SLEEP APNEA DETECTION

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Certificate of correctness and approval

This is to certify that Sleep Apnea Detection is an original work of Adeel Zafar, Adnan Sharif and Simmal Pasha, any contribution for research purpose is explicitly acknowledged in the thesis and that in my opinion it meets the criteria of approving the thesis in the partial fulfillment of the requirements of Computer Software Engineering, Military College of Signals, NUST.

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Abstract

Sleep Apnea Syndrome occurs due to the when the glands in the mouth relax further into the throat while sleeping causing blockage in the breathing passage resulting in pauses or apnea. This “pause” may last from 10 to over 30 seconds jolting the patient out of sleep. To detect if the person has apnea a sleep study known as polysomnography (PSG) is conducted in the hospitals where the patient stays overnight and the breathing pattern of the patient is studied.

The Android application serves as a replacement of polysomnography, it allows users to monitor themselves in their sleep to detect sleep apnea. The system uses three sensors, a finger probe, a stretch sensor and a breath rate sensor. The android application is going to record these readings from hardware device to monitor patient during sleep. Android application is being developed using Eclipse and SDK 3.0.The recordings of all three sensors will be passed through the microcontroller over Bluetooth to the android application which will maintain graphs of these readings.

When sleep apnea is detected the application sounds an alarm. It will also maintain the history of the patient which can be viewed by the doctor and will also detect how severe apnea is. The product will help out the sleep apnea patients to monitor themselves in sleep at their homes. It provides efficient, convenient and flexible sleep monitoring for personal use.

Dedication

Dedicated to our parents and mentors who have been a constant source of encouragement and inspiration for us.

Acknowledgements

In the name of Allah, the most gracious, the most merciful

All praises and glory to Almighty Allah who gave the strength in completing this work. We are grateful and would like to express our gratitude to our supervisor Assistant Professor Athar Mohsin Zaidi for his guidance, continued encouragement and constant support in making this project possible.

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1 Introduction

1.1 Background

Sleep apnea is a sleep disorder characterized by pauses in breathing or instances of shallow or infrequent breathing during sleep. Each pause in breathing, called an apnea, can last for several seconds to several minutes, and may occur, by definition, at least 5 times in an hour. Traditionally apnea is determined by a sleep study carried out by the hospitals where the patient's readings are taken during his sleep. Thousands of people are affected by apnea, the cases are more because most of the people are not aware that they have sleep apnea.

Obstructive sleep apnea occurs when the muscles in the back of your throat relax. These muscles support the soft palate, the triangular piece of tissue hanging from the soft palate (uvula), the tonsils, the side walls of the throat and the tongue. When the muscles relax, your airway narrows or closes as you breathe in, and you can't get an adequate breath in. This may lower the level of oxygen in your blood. Your brain senses this inability to breathe and briefly rouses you from sleep so you can reopen your airway. This awakening is usually so brief that you don't remember it. You may make a snorting, choking or gasping sound. This pattern can repeat itself five to 30 times or more each hour, all night long. These disruptions impair your ability to reach the desired deep, restful phases of sleep, and you'll probably feel sleepy during your waking hours. People with obstructive sleep apnea may not be aware that their sleep was interrupted. In fact, some people with this type of sleep apnea think they sleep well all night.

Central sleep apnea, which is much less common, occurs when your brain fails to transmit signals to your breathing muscles. You may awaken with shortness of breath or have a difficult time getting to sleep or staying asleep. Like with obstructive sleep apnea, snoring and daytime sleepiness can occur. The most common cause of central sleep apnea is heart failure and, less commonly, a stroke. People with central sleep apnea may be more likely to remember awakening than are people with obstructive sleep apnea.

1.2 Project Overview

The system serves as a replacement of Polysomnography **(**PSG), which is a manual technique used for sleep monitoring. **PSG** is a complex technique only carried out by experts to monitor sleep apnea. Polysomnography is a comprehensive recording of the biophysiological changes that occur during sleep. It is usually performed at night, when most people sleep, though some labs can accommodate shift workers and people with circadian rhythm sleep disorders and do the test at other times of day. The PSG monitors many body functions including brain (EEG), eye movements (EOG), muscle activity or skeletal muscle activation (EMG) and heart rhythm (ECG) during sleep. After the identification of the sleep disorder sleep apnea in the 1970s, the breathing functions respiratory airflow and respiratory effort indicators were added along with peripheral pulse oximetry.

