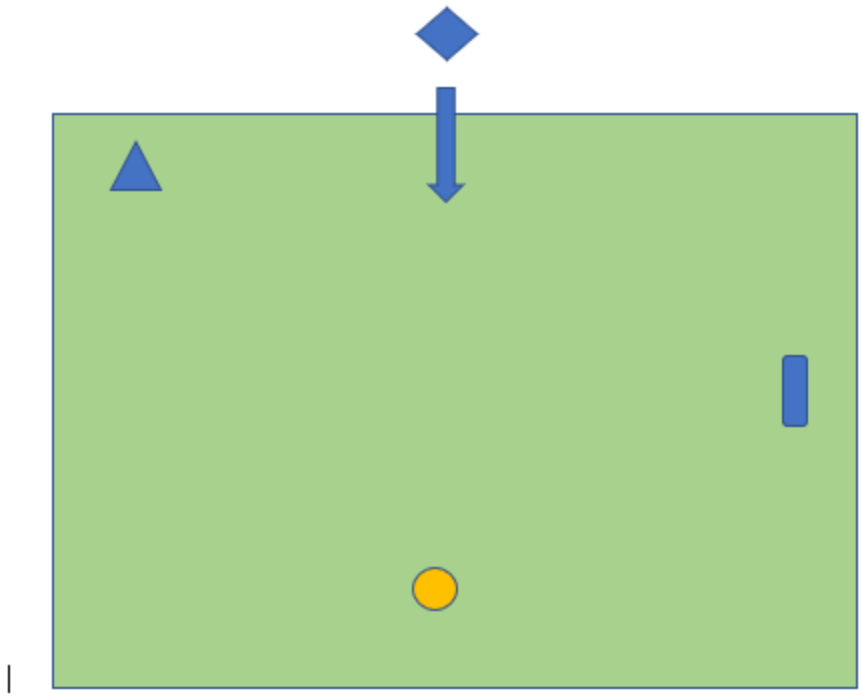

Figure 2: User walks into room containing smart device and triggers the activation of the smart device

