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CareCloud – An Application for Smart Personal Health Care Devices

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CareCloud – An Application for Smart Personal Health Care Devices

by

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Report

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Dedication

To my parents, Mrs. Nalini Govindan and Mr. T. P Govindan,

A constant source of inspiration in my life.

Acknowledgements

I would like to thank Dr. Suzanne Barber and Dr. Thomas Graser for sparing their valuable time to provide guidance and supervising and reading my report.

On a personal note, I would like to acknowledge the love, support and encouragement of my husband, Param Kollengode, while I worked towards getting my Masters degree. He is the strength and motivation behind me going back to school after so many years. I have to make a special mention here of our beautiful daughters, Divya and Sriya, who bring so much joy into our lives. Seeing them makes me want to be the best that I can be.

Abstract

CareCloud – An Application for Smart Personal Health Care Devices

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The University of Texas at Austin, 2014

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As personal health care devices like blood pressure monitors, glucose monitors, thermometers are becoming more intelligent, with wireless communication abilities, there exists a huge potential for mobile applications that can aid users in their home health care. These mobile applications can talk wirelessly to the health devices via protocols like Bluetooth, Zigbee etc. and simplify daily tasks for users like logging daily readings, creating alerts, reminders, tracking supplies, messaging care-providers etc.

This report will explore the design and architecture for the development of such a mobile application. A remote, integrated, web service can provide storage, web access, and analysis for the data, retrieved by the application, from personal health devices. The report will explore IEEE standards that define a standard format for information exchanged to/from these devices. It will also delve into security and privacy considerations in the system for patient health data.

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Chapter 1: Introduction

Advances in technology, along with rising health care costs, have brought about new ways to administer health care to patients. Remotely monitoring a patient's health statistics can aid in cost effective, and more importantly, preventative health care. This is possible today as personal health care devices are becoming wireless and equipped to communicate via connectivity protocols like Wi-Fi, Bluetooth and Zigbee. Smart phones, now ubiquitous and an integral part of people's lives, can easily connect to these devices, store the readings, analyze them, and share them with health care providers if necessary. A patient can be in the comfort of their home, and still be able to provide health information to caregivers via telemedicine capabilities.

This report presents to you the requirements, design and architecture of a telemedicine system – CareCloud. This system was envisioned based on requirements gathered from patients and caregivers. It essentially allows patients to connect to their personal health devices wirelessly from their smart phone, transfer the health data to their phone, and store it, locally and in the cloud, for further processing and analysis. The system is comprised of the following components –

A bluetooth enabled personal health care device (for example - a glucose meter or a blood pressure monitor). This device will be able to transmit its readings wirelessly, via Bluetooth, to a paired smart phone.

A mobile application - CareMobile. Patients will use this application, installed on their smart phone, to connect to their personal health care device and retrieve the latest health data. Later chapters will provide detail on the features of this application. In addition to local storage on the smart phone, the data is uploaded to a cloud based web service for storage and broader analysis.

A Web Service - CareConnect This web component will be primarily responsible for reliable and secure data storage and analysis. The web service will also feature a portal that users can securely access to view and share health information.

Chapter 2 will provide insight into related work, and the key contribution of our system. System requirements and the product vision are presented in Chapter 3. Chapter 4 discusses the overall architecture and technologies used in the system. Chapter 5 concludes by discussing the future roadmap.

Chapter 2: Related Work

According to the Center for Medicare and Medicaid Services (CMS), health care costs could reach 20 percent of our gross domestic product (GDP) by 2022 without interventions. Therefore, there is lot of interest in the research community, along with policy makers, caregivers and patients to look for effective healthcare delivery systems.

Kvedar, Coye and Everett [KCE14] have examined the adoption of electronic technologies and telemedicine as key strategies to making healthcare more cost-effective.

Microsoft Health Vault [1] is a web-based platform to store and maintain health information. It integrates with a growing list of devices like heart rate watches, blood pressure monitors and weighing scales. These devices, however, have to be Health Vault-approved. Our system will aim to overcome this limitation and have the ability to interface with any Bluetooth health device that adheres to the ISO/IEEE 11073 Personal Health Data Standards. The report will discuss more about these standards in later chapters.

A competitor to Microsoft Health Vault used to be Google Health [2]. Google Health was still working on importing data from health devices into their system, however Google announced in June 2011 that the project would be discontinued in 2013, due to lack of broader adoption.

There are several Bluetooth enabled health devices in the market. iHealthLabs [3] have a series of wireless devices like blood pressure monitors, glucose monitors, pulse oximeter, weight scale that can be integrated with their proprietary mobile app called iHealth MyVitals [4]. Entra Health Systems markets the first FDA Approved Bluetooth Enabled Glucose Meter called myGlucoHealth [5]. This also comes with an Android

Mobile Application, and an online web portal www.myhealthpoint.com that can be used to upload and report blood glucose readings.

From their literature, iHealthLabs and myGlucoHealth only provide custom mobile apps that work with only their own health devices. As mentioned earlier in this chapter, our project aims to deliver an application that is open to interfacing with a wider variety of health devices.

Chapter 3: System Requirements

The author approached potential users of CareCloud – patients, caregivers and health care professionals, and conducted interviews to gather the requirements for CareCloud. From the interviews, a vision for the product was developed. This vision is presented in this chapter.

3.1 Product overview

Clinical studies have shown that for patients with chronic illnesses, like diabetes or high blood pressure, keeping track of their health data on a regular basis, and communicating them to their caregiver, is of great importance. The goal of our system, CareCloud, is to streamline that process.