The proposed system introduces a way of viewing, recording, analyzing sleep study patterns by the patient himself. The system displays all the information with help of graphs, charts and tables for easy reading of the patient as well as the doctor.

Three sensors are used for making the device, a SPo2 sensor, which determines the blood oxygen level in the body of the patient, an air flow sensor which determines the rate of flow of air and a stretch band sensor which determines the compressions and stretches of the abdomen. The readings from all three sensors are used to detect of sleep apnea has occurred. In case of emergency the application also sounds an alarm.

1.3 Objectives

The objective of this project is to develop a device which can be used for smoothly conducting the sleep study for determining apnea. The device can be used by patients at their home instead if going to the hospital for conducting sleep study. Three sensors can be used easily by the patient for recording the readings and later present them to the doctor. The device also records the severity with which apnea is occurring and the device is built to sound an alarm in case apnea is occurred to wake up the patient.

Also a SMS feature is developed in the case of patient wanting to send an alert to hospital or a relative in case of emergency.

1.4 Proposed Model

The solution model is an Android application which is used for recording the readings and maintaining the patient's history as well as maintaining live graphs. An Arduino device is used for processing the values from the sensors and as well as sending these processed values over Bluetooth to the application. Figure 1-1 shows the general diagram of the system.

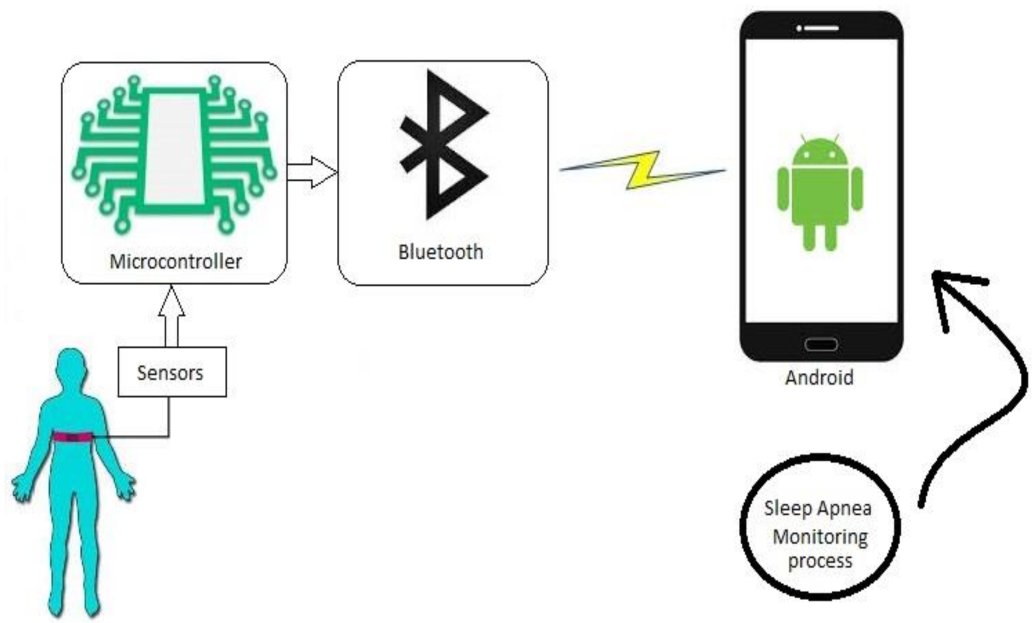

Figure 0-1 General Diagram of the system

The figure shows the patient wearing three sensors which take these readings and pass them to the connected microcontroller which will convert these readings and pass them over Bluetooth to the Android device.

The device is built for personal use by the doctor and the patient. It can be taken by patient at home and still perform the sleep study that requires the patient to go to hospital for it. Discussed below are the few introduced features in our device that are not yet available in the systems that are in the market.

The device will maintain the apnea history of the patient and saving the readings in the device for the doctor to see. The device is built to sound an alarm (if the patient has customized it) in case of apnea occurs to wake up the patient.