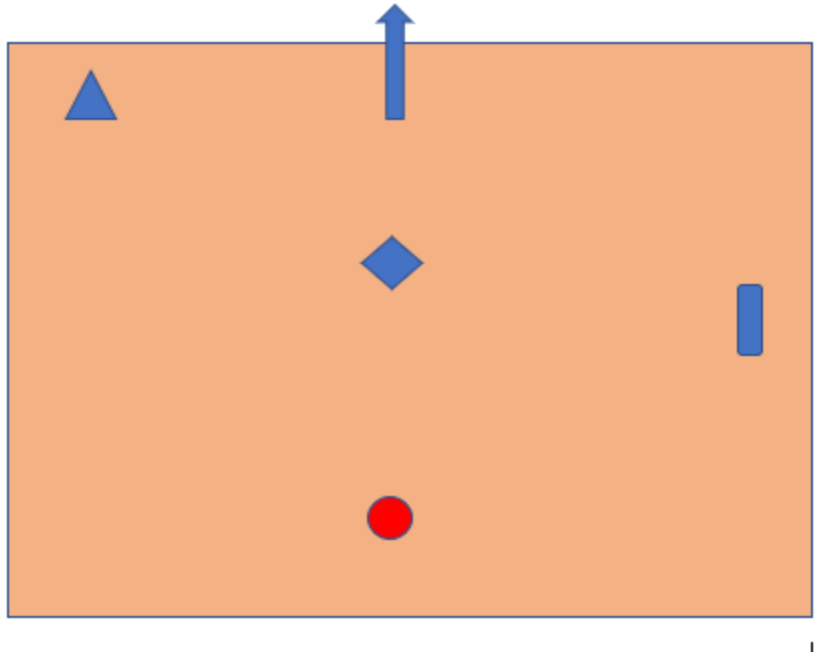

Figure 3: User exits room disabling the current routine in the room

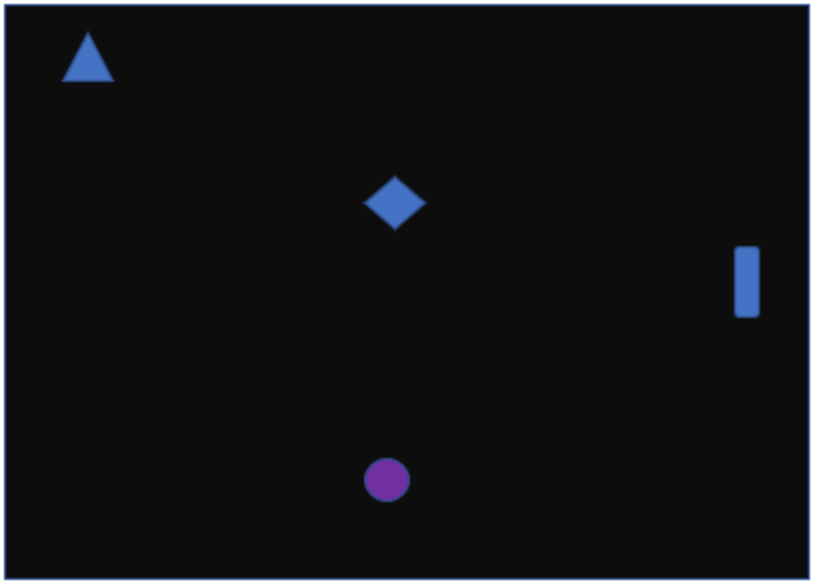

Figure 4: User is in the current room during a certain time period triggering a time day function in which the routine differs

1.3 Important Considerations

There are many concerns and considerations that need to be addressed through the creation of the HomeMe system. The most important considerations to look for are the privacy concerns and allowing the user to opt in to the tracking of their location through bluetooth inside their home. Along with the tracking of their location, it is important to take into consideration that HomeMe will manipulate devices power and use Alexa. The user would have to allow those changes. The system has to be designed and engineered well in order to protect the devices that it takes control over and especially the users phone.

Factor	**Applies to Project Yes/No**	**Brief Discussion**
Public Health	No	The user's and public health in general is not affected by the device
Privacy	Yes	The device could be hacked gaining information on a user's home
Safety	Yes	The device could allow access to homes smart devices through hacking and

		manipulate them
Welfare	No	Should not affect anyone's welfare
Global	No	Should not have a global impact on anything
Cultural	Yes	Encourages smarter living and energy efficiency if connected properly to turn off smart devices throughout the home
Social	Yes	Encourages smarter living
Environmental	Yes	Can be used to reduce power and electricity, benefits the environment
Economic Factors	Yes	Can be used to reduce power costs

2. Systems Design

2.1 Systems Overview

Components

There are many components that comprise the HomeMe system. The only component that is supplied by the group is the Arduino Nano 33 BLE bluetooth beacons. The beacons are used for the tracking of the users phone and are the reason the system is able to function how it does. The components that are supplied by the user are an Android smartphone with bluetooth 5, an Amazon Alexa with the smart device hub, and Amazon Alexa compatible smart devices.

Bluetooth Beacon

The Arduino Nano 33 BLE was chosen for many reasons relating to the system. As shown in Figure 5, the Arduino Nano 33 BLE has a NINA B306 Bluetooth module which allows for bluetooth 5 capabilities. Bluetooth 5 allows for connectionless indoor tracking that can precisely measure where the user will be located. Another reason the Arduino Nano 33 BLE was chosen is that it has Bluetooth BLE capabilities meaning that operating this device will take less power to operate than traditional bluetooth devices. The small form factor of this device allows for the device to easily be attached to a battery pack and encased in a shell that makes the board more desirable for consumers.