Here are some scenarios that give more insight into the motivation for our system:

1) Jane is a middle-aged woman, who needs to monitor both, her blood glucose levels, and her weight, on a regular basis, as part of her healthcare regimen. She uses a personal glucose meter and a weighing scale to manually log her readings, and report them to her doctor at her next visit to the doctor's office. Traveling to her doctor's office on a regular basis is getting difficult for Jane. She needs a system that can automatically transfer the health data from her meters to her smartphone, and to a secure location accessible by her doctor. Her personal health devices are enabled to communicate over wireless technology, and come with custom applications, that can be installed on her smartphone. However, Jane is not comfortable managing her health data across multiple applications. She needs a single mobile application that can interface with both

her meters (and any other personal health devices she may need in the future). In addition, the two health statistics, of weight and glucose levels, are dependent on each other in her case. She has been told that managing her weight is an important factor in managing her diabetes. So she would like to see both these statistics in one system, for ease of analysis. This motivated the need for a mobile application in CareCloud. This mobile application will be easy to use, and be able to interface with a wide variety of personal health devices, as long as they implement the ISO/IEEE 11073 Personal Health Data Standards.

2) Jane's caregivers and health care professionals need a way to stay on top of her health conditions. They would like to be able to proactively keep track of her health data, and make medical decisions as part of her preventative healthcare. Waiting until Jane comes in for her next doctor visit, or contacts her caregivers with any concerns she has, may result in wasting precious time. In today's modern world, though time and distance may separate us from our loved ones, the internet has helped bridged physical distances. The easiest way for them to view Jane's health data, and be alerted in case of any abnormal readings, is via a web portal accessible over HTTP. They would also like to have a secure way of communication with Jane to respond to any inquiries she may have. This reduces the need for in-person visits, and at the same time results in more effective health care delivery. CareCloud will include a web service to serve this need for caregivers and health care professionals.

As seen from the scenarios above, CareCloud will be comprised of two separate subsystems. 1) CareMobile - A mobile application that runs on the patient's smart phone that will handle connections and data transfer from/to the health devices via Bluetooth, and 2) CareConnect - A web service that handles storage and analysis of the health data, and provides a web portal for users.

To use the system, the user will first install the mobile application CareMobile on their smart phone. They can then use CareMobile to establish a secure connection via Bluetooth with their health device. This needs to be done only during the first usage of our system. Once the device is paired with the user's smart phone, the user will be able to navigate through the user-interface of CareMobile to retrieve the latest health data and display it. CareMobile will also handle uploading the health data to our remote web service, CareConnect. The user will be able to log in to CareConnect using HTTP, and view more detailed analysis of their health data over time. They can choose to share this data with their caregivers.

3.2 User Description

3.2.1 User Profiles

User	Description
Patients	Mostly middle age consumers, that are often at risk for health conditions that require frequent or preventative monitoring
Caregivers	Friends and family of patients, who would like to keep track of their loved ones' health data.
Health care professionals	Health care professionals, who would like to view a patient's shared health data, to act promptly and in a preventative manner to provide effective health care.

Table 1: User profiles for CareCloud.

3.2.2 User Environment

CareMobile, the mobile application in the system, needs to be installed on a smart phone running Android OS. The application should be compatible with the JellyBean SDK of Android since it is the most used SDK version [6]. Patients will be using CareMobile on their Android Smartphone.

CareConnect, the web-portal will be hosted on a PAAS (Platform as a Service) Infrastructure. This will eliminate the need to host and manage our own servers. Patients, Health care personnel and Caregivers will be using CareConnect via the web.

3.2.3 Key User Needs

User	Needs
Patients	- System should allow them to connect to their health care device, via Bluetooth, and retrieve the latest health data reading. - System should be secure. A malicious agent should not be able to hack into the data transmission between the device and smartphone. - User should be able to view their results in various tables and graphs. - System should allow user to create alerts for their caregivers or health care professionals. - System should allow the user to create user accounts for those with whom they wish to share their health data. They can also choose which data they wish to keep private. - System should allow the user to email out a chosen section of their data.
Caregivers and Health care Professional.	- Authorized caregivers should be able to login to the system and authenticate themselves, with the user account created by the patient. - Authenticated caregivers should be able to view shared health data from the patients. - Authenticated caregivers should be able to create alerts based on thresholds they can set for the patient's health data. - System should also provide a secure messaging system by which the users can communicate with each other.

Table 2: Key User Needs

3.3 Product perspective

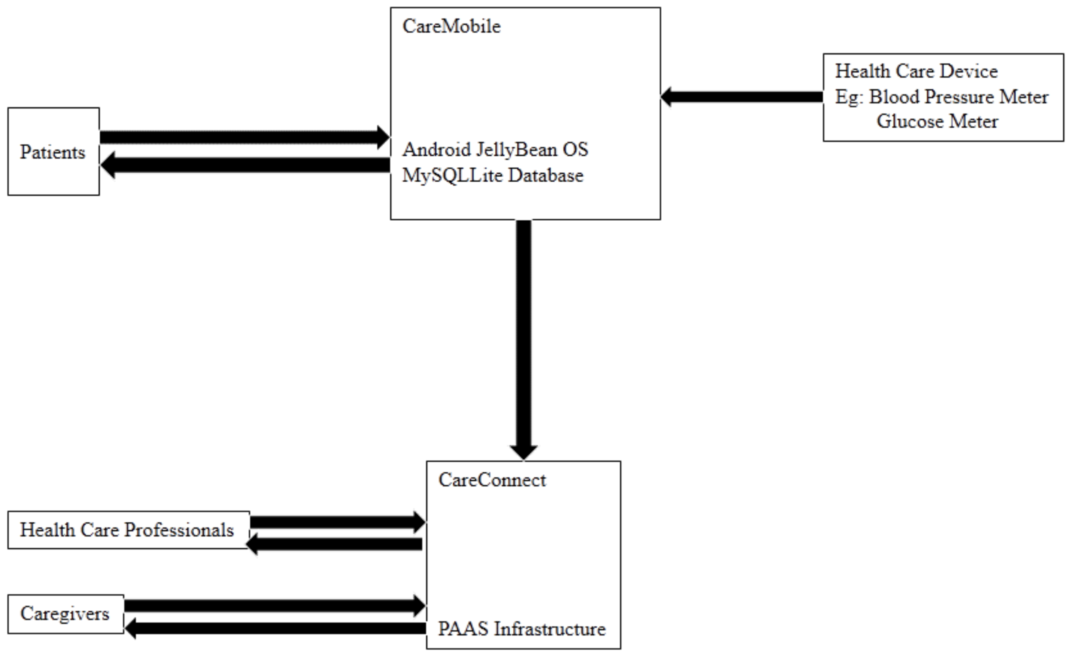

Figure 1: Product Perspective of CareCloud

3.4 Product position statement

CareCloud will be a wireless, easy-to-use and secure way for patients to monitor their health data from any of their Bluetooth enabled personal health devices that implement the ISO/IEEE 11073 Personal Health Data Standards, while also offering the ability to share this data with their authorized caregivers and health care professional.