Also, the device provides the function of sending an SMS in case emergency is occurred and the patient needs help. This device unlike other devices which only use one sensor SAD uses a combination of 3 different sensors for taking the readings for getting more accurate and precise readings of the current condition of the patient. The device also display the severity with which apnea has occurred till the last time the patient wore the device and with the help of it tell if the apnea occurring is sever or mild.

1.5 Applications

This device can be used by the apnea patients to monitor them, as well as by the doctor to conduct the sleep study. It is software alternate to the sleep study and will help overcome the wastage of paper used in writing the readings of the patient while monitoring him.

It helps in reducing the man-power as well by taking all the readings and storing it itself.

Also the device has three different sensors which might be re-used in another medical application as well as it can be re-used as whole to serve as a sub-system in a device with a larger scope.

1.6 Organization of the document

This thesis will cover the literature review of the project in the second chapter, in chapter three and four it will cover the system requirements and system design, test cases are discussed in chapter five and future work and conclusion is discussed under chapter six and seven respectively.

Each chapter starts with introduction of that chapter and ends with a conclusion that sums the headings discussed in that respective chapter.

2 Literature Review

2.1 Introduction

This chapter will discuss in detail about what sleep apnea is and how many people are affected by it. It will also cover what work so far has been done on this topic and also discusses the new features introduced by this project.

2.2 Sleep Apnea

Sleep apnea affects the way you breathe when you're sleeping. These breathing pauses, each of the pauses called as apnea, typically last between 10 to 20 seconds and can occur up to hundreds of times a night. During an obstructive sleep apnea episode, the diaphragm and chest muscles work harder to open the obstructed airway and pull air into the lungs. Breathing usually resumes with a loud gasp, snort, or body jerk. These episodes can interfere with sound sleep. They can also reduce the flow of oxygen to vital organs and cause irregular heart rhythms. Figure 2-1 shows the difference between a normal person and a apnea patient.

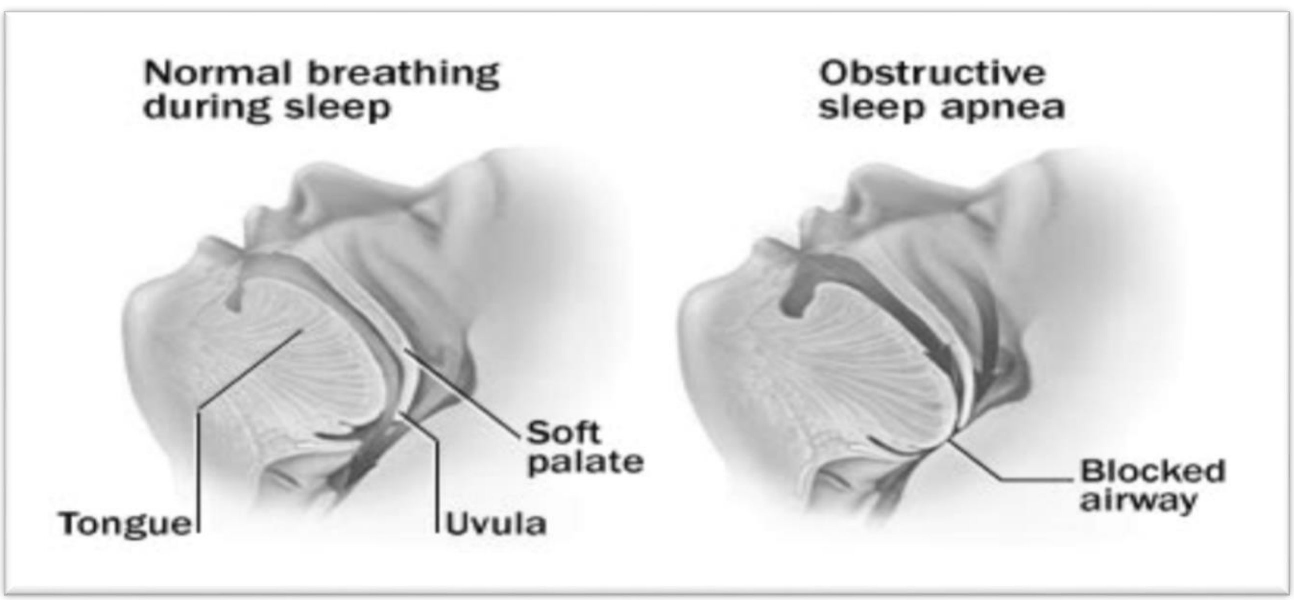

Figure 2-1 Diagram showing the contrast of a normal person and a sleep apnea patient