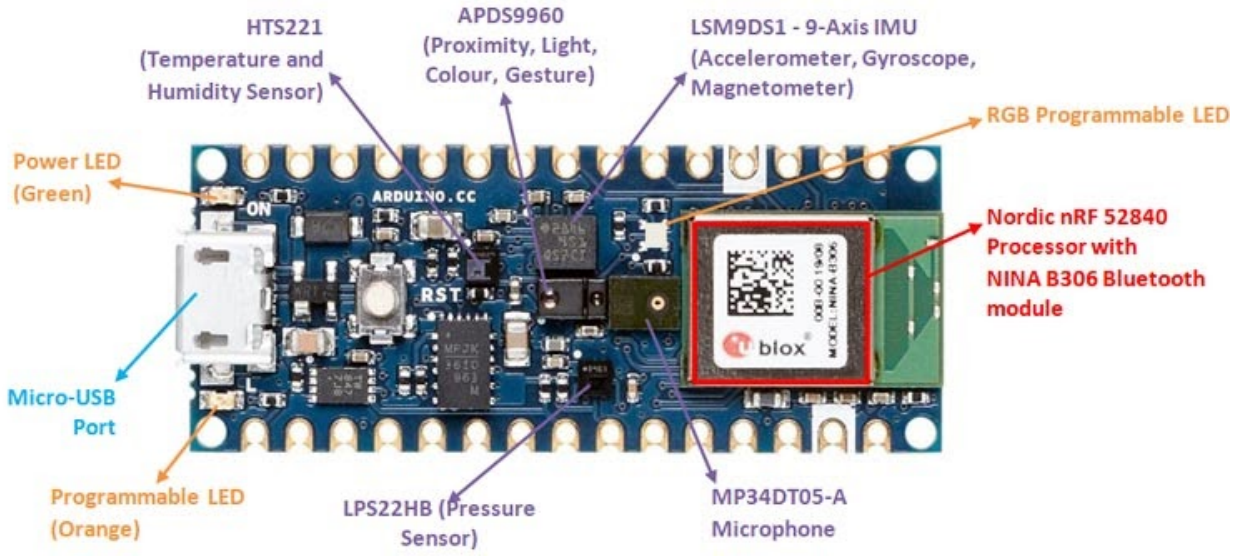

Figure 5. (Raj): FIgure 2 Pictures the Nano 33 BLE Board Hardware Features

Android Smartphone

The Android smartphone was chosen because it is very popular throughout the world and has pre existing functionality for Amazon Alexa through the Amazon Alexa app for android. The android platform was chosen because of the ability to develop on the platform through the C++ and Java languages. Android is the most popular platform in the world for smartphones and has the most development tools for bluetooth BLE technology.

Amazon Alexa

The Amazon Alexa smart home speaker with smart home hub was chosen because it is one of the most popular smart home devices. Along with the Amazon Alexa comes the Amazon Alexa app, which allows you to enable skills, create rooms of smart devices, and create routines for smart devices. The smart home hub technology allows the Amazon Alexa to manipulate the smart home devices.

Alexa Compatible Smart Home Devices

The other hardware involved in the system is the users smart home devices. These devices are required to be Amazon Alexa compatible. These devices can range from bluetooth speakers to light bulbs or even thermostats. Amazon Alexa compatible smart devices are plentiful and offer future proofing through the Amazon Alexa brand.

2.2 Design Alternatives and Constraints

When designing the HomeMe system there are many alternatives that we could choose to implement such as how to power the bluetooth beacon devices, what technology to implement for communication between the phone and beacon, what platform to develop on between android and ios, and lastly implementing time of day modes to perform different functions based on the time of day.

Beacon Powering

The Arduino Nano 33 BLE bluetooth beacons that are used in the HomeMe system operate at 5 volts through their USB input. The fact that they operate at 5 volts through USB leaves two choices for powering the device. The beacon could be powered through the USB via a 5 volt wall adaptor or using a battery pack. If the beacon were to be powered via the wall outlet, the benefit would be that it would not require changing batteries at all. On the other hand the beacon would be limited to certain places in the room, and would possibly require a price increase of approximately 10 dollars for supplying the micro USB cable and 5 volt outlet box. The battery pack would greatly benefit the beacon in terms of where it can be put inside the house. However, the device would require battery changes and if the system is not power efficient it could lead to many battery changes over the course of a short time. The battery powering also comes with the extra cost of the battery pack as well as the USB cable. The battery pack powering is what is planned on being chosen because it allows the user to place the device wherever the user desires and since the beacon is a Bluetooth BLE device the power should be minimal anyways. Bluetooth BLE devices average from 1 to 50 percent power from original Bluetooth technology, meaning if 1 watt is the Bluetooth reference a Bluetooth BLE device would have 0.01 to 0.5 watts of power consumption (wikipedia).