3.5 Feature attributes

The product features, mentioned in section 3.6 are classified based on these feature attributes –

Priority: 1 – Critical, 2 – High, 3 – Normal, 4 – Low

Effort: 1 – High; 2 – Medium, 3 – Low

3.6 Product Features

3.6.1 Feature: Mobile Application, CareMobile, available for download from the Android App Play Store

Priority: Critical

Effort: High

3.6.2 Feature: Ability to connect to a personal health device from CareMobile

Priority: Critical

Effort: High

The system should allow the user to pair their smart phone with their health care device via Bluetooth.

3.6.3 Feature: Ability to retrieve and display latest health data reading from the health care device.

Priority: Critical

Effort: High

The system should be able to retrieve and parse the latest health data from the personal health device, and display it in various graphical and tabular formats. The assumption here is that the device will implement the ISO/IEEE 11073 Personal Health Data Standards.

3.6.4 Feature: Ability to set thresholds and alerts

Priority: Critical

Effort: Medium

The system should allow the user to create acceptable thresholds for health data.

For e.g.:

Blood pressure of 120/80 mm Hg,

Weight between 130 lbs. and 150 lbs.

System will allow the user to create alerts via SMS and email if the health data does not meet the thresholds.

3.6.5 Feature: A remote web service, CareConnect, that provides data storage and a portal for users

Priority: Critical

Effort: High

System should include a remote web service hosted on a PAAS (Platform as a service). This remote service will handle data storage, and will also feature a web portal that the users can log into and view and manage their health data.

3.6.6 Feature: Ability to create user accounts for caregivers and health care professional

Priority: High

Effort: Medium

Patients should be able to create accounts on the web portal for caregivers and health care professionals they wish to share their health data with.

3.6.7 Feature: Messaging System

Priority: High

Effort: High

Users of the web portal should be able to communicate securely using a messaging system. Patients, Caregivers and Health care professionals should be able to message each other along with data screenshots if necessary.

3.6.8 Feature: Cost

Priority: Critical

Effort: Medium

The cost of maintaining the system should be under 30K per year.

3.7 Non Functional requirements

3.7.1 Performance

Scope: For all requests by the user to the web portal

Evaluation criteria: Measure response time for user requests. It should be no more than 2 seconds

3.7.2 Security

Scope: Health Data

Evaluation criteria: Inspect the health data when it is stored and transmitted. It must be encrypted.

3.7.3 Usability

Scope: Accessibility to the Mobile Application

Evaluation criteria: CareMobile should be launched from a single click icon on the smart phone.

Chapter 4: Architecture and Implementation

CareCloud is comprised of the following components:

1) Bluetooth enabled Personal Health Care Devices
2) Smart Phone running Android OS (JellyBean or higher)
3) CareMobile – An Android Application
4) CareConnect – A Web service.

These components will be discussed in detail in this chapter.

4.1 Bluetooth enabled Personal Health Care Devices

In the United States, the Food and Drug Administration has published a document [7] that lays out best practices for wireless communication. This includes the suggestion that wireless medical devices should limit their RF output to the lowest power necessary to reliably accomplish their intended medical functions.

Low energy has been the hallmark of Bluetooth[1] technology. Bluetooth technology is a global wireless standard, enabling secure connectivity for an ever-expanding range of devices. It allows you to share voice, data, music, photos and other information between paired devices. Bluetooth Smart is the intelligent, power friendly version of Bluetooth wireless technology. Bluetooth Smart is also very application friendly. It makes it easy for developers to create solutions that will work with smartphone apps. Because of these two features of Bluetooth Smart, many fitness and sports companies rushed to adopt this

[1] An interesting titbit of information is that the name "Bluetooth" comes from a 10^{th} century Danish King, Harold Bluetooth. King Bluetooth helped unite warring factions in parts of what are now Norway, Sweden and Denmark. Bluetooth technology aims similarly to be an open standard to allow connectivity between disparate products.

technology. It was a perfect fit for a wide range of medical devices like heart rate monitors, glucose meters, blood pressure monitors.

Major platforms like Apple, Android and Windows 8 are committed to easy integration with Bluetooth Smart products. Apple is giving developers more choices, and making it simpler for them to create new applications and products. With native support of key Bluetooth profiles and functionality, developers can focus on making a great app for consumers instead of how the application interacts with the OS. Android-powered Bluetooth Smart Ready devices, running the latest OS, will be compatible with virtually any Bluetooth enabled product. Windows 8 offers native integration of Bluetooth 4.0.

There are already more than 40 million Bluetooth enabled home and professional health care devices on the market from leading manufactures like 3M and A&D. Analyst research firm, IMS (now part of IHS Inc.) [8], estimates that by 2016, 5.7 million Bluetooth Smart products will be shipped, representing more than 50 percent of all wireless-enabled consumer medical devices.

These factors make Bluetooth technology the ideal for connected health and the author's choice for the wireless technology in the system - CareCloud.

4.2 SMART PHONE RUNNING ANDROID OS

4.2.1 Android vs. iOS Platforms

Google's Android and Apple's iOS are the major operating systems used today in mobile technology, such as smartphones and tablets. Android is the now the world's most commonly used smartphone platform, and is used by many different phone manufacturers. iOS is only used on Apple devices.

Android's popularity, along with its customizability and open source nature motivated the author to use Android smart phones for CareCloud.

Here is a tabular comparison of some features between Android and iOS operating systems, validating the author's observations above.