As a consequence, you spend more time in light sleep and less time in the deep, restorative sleep you need to be energetic, mentally sharp, and productive the next day. This chronic sleep deprivation results in daytime sleepiness, slow reflexes, poor concentration, and an increased risk of accidents. Sleep apnea can also lead to serious health problems over time, including diabetes, high blood pressure, heart disease, stroke, and weight gain.

2.2.1 Types of apnea

2.2.1.1 Obstructive Sleep Apnea

Obstructive sleep apnea (OSA) is the most common category of sleep-disordered breathing. The muscle tone of the body ordinarily relaxes during sleep, and at the level of the throat the human airway is composed of collapsible walls of soft tissue which can obstruct breathing during sleep. Mild occasional sleep apnea, such as many people experience during an upper respiratory infection, may not be important, but chronic severe obstructive sleep apnea requires treatment to prevent low blood oxygen (hypoxemia), sleep deprivation, and other complications.

Individuals with low muscle tone and soft tissue around the airway (e.g., because of obesity) and structural features that give rise to a narrowed airway are at high risk for obstructive sleep apnea. The elderly are more likely to have OSA than young people. Men are more likely to suffer sleep apnea than women and children are, though it is not uncommon in the last two population groups.

The risk of OSA rises with increasing body weight, active smoking and age. In addition, patients with diabetes or "borderline" diabetes have up to three times the risk of having OSA.

Common symptoms include loud snoring, restless sleep, and sleepiness during the daytime. Diagnostic tests include home oximetry or polysomnography in a sleep clinic.

Some treatments involve lifestyle changes, such as avoiding alcohol or muscle relaxants, losing weight, and quitting smoking. Many people benefit from sleeping at a 30-degree elevation of the upper body or higher, as if in a recliner. Doing so helps prevent the gravitational collapse of the airway. Lateral positions (sleeping on a side), as opposed to supine positions (sleeping on the back), are also recommended as a treatment for sleep apnea largely because the gravitational component is smaller in the lateral position. Some people benefit from various kinds of oral appliances such as the Mandibular advancement splint to keep the airway open during sleep. Continuous positive airway pressure (CPAP) is the most effective treatment for severe obstructive sleep apnea but oral appliances are considered a first line approach equal to CPAP for mild to moderate sleep apnea according to the AASM parameters of care. There are also surgical procedures to remove and tighten tissue and widen the airway.

Snoring is a common finding in people with this syndrome. Snoring is the turbulent sound of air moving through the back of the mouth, nose, and throat. Although not everyone who snores is experiencing difficulty breathing, snoring in combination with other conditions such as overweight and obesity has been found to be highly predictive of OSA risk. The loudness of the snoring is not indicative of the severity of obstruction, however. If the upper airways are tremendously obstructed, there may not be enough air movement to make much sound. Even the loudest snoring does not mean that an individual has sleep apnea syndrome. The sign that is most suggestive of sleep apneas occurs when snoring stops.

Other indicators include (but are not limited to): hypersomnolence, obesity BMI >30, large neck circumference (16 in (410 mm) in women, 17 in (430 mm) in men), enlarged tonsils and large tongue volume, micrognathia, morning headaches, irritability/mood-swings/depression, learning and/or memory difficulties, and sexual dysfunction.

The term "sleep-disordered breathing" is commonly used in the U.S. to describe the full range of breathing problems during sleep in which not enough air reaches the lungs (hypopnea and apnea). Sleep-disordered breathing is associated with an increased risk of cardiovascular disease, stroke, high blood pressure, arrhythmias, diabetes, and sleep deprived driving accidents. When high blood pressure is caused by OSA, it is distinctive in that, unlike most cases of high blood pressure (so-called essential hypertension), the readings do *not* drop significantly when the individual is sleeping.Stroke is associated with obstructive sleep apnea.