Bluetooth Communication

The main alternative that comes with the system is the bluetooth technology that will be implemented between the user's phone and the bluetooth beacon. The different choices are using the newly developed bluetooth 5 in order to track the user's phone via angle of arrival coding or using the older developments of bluetooth of using polling and Received Signal Strength Indicator values to track the users phone (Gao and Hollander). The bluetooth 5 approach using an angle of arrival measurement requires an array of beacons in order to approximate where the phone will be relative to each beacon (Hollander). This solution would benefit the accuracy of the measurement for tracking purposes. The downside to using the array of beacons is the complexity of not only the coding, but the placement of the beacons inside a user's home. Using the previous generation of bluetooth Received Signal Strength Indicator technology comes with the benefits of not limiting devices that the user can use. Because bluetooth 5 is a newer technology not all android phones will have bluetooth 5. The downsides include not being able to track the location of the phone as accurately and having to implement a polling method that would turn the beacon on and off during a given time period which could be very power inefficient. The bluetooth communication problem is going to be further tested and will be resolved later.

Platform Development

The one design alternative that would be hardest to implement is using android versus ios. Designing a system on ios versus android requires understanding different programming languages to be able to develop on each platform. When developing on ios it requires the developer to use the Swift programming language. When developing on the Android platform the developer can use Java or C++ based on how the developer wants to develop the application. Although Iphones are very prominent in the mobile device market, Android as a platform is the most popular in the world because of its variety of devices and price options ("Android"). Another reason Android seems to be the better choice for developing on are the tool

kits and API's available for Android Studio using Bluetooth BLE technology. The use of these API's and tool kits allow for ease of programming.

External Factors Limiting Design Choices

When developing the HomeMe system the components and design were chosen and accounted for in a specific way to allow for the widest variety of users and devices. The Android platform was chosen in order to allow for the biggest variety of phones to be used and the Amazon Alexa was chosen because it is the most used smart home device. With those choices the system is opened up to the most potential users and consumers. However these choices limit the systems development to only work on certain phones and certain smart home devices. Another limiting factor that comes along with the systems choice of using bluetooth technology over some other technology is that the bluetooth beacons are class 2 bluetooth devices. Class 2 bluetooth devices have a limited range of approximately 33 feet, so if a room were to be larger than 33 feet and the beacon was poorly placed it is possible that the system will not work properly or require multiple beacons to control one room. With most smart home devices the alexa will need to be connected to the internet to allow the routines to be activated by the HomeMe system.

2.3 Engineering Standards

The main concerns with engineering standards of the HomeMe system is with the data privacy. The storing of the data in the HomeMe app will not be sold to any other companies, nor will it be collected . The data that HomeMe has access to will all be stored via the HomeMe app in order to control smart devices. The IEEE privacy policy is not violated by the HomeMe system because it does not misuse the users data in any way (IEEE Privacy Policy). Another issue that will be solved by explicitly stating it when downloading the app is that a state will disclose that the HomeMe system is not liable for the possible breaking of other smart devices while using the product (IEEE Board of Directors). As for safety standards, the HomeMe system is completely safe and will meet all of the IEEE safety guidelines.

2.4 Hardware Design

The Hardware system and design is made up of bluetooth beacons, Arduino Nano 33 BLE devices, an Android smartphone supplied by the user or consumer of the system, an Amazon Alexa with smart hub and Amazon alexa compatible smart devices.

Bluetooth Beacon

The function of the Bluetooth beacon as a hardware device in the system is to use its Bluetooth capabilities to track the android smartphone. As illustrated in figure 6, the line of communication from the beacon is directly to the smartphone. The microprocessor is used to access the bluetooth module

Android Smartphone

The primary function of the android smartphone is to be able to download the HomeMe android companion app. The smartphone must include bluetooth capabilities, bluetooth 5 in particular to give access to bluetooth BLE. The smartphone must have the Amazon Alexa app with the HomeMe skill enabled in order to make changes in routines and rooms. The smartphone will have to be connected to the internet via wifi or cellular in order to make changes to the Alexa.

Amazon Alexa

The Amazon Alexa with smart home hub acts as the communication between it and the smart devices. The Alexa needs to be connected to wifi in order to make changes with all the paired smart devices.