	Android	**iOS**
Company/Developer	Google	Apple Inc.
Source model	Open source	Closed, with open source components.
Open source	Kernel, UI, and some standard apps	The iOS kernel is not open source but is based on the open-source Darwin OS.
Available on	Many phones and tablets, including Kindle Fire(modified android), LG, HTC, Samsung, Sony, Motorola, Nexus, and others.	iPod Touch, iPhone, iPad, Apple TV(2nd and 3rd generation)
Market share	81% of smartphones, 3.7% of tablets in North America (as of Jan'13) and 44.4% of tablets in Japan (as of Jan'13). In the United States in Q1 2013 - 52.3% phones, 47.7% tablets.	12.9% of smartphones, 87% of tablets in North America (as of Jan'13) and 40.1% of tablets in Japan (as of Jan'13)
Device manufacturer	Google, LG, Samsung, HTC, Sony, ASUS, Motorola, and many more	Apple Inc
Website	android.com	apple.com

Table 3: Differences between Android and iOS platforms.

4.2.2 Bluetooth support in Android

As discussed in section 4.1, Android now has built in support for Bluetooth Smart. This was introduced in Android 4.3. It provides a standard set of APIs that apps can use to discover nearby devices and transmit data. This, again, makes Android a good choice for CareCloud.

Figure 2:	Bluetooth Support in Android

4.3 CareMobile – An Android Application

4.3.1 Android Platform Architecture

This section discusses the infrastructure, APIs and development tools provided by the Android platform that can be used to implement CareMobile.

Android is an open-source software platform developed by Google, for mobile app development on devices powered by the Android OS. It is a complete software stack that provides all the middleware needed to run end-user applications on mobile devices and a complete Java development environment. This section provides an introduction to the Android framework and describes the platform architecture and key concepts pertinent to the needs of CareMobile app, which are more generally applicable to other apps as well. As shown in the Figure 3, the Android software stack is a tiered architecture that consists of 5 principle layers.

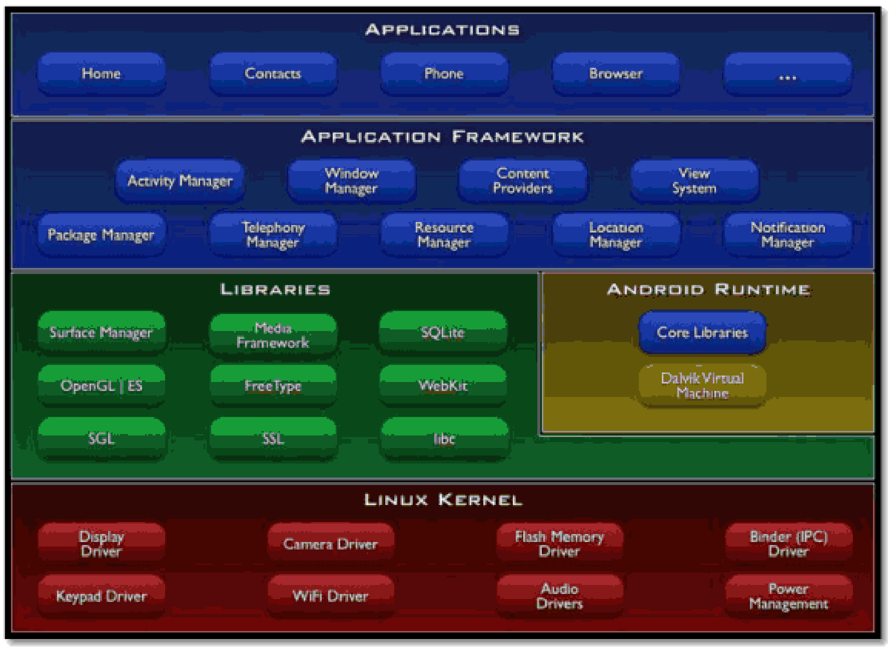

Figure 3: Android Architecture

Linux kernel is the basic layer in Android architecture. Android OS is built on top of the Linux Kernel with some further architectural changes made by Google. It never really interacts with the users and developers, but is at the heart of the whole system.

The next layer is the Android's native libraries. Native Libraries Layer enables the device to handle different types of data. CareMobile will use SQLite from this layer. SQLite is the database used in android for data storage purposes

Android Runtime layer consists of Dalvik Virtual machine and Core Java libraries. Dalvik Virtual machine is a type of Java VM responsible for running apps on Android devices and is optimized for low processing power and low memory environments. Android application programmers build their apps using the Java programming language.

4.3.2 Bluetooth development support in Android

Android provides a default Bluetooth stack, BlueDroid, that is divided into two layers: The Bluetooth Embedded System (BTE), which implements the core Bluetooth functionality and the Bluetooth Application Layer (BTA), which communicates with Android framework applications. Shown below is the general structure of the Bluetooth stack, and a brief description of some of the major components.

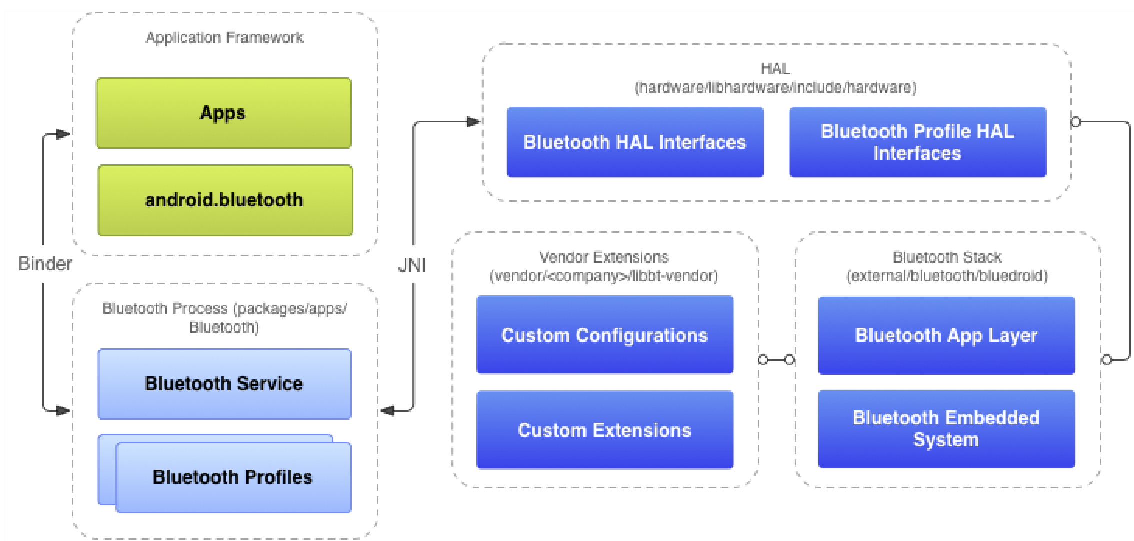

Figure 4: Bluetooth stack in Android

<u>Application framework</u>

At the application framework level is the app's code, which utilizes the android.bluetooth APIs to interact with the Bluetooth hardware.