It has been revealed that people with OSA show tissue loss in brain regions that help store memory, thus linking OSA with memory loss. Using magnetic resonance imaging (MRI), the scientists discovered that sleep apnea patients' mammillary bodies were nearly 20 percent smaller, particularly on the left side. One of the key investigators hypothesized that repeated drops in oxygen lead to the brain injury.

2.2.1.2 Central Sleep Apnea

In pure central sleep apnea or Cheyne–Stokes respiration the brain's respiratory control centers are imbalanced during sleep. Blood levels of carbon dioxide, and the neurological feedback mechanism that monitors them, do not react quickly enough to maintain an even respiratory rate, with the entire system cycling between apnea and hyperpnea, even during wakefulness. The sleeper stops breathing and then starts again. There is no effort made to breathe during the pause in breathing: there are no chest movements and no struggling. After the episode of apnea, breathing may be faster (hyperpnea) for a period of time, a compensatory mechanism to blow off retained waste gases and absorb more oxygen.

While sleeping, a normal individual is "at rest" as far as cardiovascular workload is concerned. Breathing is regular in a healthy person during sleep, and oxygen levels and carbon dioxide levels in the bloodstream stay fairly constant. The respiratory drive is so strong that even conscious efforts to hold one's breath do not overcome it. Any sudden drop in oxygen or excess of carbon dioxide (even if tiny) strongly stimulates the brain's respiratory centers to breathe.

In central sleep apnea, the basic neurological controls for breathing rate malfunction and fail to give the signal to inhale, causing the individual to miss one or more cycles of breathing. If the pause in breathing is long enough, the percentage of oxygen in the circulation will drop to a lower than normal level (hypoxaemia and the concentration of carbon dioxide will build to a higher than normal level (hypercapnia). In turn, these conditions of hypoxia and hypercapnia will trigger *additional* effects on the body. Brain cells need constant oxygen to live, and if the level of blood oxygen goes low enough for long enough, the consequences of brain damage and even death will occur. Fortunately, central sleep apnea is more often a chronic condition that causes much milder effects than sudden death. The exact effects of the condition will depend on how severe the apnea is and on the individual characteristics of the person having the apnea. Several examples are discussed below, and more about the nature of the condition is presented in the section on Clinical Details.

In any person, hypoxia and hypercapnia have certain common effects on the body. The heart rate will increase, unless there are such severe co-existing problems with the heart muscle itself or the autonomic nervous system that makes this compensatory increase impossible. The more translucent areas of the body will show a bluish or dusky cast from cyanosis, which is the change in hue that occurs owing to lack of oxygen in the blood ("turning blue"). Overdoses of drugs that are respiratory depressants (such as heroin, and other opiates) kill by damping the activity of the brain's respiratory control centers. In central sleep apnea, the effects of sleep *alone* can remove the brain's mandate for the body to breathe.

Normal Respiratory Drive: After exhalation, the blood level of oxygen decreases and that of carbon dioxide increases. Exchange of gases with a lungful of fresh air is necessary to replenish oxygen and rid the bloodstream of built-up carbon dioxide. Oxygen and carbon dioxide receptors in the blood stream (called chemoreceptors) send nerve impulses to the brain, which then signals reflex opening of the larynx (so that the opening between the vocal cords enlarges) and movements of the rib cage muscles and diaphragm. These muscles expand the thorax (chest cavity) so that a partial vacuum is made within the lungs and air rushes in to fill it.

2.2.1.3 Physiologic effects of central apnea

During central apneas, the central respiratory drive is absent, and the brain does *not* respond to changing blood levels of the respiratory gases. No breath is taken despite the normal signals to inhale. The immediate effects of central sleep apnea on the body depend on how long the failure to breathe endures. At worst, central sleep apnea may cause sudden death. Short of death, drops in blood oxygen may trigger seizures, even in the absence of epilepsy. In people *with* epilepsy, the hypoxia caused by apnea may trigger seizures that had previously been well controlled by medications. In other words, a seizure disorder may become unstable in the presence of sleep apnea. In adults with coronary artery disease, a severe drop in blood oxygen level can cause angina, arrhythmias, or heart attacks (myocardial infarction). Longstanding recurrent episodes of apnea, over months and years, may cause an increase in carbon dioxide levels that can change the pH of the blood enough to cause a metabolic acidosis.