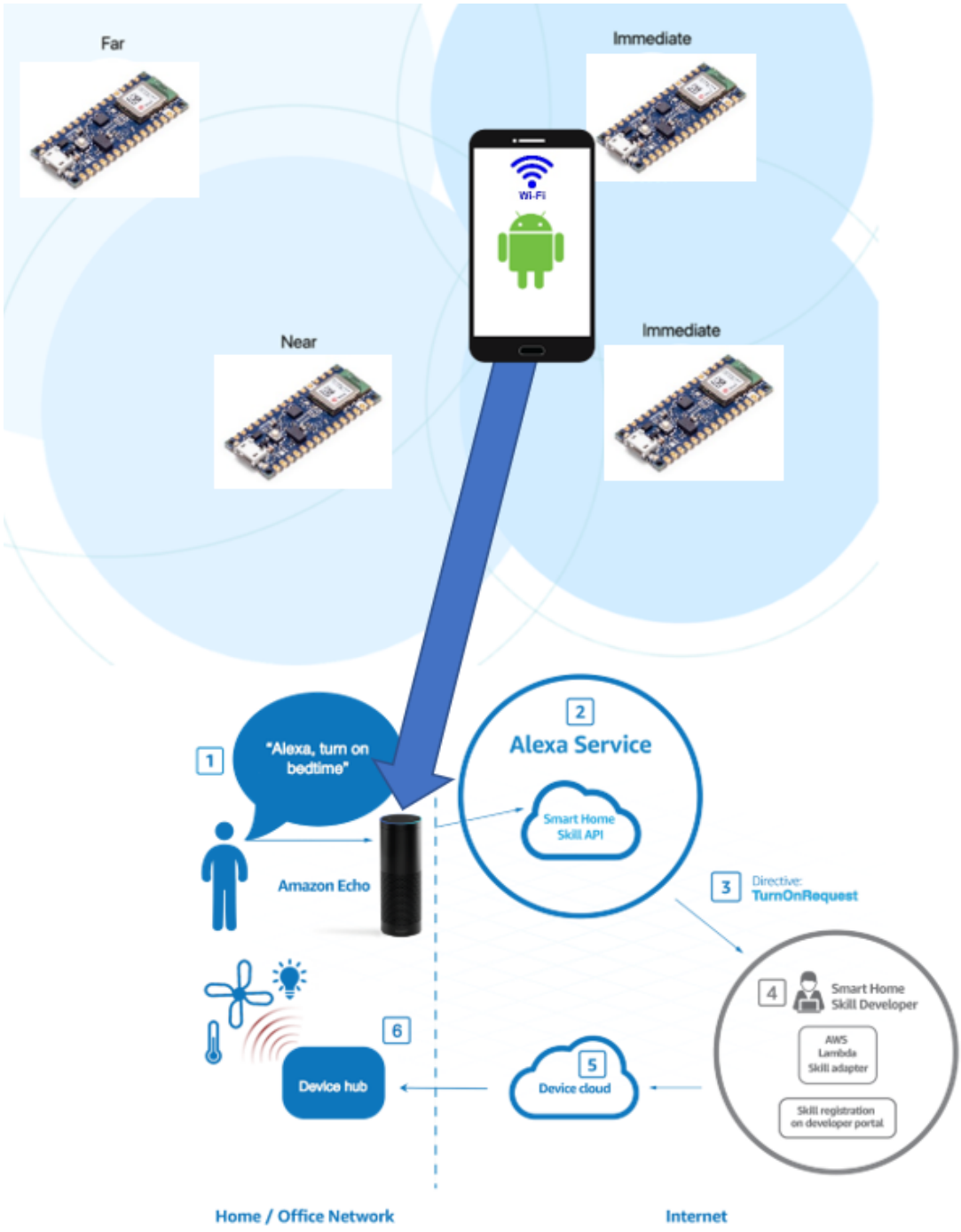

Figure 6: Hardware and HomeMe system interaction

2.5 Software Design

Amazon Alexa Skill

The Amazon Alexa HomeMe skill is required for the phone to interface with Alexa. The Amazon Alexa skill takes in the room and routine from the Android app, then activates that room or routine through the device hub on the alexa.