HAL

The hardware abstraction layer defines the standard interface that the android.bluetooth APIs and Bluetooth process calls into and that you must implement to have your Bluetooth hardware function correctly.

JNI

The JNI code calls into the HAL layer and receives callbacks from the HAL when certain Bluetooth operations occur, such as when devices are discovered.

Bluetooth system service

The Bluetooth system service, located in packages/apps/Bluetooth, is packaged as an Android app and implements the Bluetooth service and profiles at the Android framework layer. This app calls into the HAL layer via JNI.

4.3.3 CareMobile App Design

Key functional requirements, as gathered in section 3.5 are shown in Figure 5.

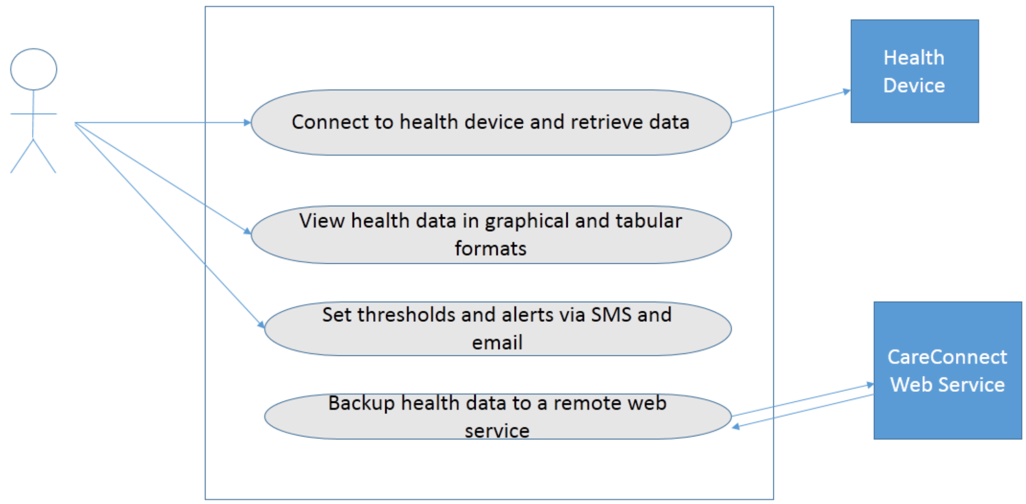

Figure 5: CareMobile – Key Functional Requirements

A core functionality of CareMobile is to connect to a health care device and transfer health data. The software component in CareMobile, designed to implement this functionality, will be called HealthDeviceManager. This section of the report will describe the general basic structure, and important concepts necessary to implement an Android Application, and specifically discuss the design of HealthDeviceManager.

4.3.3.1 Anatomy of an Android App

Below are the basic building blocks of any Android Application.

VIEW

Views are the fundamental building blocks for creating user-interfaces. A View typically consists of the content visible to the user on the screen such as a button, text field, etc. It is the point of user interaction and handles UI events such as a button press. Views are grouped into a hierarchical structure to form different layout schemes such as a lists, tables, etc. which organize the Views into specific pattern for rendering [12]. Layouts and Views are typically specified in XML files.

ACTIVITY

An Activity is essentially a piece of user-interface that consists of a set of related tasks a user can do in one screen. For example, a mail app can be divided into 3 basic activities: (1) Mail list Activity that shows all received mails (2) Mail view Activity that shows a single mail message (3) Compose Activity that allows creating and sending outgoing messages [12].

INTENTS

Intents are the fundamental message passing constructs in Android which allow communication of data and action between and among different system components such as: Applications, Activities, Services, etc. For example, when a new email is received, Intents are fired from the mail listener service to update the mail list screen to show the newly received messages.

Apps can also register to receive specific kinds of Intents (generated internally or externally) in order to wake up and execute code when the appropriate Intent is received. For example, say the user wants to pick a photo to attach to a mail message. An Intent is fired that looks for the best available source of photos. It may determine that the photo gallery is the best match and use it. If later, a better source of photos is added, such as an online web album on Flickr or Picasa, the photo gallery is replaced by the web album as the preferred source. This late binding between action and action handler allows components to be re-used or replaced at run-time. Any task triggered by an Intent is therefore an opportunity to replace or re-use a component [12]. For instance, an Intent for viewing emails can first be sent to the mail service which fetches any new mails from the server and updates the mail listing before opening the inbox.

SERVICES

Services are background processes launched from Activities that typically perform long-running tasks and have no user interface. For example, a music player can be started as a service and keep playing music while the user may be checking emails. Other Activities or Applications can also bind to the service for performing specific tasks such as pausing, rewinding or fast-forwarding the music [12].

4.3.3.2 Feature Design – HealthDeviceManager to connect to health device and retrieve data

Android 4.0 (API level 14) introduces support for the Bluetooth Health Device Profile (HDP) via the BluetoothHealth API [9]. This lets you create applications to communicate with health devices that support Bluetooth, such as heart-rate monitors, blood meters, thermometers, and scales. The HealthDeviceManager Component in CareMobile will use this API to achieve its functionality as shown in the Figure 6.