2.2.1.4 Mixed apnea and complex sleep apnea

Some people with sleep apnea have a combination of both types; its prevalence ranges from 0.56% to 18%. The condition is generally detected when obstructive sleep apnea is treated with CPAP and central sleep apnea emerges. The exact mechanism of the loss of central respiratory drive during sleep in OSA is unknown but is most likely related to incorrect settings of the CPAP treatment and other medical conditions the person has.

2.3 Existing Systems

Discussed below are the two projects MIR Spirodoc and a project presented in FICS NUST, which are similar to this project, in their working or by the hardware that is used in these projects. Following paragraphs give a summary of what these respective projects where and what was accomplished by them.

2.3.1 MIR Spirodoc

MIR Spirodoc, is a device with detects the oxygen level of the patient’s blood. The oxygen level drops significantly low when apnea occurs, the device displays this oxygen level of the patient, built using the SpO2 sensor. Also it displays the current oxygen saturation level on the mobile screen.

2.3.2 FICS, NUST

A project was presented by BEE-2, SEECS students in FICS (Finding innovative and creative solutions) competition held in NUST in 2014, which got readings using Arduino and other sensors. Similar to how measurements from sensors will be passed over Bluetooth in our system using Arduino.

2.4 Issues that are addressed by our project

The device is built for personal use by the doctor and the patient. It can be taken by patient at home and still perform the sleep study that requires the patient to go to hospital for it. Discussed below are the few introduced features in our device that are not yet available in the systems that are in the market.

2.4.1 Maintain patient history for the doctor

The device will maintain the apnea history of the patient and saving the readings in the device for the doctor to see.

2.4.2 Generating Alarm and sending SMS

The device is built to sound an alarm (if the patient has customized it) in case of apnea occurs to wake up the patient.

Also, the device provides the function of sending an SMS in case emergency is occurred and the patient needs help.

2.4.3 Use of multiple sensors

This device unlike other devices which only use one sensor SAD uses a combination of 3 different sensors for taking the readings for getting more accurate and precise readings of the current condition of the patient.

2.4.4 Indicate the severity of apnea

The device also display the severity with which apnea has occurred till the last time the patient wore the device and with the help of it tell if the apnea occurring is sever or mild.

2.5 Conclusion

Sleep apnea can cause serious health issues. The device is unique introducing features of maintain the patient history, generating alarm and sending SMS, using multiple sensors and indicating the severity of apnea. Types of apnea are briefly discussed with possible symptoms and their effects.

3 System Requirements

3.1 Introduction

This chapter will cover in detail the functional requirements of the system in detail. Each major function with its function requirements is discussed separately. Non-functional requirements and the system constraints are mentioned which define the project.

3.2 Functional Requirements

The functional requirements of the system are distributed by the system features that the application provides.

3.2.1 Turn on Bluetooth

This is first function identified of the project discussed below is the description and the functional requirements that are derived from this function.

3.2.1.1 Description

This function will allow the user to turn on Bluetooth. This function is of high priority because most of the functions are dependent upon the connectivity of the Bluetooth.

3.2.1.2 Stimulus/ Response Sequences

3.2.1.2.1 Press the Bluetooth button to turn it on.

3.2.1.2.2 After the Bluetooth is turned on user will be notified about it on the screen.

3.2.1.2.3 If the Bluetooth is already on it will show the message on screen that Bluetooth is already on.

3.2.1.3 Functional Requirements

REQ-4.1.3.1: The system shall be able to identify if the Bluetooth is on or off.

REQ-4.1.3.2: The system shall not allow the user to perform any functions which are done over Bluetooth if Bluetooth is off.

REQ-4.1.3.3: If the Bluetooth is not turned on even after pressing the Bluetooth button the system shall generate an error message.

3.2.2 Connect with Integrated Sensors Module

This is the second function identified of the project discussed below is the description and the functional requirements that are derived from this function.

3.2.2.1 Description

This function would connect the Android device's Bluetooth to the integrated sensor module's Bluetooth to enable communication between Android and hardware sensor device.

This function is of high priority because Bluetooth connection between Android device and hardware device is necessary to pass sensors data for further processing on data.