Android App

The Android apps basic functions as shown in figure 7, are to calibrate the system, schedule routines and allow an operation time. The Android App's main function is to read the Received Signal Strength Indicator (RSSI) values from the bluetooth beacons to locate the current room. The Android app also has to be able to calibrate the system to help identify the rooms given the different bluetooth beacons. The calibration also includes identifying the Amazon Alexa that manipulates the smart devices, and to set up and affiliate the bluetooth beacons with a room that is already identified in the Alexa app. Another responsibility of the app is to allow the user to choose routines. Routines allow the user to manipulate the smart devices given their location and time of day. The last function of the app is to schedule the operation time of reading values from the bluetooth beacons via an operating times function. The operating times function would allow the user to schedule when the system operates

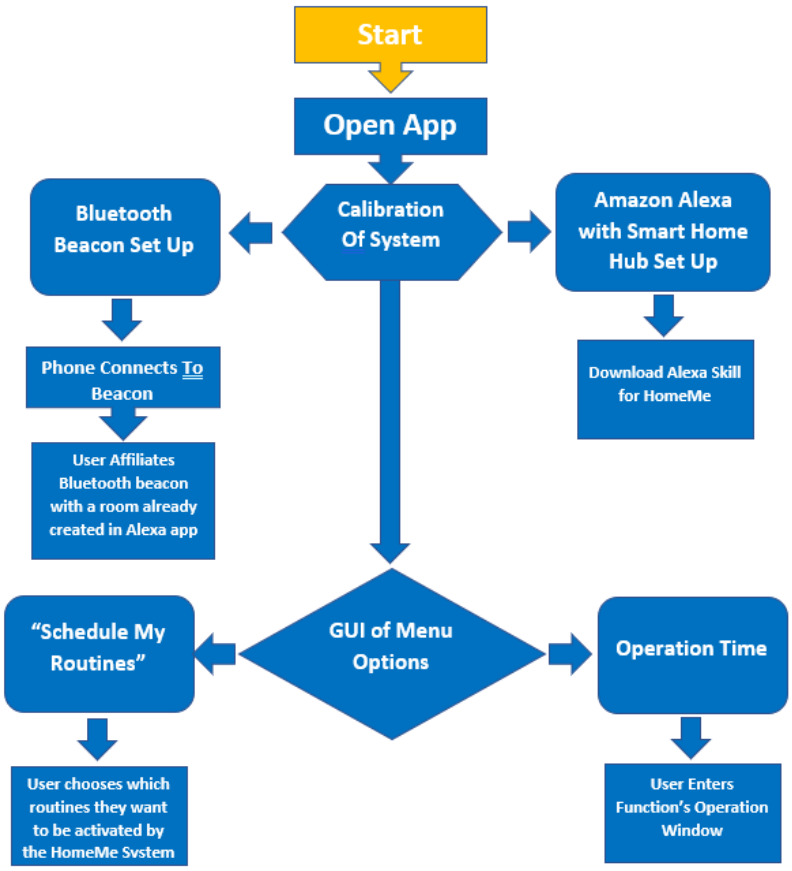

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Figure 7: Flowchart of the design and operation of the HomeMe Android Companion App

Beacon Software

The bluetooth beacon is programmed to sleep and wake on a given interval in order to conserve power. The beacon then checks for the phone's unique bluetooth identifier key. If the phone's unique identifier key is in range then it sends the Received Signal Strength Indicator. After the sending of the RSSI value the beacon sleeps and will repeat the cycle.