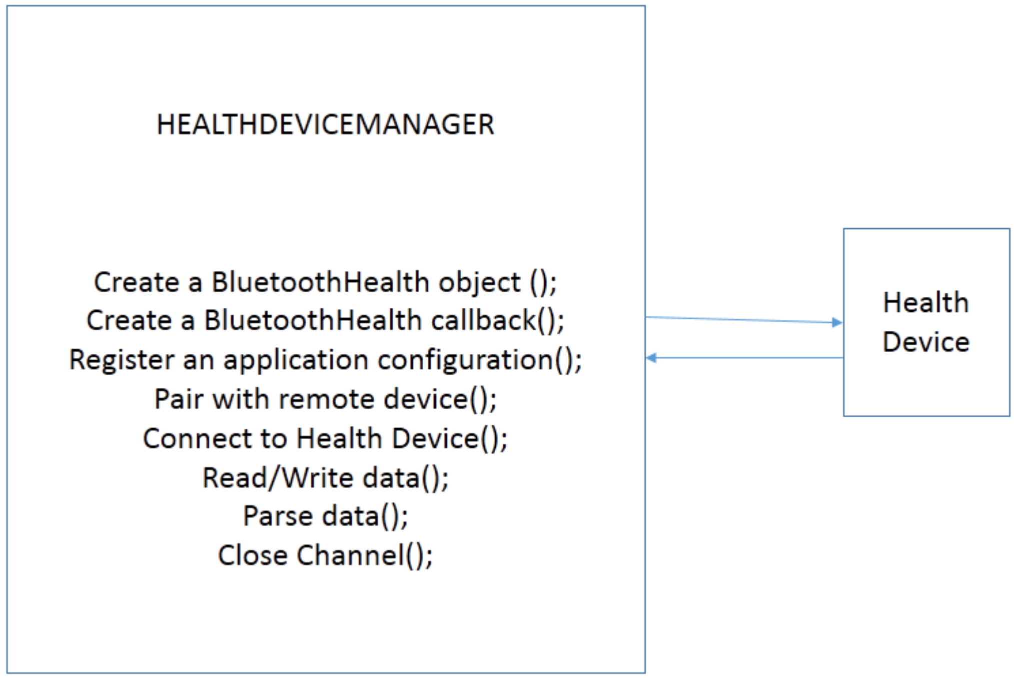

Figure 6: CareMobile – HealthDeviceManager component.

In using the Bluetooth Health API, it is helpful to understand these key HDP concepts:

Source: A role defined in HDP. A *source* is a health device that transmits medical data (weight scale, glucose meter, thermometer, etc.) to a smart device such as an Android phone or tablet.

Sink: A role defined in HDP. In HDP, a *sink* is the smart device that a CareCloud user will use to receive and view the medical data. In an Android HDP application, the sink is represented by a BluetoothHealthAppConfiguration object from the Bluetooth API.

Registration: Refers to registering a sink for a particular health device.

Connection: Refers to opening a channel between a health device and a smart device such as an Android phone or tablet.

Knowing the above concepts, here are the basic steps, shown in Figure 6, to connect and retrieve data from a health device

Create a BluetoothHealth object():

BluetoothHealth is a proxy object for controlling the Bluetooth Service. The method getProfileProxy(Context, BluetoothProfile.ServiceListener, int) can be used to get the BluetoothHealth proxy object.

Create an BluetoothHealth callback ()

BluetoothHealth callback will inform the application of channel state change.

Register Application Configuration()

Call registerSinkAppConfiguration(String, int, BluetoothHealthCallback) to register an application configuration. This registers our application as a sink, in order to communicate with health devices.

Pair with the remote device()

This currently needs to be done manually from Bluetooth Settings

Connect to a health device ();

Call connectChannelToSource(BluetoothDevice, BluetoothHealthAppConfiguration) to connect to the device over a channel.

Read/Write data();

Use the file descriptor provided with a connected channel to read and write data to the health channel.

Parse data();

A software component called HealthDataManager, in CareMobile, will have the ability to parse data from different types of health devices. As mentioned in the product features in section 3.6.3, this function is an important differentiator for CareCloud.

HealthDataManager will be an integration layer that will reside on top of the IEEE 11073-20601 [10] protocol for communicating between the mobile application and the health device. This protocol will form the basis of this component since the Bluetooth SIG mandates for HDP the usage of the IEEE 11073-20601 Personal Health Device Communication Application Profile as the only allowed protocol for data exchange between HDP devices. The FDA also recently recognized multiple standards that collectively help support medical-device interoperability and cyber security. IEE 11073-20601 is among the 25 standards listed. [11]

A key definition, that needs to be understood from the IEEE 11073 PHD standards, is that of Agents and Managers. The agents are the personal health devices. The Managers are typically personal computers or smart phones with greater computing resources.

Consider a weighing scale, as an example of an agent, to provide a high level description of how our parsing functionality would work. This can be extended out to any device supporting the IEEE 11703 20601 standards.

Once the user's smartphone has registered an application configuration with the weighing scale, CareMobile can request a configuration report containing details of all of the objects the weight scale contains, and their static attributes (Body Weight, Body Height and Body Mass Index objects, in this case). CareMobile will store all this data for future reference. CareMobile can then initiate event messages to request the weighing scale to transfer measurements. And since CareMobile now knows the attributes the weighing scale will transfer, it can use that information to parse, display and store the data.

Close channel();

After data transfer, close the health channel by calling disconnectChannel(BluetoothDevice, BluetoothHealthAppConfiguration, int) and unregister the application configuration by calling unregisterAppConfiguration(BluetoothHealthAppConfiguration)

4.4 CareConnect – A web service

The key functional requirements in CareConnect as discussed in section 3.6 are outlined in Fig 7.