3.2.2.2 Stimulus/ Response Sequences

3.2.2.2.1 System shall search for Bluetooth connections.

3.2.2.2.2 Select the Bluetooth connection of the sensor module.

3.2.2.2.3 System shall then connect with the Bluetooth.

3.2.2.2.4 System shall update connection status as connected.

3.2.2.3 Functional Requirements

REQ-4.2.3.1: The system shall be able to search Bluetooth devices available in area.

REQ-4.2.3.2: If the Bluetooth is not turned on the system shall prompt the user to turn on Bluetooth first before searching for connection.

REQ-4.2.3.3: If the Bluetooth is connected it shall show status as connected.

REQ-4.2.3.4: If the system is unable to connect to Bluetooth it shall show the error message on the screen of android phone.

3.2.3 Read Sensors Data

This is the third function identified of the project discussed below is the description and the functional requirements that are derived from this function.

3.2.3.1 Description

This function would collect data from sensors and then send sensors data via Bluetooth to android phone. This feature is of high priority because all other functions of application are dependent upon the data received from the sensors.

3.2.3.2 Stimulus/ Response Sequences

3.2.3.2.1 Press the button to get values from the sensors.

3.2.3.2.2 System checks whether the sensors are working or not.

3.2.3.2.3 Sensors get runtime values from user's body and pass the values to Android phone via Bluetooth.

3.2.3.3 Functional Requirements

REQ-4.3.3.1: The system shall provide the option to connect to sensors.

REQ-4.3.3.2: The system shall be able to check available sensors.

REQ-4.3.3.3: The system shall be able to check connectivity issues of the sensors.

REQ-4.3.3.4: The system shall be able to generate error message in case of connectivity issue.

REQ-4.3.3.5: If the error is generated the system shall ask the user to try again after checking issues.

3.2.4 Monitor Data

This is the fourth function identified of the project discussed below is the description and the functional requirements that are derived from this function.

3.2.4.1 Description

This function would start monitoring data received from sensors in order to detect sleep apnea. This feature would periodically check the breath rate, pulse and SpO2 values and compare them together to see if there is possibility of apnea or not. This function is of high priority as it is the monitoring processes to detect sleep apnea which leads to other functions.

3.2.4.2 Stimulus/ Response Sequences

3.2.4.2.1 Select the start monitoring option from menu.

3.2.4.2.2 System shall store sensor values in database.

3.2.4.2.3 System shall compare values with set standards (already stored in the database) to detect sleep apnea.

3.2.4.3 Functional Requirements

REQ-4.4.3.1: The system shall be able to access database to store sensor data.

REQ-4.4.3.2: The system shall generate an error message if the database is not accessible.

REQ-4.4.3.3: The system uses internal memory to store data, it shall generate an error message in case of insufficient memory.

3.2.5 Generate Alarm

This is the fifth function identified of the project discussed below is the description and the functional requirements that are derived from this function.

3.2.5.1 Description

This feature shall generate alarm if sleep apnea is detected. In case if apnea has occurred user shall be informing of critical situation and system would do it by generating an alarm.

This function is of high priority because informing the patient of any discrepancy is sole purpose of application.

3.2.5.2 Stimulus/ Response Sequences

3.2.5.2.1 The system shall monitor data continuously.

3.2.5.2.2 The system shall compares all sensor values periodically.

3.2.5.2.3 In case of extreme discrepancy an alarm shall generated by the application.

3.2.5.3 Functional Requirements

REQ-4.5.3.1: The system shall be able to access android alarm service to generate alarm.

REQ-4.5.3.2: If alarm is triggered, the system shall provide the option to turn off alarm.

3.2.6 Generate SMS Alert

This is the sixth function identified of the project discussed below is the description and the functional requirements that are derived from this function.

3.2.6.1 Description

This feature shall generate SMS alert to the user specified emergency number if sleep apnea is detected. This function is of medium priority because it is up to the user if they want to send an SMS to someone or not.

3.2.6.2 Stimulus/ Response Sequences

3.2.6.2.1 The system shall monitor and compare sensor data values to set standard (already stored in the database).

3.2.6.2.2 The system shall be able to detect sleep apnea.

3.2.6.2.3 The system shall generate a SMS alert to the emergency number.

3.2.6.3 Functional Requirements

REQ-4.6.3.1: The user shall have to specify emergency number in application.