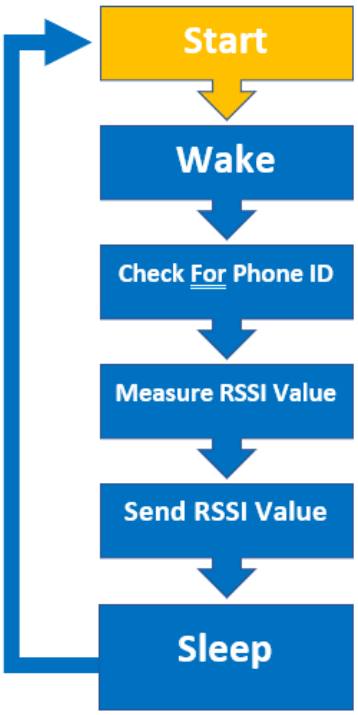

Figure 8: Flow Chart of Bluetooth Beacon Software

3. Prototypical Implementation

3.1 Implementation Details

Implementation

The HomeMe system was implemented by using the bluetooth beacons, a Samsung Galaxy s10e for the Android smartphone, an Amazon Alexa Echo Plus 3rd generation, and various smart devices including smart lights and plugs. The system is being implemented in the following plan. There will be one bluetooth beacon in a room. That bluetooth beacon is responsible for waking and sleeping at certain intervals. While the beacon is awake it will check whether the phone's unique bluetooth id is present. If the phone's unique id is present the beacon will send a received signal strength indicator to the phone. The phone will then check with the app the unique id of the bluetooth beacon to determine the room and routine affiliated with the phone's position. If the state of the room or routine within the room has changed, then the phone accesses the Alexa via the Alexa app and activates the routine. The Alexa app then tells the Alexa to manipulate all the smart devices affiliated with the routine.

Tools

In order to develop the system there are many tools that have to be used to program the hardware. To program the bluetooth beacons, the Arduino Web Editor and Arduino device manager tools are being used. These tools include various Bluetooth BLE libraries that are used

to implement the final system. To develop the Android smartphone app, Android Studio is being used. The Android Studio development editor also comes with different API's such as the Bluetooth BLE library and others. In addition to these software editing platforms the team is going to be using github in order to create a project repository to keep each other up to date on what has been done. This will also help for each member to understand exactly what the other person is doing and what changes have been made.

3.2 Testing Details

Beacon Testing

The testing will be conducted following a scaling model. The first step in order to test the system's success is to start with the bluetooth beacon recognizing the phone's unique id and being able to connect the phone to the beacon. Once the phone has been able to connect to the bluetooth beacon and show its measured received signal strength indicator value the next test can be conducted. The second test is to measure the signal strength from 2 different bluetooth beacons and have the phone identify which beacon is closer. The test will be successful when it can correctly identify which beacon is closer.

App Testing

Testing the Android app will be conducted by first testing the interfaces. Testing the interfaces entails that the user is able click on each menu option. The options will actually redirect or prompt the user into doing something. Then if the user is redirected and prompted, the app has to be able to store and collect the data that the user wants. The next step in testing the app is to see if it can recognize the Alexa device and control it.

System Testing

The system will start by testing only a single room with a single routine. Inside that room will be one bluetooth beacon and one smart device. If the phone can obtain a RSSI value and manipulate the smart device according to the routine the test will be measured as a success. The system then will be scaled up to test the routine switching in a single room. The test will be the same as before except for having two routines for the smart device instead of one. The test will be counted successful if the routine is correctly switched during the time that it is supposed to. After one room has successfully been tested the system is ready to be tested with two rooms each containing one beacon and one smart device. The test is successful if the system can activate the unique routines of the rooms and can recognize which room the phone is in. These tests will allow for the smaller tests and increments to be accounted for, after the completion of these tests the system is ready to be scaled to any number of rooms with any number of devices.

4. Conclusion

4.1 Results and Outlook

Results

Currently the majority of work has been getting familiar with the Arduino Web tools and coding onto the Arduino Nano 33 BLE boards. The boards have been successfully programmed to recognize and connect the Android smartphone’s unique id.

Outlook

The outlook for the rest of the system is going to be to further develop the bluetooth beacons to wake and sleep during certain periods. The wake and sleep needs to be calculated to be power efficient and not too long of times that it will sacrifice accuracy of where the phone is located. The majority of the remaining semester is going to be devoted towards developing the Android app as it is the most influential part of the system and everything else will be derivative of the app working.

4.2 Lessons Learned

The important takeaways from our project so far is that there are a lot of working parts. Those parts really need to come together in order for the project to work. The one thing that ties the project together is the development of the Android app. The Android app is of the utmost priority and will take the most time on the system. It is important to get it operational to test everything and then advance it to a more complete state later.

The project is definitely subject to change and improve. The biggest change that we know of is the deciding between the two options for bluetooth technologies that are possible for the project. The change from bluetooth 5 to Received Signal Strength Indicator values is the most like change to occur. Along with that might be the change from a battery pack to a wall plug in.

4.3 Teamwork Experience

With all that has happened this semester it has made the project harder to complete and work in a team environment. With all the troubles of this semester though it has made it so that each team member has to get more involved with every portion of the project. The team is working together well and diving more into each other's areas than what was planned. Going forward the team is going to be using all the git tools to see the changes in software and more easily able to see what the others ideas are.

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