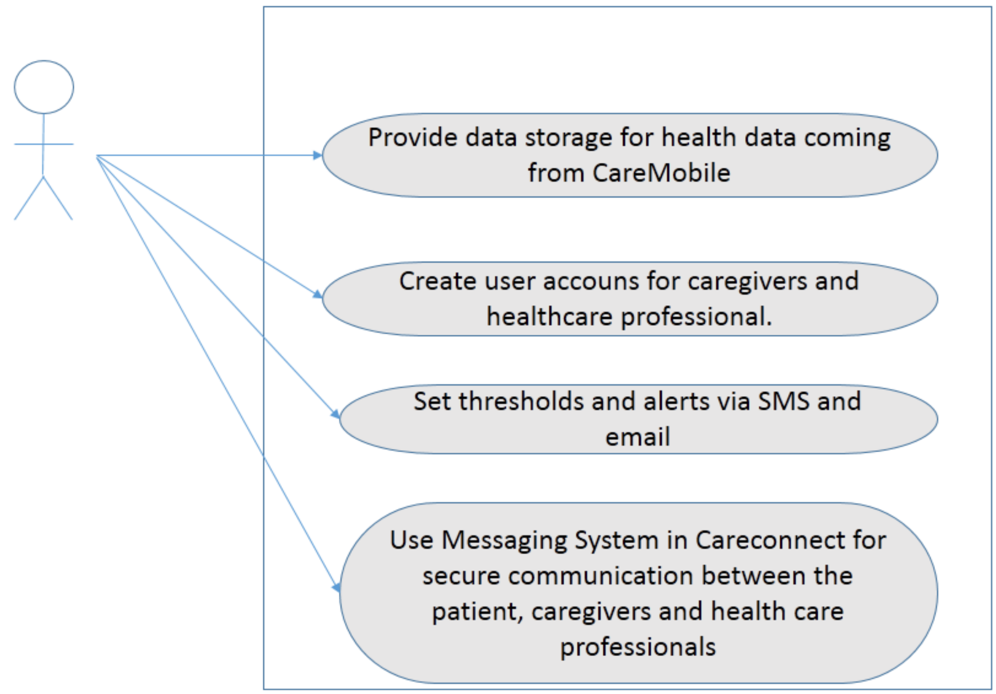

Figure 7: CareConnect – Key Functional Requirements.

The premise of Web services has evolved. Cloud computing and Platform as a Service (PAAS) technologies make it easier build, deploy, and distribute applications. They eliminate the need to maintain your own server infrastructure, thereby reducing cost and effort. This section will discuss the benefits of choosing PAAS for CareConnect infrastructure, and present a high level design of the web service using Google App Engine [13] as the PAAS provider.

4.4.1 Advantages of Platform as a Service (PAAS) infrastructure

Cloud computing [14] allows companies to store their software and data on a provider's remote servers. Outsourcing this IT function saves money, time, and reduces the number of in-house IT personnel required. PaaS is a concept that is geared toward software developers and programmers to host their in-progress projects.

Writing the code for software and deploying programs requires significant server space, advanced software to create programming environments, and steps to keep data secure. Investing in this infrastructure is expensive. Many companies are unable to afford the infrastructure and software purchases needed to launch or grow their programming efforts. Platform as a Service vendors offer developers an alternative. For a monthly fee, developers are able to access these tools, servers, and programming environments remotely. Instead of being housed on the developers' servers, everything is stored in the cloud.

Since there is a cost constraint of <30K per year, as mentioned in section 3.6.8, a PAAS solution is ideal for CareConnect.

On comparing Windows Azure [15] and Google App Engine, the author decided to use Google App Engine for CareConnect, for reasons elucidated here. It is important for our system to be able to create alerts via SMS and email (feature 3.6.4). In Windows Azure, Email-as-a-Service is not provided out of the box. The system would have to integrate with an external partner like SendGrid [16] for this feature. Google AppEngine, on the other hand does have this functionality. AppEngine also has great integration with many of the Google offerings - calendars, mail etc. User management in CareConnect can also be delegated to Google. An advantage of this is that CareMobile can use Google's authentication too, since it is an Android Application. This will make the system more usable and friendly for our users, as they will have a common user login to both CareMobile and CareConnect.

Azure Web Sites services are offered in three tiers. The entry-level tier is the "free" tier. The free tier supports up to 10 websites with 1 GB of content storage, and is limited to 165 MB of daily data egress. Google App Engine is more economical for CareConnect with 5 GB of free cloud storage and 1 GB daily outgoing traffic free, per application.

Even if these free limits are exceeded, the pricing model allows paying only for the excess usage, and the minimums appear to be cheaper than other vendors charge.

4.4.2 High level design of CareConnect using Google App Engine

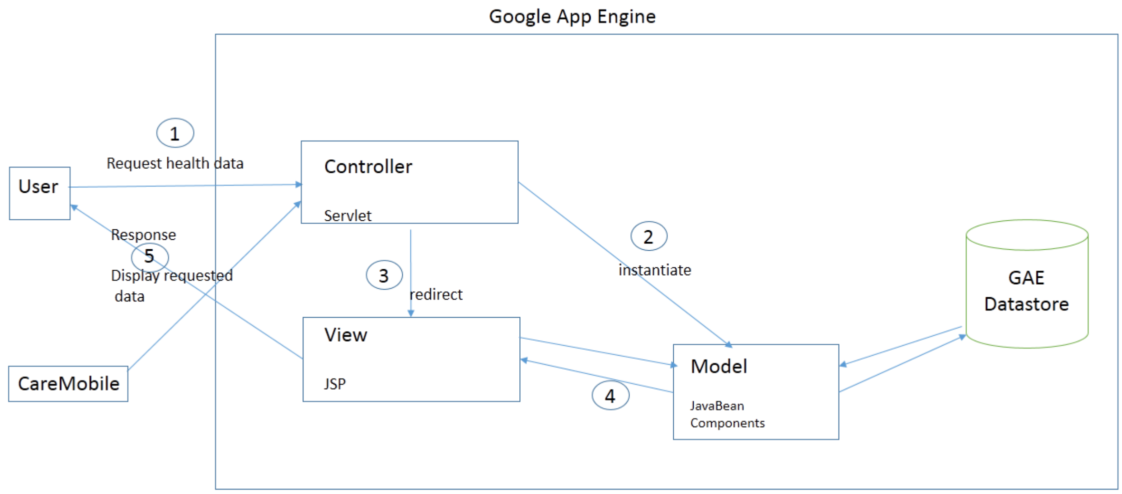

Figure 8: CareConnect – High level design.

CareConnect will be implemented as a Java Web Application, following the Model-View-Controller (MVC) architecture [17]. The MVC architecture separates data access, business logic and the presentation layers. Such separation improves the application's modularity and extensibility by providing a clear separation of the components. In a Java Web Application, the Model is often represented by Java Beans, Controller by Servlets and Views by Java Server Pages (JSP). Data Storage in Google App Engine is provided by the GAE DataStore.

Let us consider one functional requirement (from section 3.6.5) where a user requests to see a patient's health data in the web portal.

The sequence of events are as follows 1) The user makes a request from their browser via HTTP to the CareConnect web service, requesting for health data. 2) This request is handled by a Servlet. The servlet is responsible for creation of any beans or objects associated with the request. For this request, these beans will contains the health data from the GAE data store. 3) JSP is used as a View. It doesn't do much processing. It is simply responsible for retrieving objects/beans created by the Servlet, extract the content from them, and render them appropriately in the user's browser.

4.5 Security and Privacy considerations

Electronically storing and transmitting medical data requires careful consideration of patient privacy regulations. The Health Insurance Portability and Accountability Act (HIPAA) enacted in 1996 aims to streamline electronic health record systems and impose strict electronic security regulations. As the trend towards smart medical devices and telemedicine continues, applications have the same duty to safeguard a patient's health data. This is of high importance as electronic data can more easily be duplicated and transmitted. Digital security needs to be carefully considered in the development of any portable medical device.

In CareCloud, Bluetooth is used as the wireless protocol between our devices, because of its inherent security mechanisms of encryption, authentication and authorization [18]. The encryption technique uses the advanced encryption standard (AES), which was a technique adopted as a standard by the U.S government.

Unlike a doctor or health plan, CareCloud is not regulated by the Health Insurance Portability and Accountability Act (HIPAA), a federal law that establishes data confidentiality standards for patient health information. This is because CareCloud does not store data on behalf of health care providers. Instead, our primary relationship is with the user. Under HIPAA, patients have a right to obtain a copy of their medical records. If they choose to use CareCloud, the system will help them store and manage their medical records online. CareCloud will be committed to user privacy and have in place strict data security policies and measures, and ensure that users control access to their information. A user's personal medical records are stored in their secure account and can only be accessed by those the user chooses, and they can revoke access at any time.

This concludes the discussion on the high-level architecture and design considerations for CareCloud. We discussed the individual components in the system – 1) Bluetooth Enabled Personal Health Devices, 2) Smart Phones running Android, and our vision for 3) CareMobile and 4) CareConnect. We also briefly addressed security and privacy considerations in CareCloud.

Chapter 5: Conclusions and Future Work

This report began by introducing the reader to the growing importance of preventative healthcare and telemedicine in today's world. Through Chapters 2, 3, and 4, it walked the reader through a system – CareCloud that aims to help users with remote and preventative healthcare. CareCloud provides patients with a wireless, easy-to-use and secure way to monitor their health data from any of their Bluetooth enabled personal health devices, while also offering the ability to share this data with their authorized caregivers and health care professionals.

In Chapter 2, the report looked at related work and competing platforms to CareCloud. Chapter 3 introduced the reader to the system requirements by discussing the product overview, the product position statement, the product features and non-functional requirements. The author then discussed the top down architecture for CareCloud in Chapter 4, focusing on the individual components of the system. Justifications were presented for choosing Bluetooth as the wireless technology, Android as the mobile platform, and Google App Engine as the cloud platform. The author also discussed privacy (HIPAA), and security considerations in this chapter.

This is an evolving project, and our next steps will be along the implementation of this system. The goal is for CareMobile to be available from the Google Play Store, and CareConnect to be available as a web portal accessible via HTTP. In the future, CareMobile can be made available for more mobile platforms like iOS, Windows Phone etc.

An important direction for future work in the system can be to use data mining algorithms on the stored health data. Collected health data from personal health devices can be very voluminous to be analyzed by manual methods. Data mining can provide the technology to transform this data into useful information for decision-making. It can aid in forecasting potential health problems, and recommend preventative courses of action for the patient. Healthcare professionals can use this information for effective health care.

In conclusion, systems like CareCloud, that integrate with a wide variety of personal health devices, have lot of potential, and the ability to make a positive impact on personal health care.

Bibliography

[KCE14] Joseph Kvedar, Molly Joel Coye, and Wendy Everett, "Connected Health: A Review Of Technologies And Strategies To Improve Patient Care With Telemedicine And Telehealth," Health Affairs 33 (2014): 194-99

[1] Microsoft Health Vault, https://www.healthvault.com/us/en

[2] Google Health, http://www.google.com/intl/en_us/health/about/

[3] iHealthLabs, http://www.ihealthlabs.com/

[4] MyVitals Mobile App, http://www.ihealthlabs.com/ihealth_myvitals_app.htm

[5] myGlucoHealth, http://www.myglucohealth.net/src/wireless.html

[6] Android SDK Versions, http://www.appbrain.com/stats/top-android-sdk-versions

[7] FDA Regulations, http://www.fda.gov/MedicalDevices/DeviceRegulationandGuidance/GuidanceDocuments/ucm077210.htm

[8] IMS Research, https://technology.ihs.com

[9] Bluetooth in Android, http://developer.android.com/reference/android/bluetooth/BluetoothHealth.html

[10] Standards for Personal Health Devices ,http://www.iso.org/iso/catalogue_detail.htm?csnumber=54331

[11] IEEE 11073 standards, https://standards.ieee.org/news/2013/ieee_11073_medical-device_communication.html

[12] A. D. Team. (2007, Nov.) YouTube presentation. [Online], http://www.youtube.com/watch?v=Mm6Ju0xhUW8

[13] Google App Engine, https://developers.google.com/appengine/

[14] Cloud Computing, http://en.wikipedia.org/wiki/Cloud_computing

[15] Windows Azure,

http://azure.microsoft.com/en-us/

[16] Sendgrid,

http://sendgrid.com/

[17] Model View Controller Architecture,

http://en.wikipedia.org/wiki/Model%E2%80%93view%E2%80%93controller

[18] Security in Bluetooth classic

https://developer.bluetooth.org/TechnologyOverview/Pages/Security.aspx