REQ-4.6.3.2: The system shall be able to access emergency contact number.

REQ-4.6.3.3: The system shall send SMS to emergency number which shall be an emergency message.

REQ-4.6.3.4: If the system is unable to send SMS alert in case of insufficient balance or wrong number the system shall generate an error message to inform user accordingly.

3.2.7 Save Record

This is the seventh function identified of the project discussed below is the description and the functional requirements that are derived from this function.

3.2.7.1 Description

This feature saves record and history of the patient about sleep apnea in database. The record shall contain time/ date details and sensor values of the patient when sleep apnea occurred. This feature shall allow the user to analyze the severity of sleep apnea by maintaining complete history of patient. This function is of high priority because giving the patient an overview of his/her health is important.

3.2.7.2 Stimulus/ Response Sequences

3.2.7.2.1 The system shall be able to detect sleep apnea.

3.2.7.2.2 The system shall read time and date from phone.

3.2.7.2.3 The system shall record the sensor values.

3.2.7.2.4 The system shall save these details in database.

3.2.7.3 Functional Requirements

REQ-4.7.3.1: The system shall be able to read date and time values from the phone's clock service.

REQ-4.7.3.2: The system shall be able to access database to save record.

REQ-4.7.3.3: In case of low internal memory to save data the system shall generate an error message telling the user that memory is low.

3.2.8 Show Records

This is the eighth function identified of the project discussed below is the description and the functional requirements that are derived from this function.

3.2.8.1 Description

This feature shall provide the user with an option to get report of his/ her history and record of sleep apnea. The "report" shall contain a graph showing frequency of sleep apnea. It would also show severity level of sleep apnea based on history.

This function is of medium priority because it is user's choice if he want to see report or not. Other features of system are not dependent upon it.

3.2.8.2 Stimulus/ Response Sequences

3.2.8.2.1 Select the show record option from menu.

3.2.8.2.2 The system shall display the records in tabular form.

3.2.8.2.3 Select show history option.

3.2.8.2.4 The system shall display the history in graphical form.

3.2.8.2.5 Severity level shall also be displayed alongside the graph.

3.2.8.2.6 Select clear history button to clear all records.

3.2.8.3 Functional Requirements

REQ-4.8.3.1: The system shall be able to access database to get saved records.

REQ-4.8.3.2: If there are no records available the system shall show user that record is empty.

REQ-4.8.3.3: The system shall clear all record and history if the user selects to clear record.

REQ-4.8.3.4: If some error occurs while generating history report it shall show error message by terminating the process and shall return to main menu.

3.2.9 Show Graphs

This is the ninth function identified of the project discussed below is the description and the functional requirements that are derived from this function.

3.2.9.1 Description

This feature shall provide the user with an option to see live graphs of sensors readings from his/ her body. It shows live graph view of pulse, breath rate and SpO2 so that users can see what is going on with patient. This function is of medium priority because this option is for persons who are analyzing patient, not for patient itself.

3.2.9.2 Stimulus/ Response Sequences

3.2.9.2.1 Select show graph option from patient.

3.2.9.2.2 System shall display the data coming from sensors in the form of graphs.

3.2.9.3 Functional Requirements

REQ-4.9.3.1: The system shall be able get data from sensors.

REQ-4.9.3.2: If there is some connectivity issue the system shall generate error message to inform the user.

3.2.10 Set Alarm

This is the tenth function identified of the project discussed below is the description and the functional requirements that are derived from this function.

3.2.10.1 Description

This feature shall provide the user with an option to set alarm of his/ her choice as an alert.

This function is of low priority because default alarm would be already set and this option only provides the user with a choice.

3.2.10.2 Stimulus/ Response Sequences

3.2.10.2.1 Select the setting option.

3.2.10.2.2 Select set alarm option.

3.2.10.2.3 Select the alarm tone from the list.

3.2.10.2.4 Press the save button.

3.2.10.3 Functional Requirements

REQ-4.10.3.1: The system shall be able get alarm tones from user files.

REQ-4.10.3.2: After pressing save button the system shall display the message of the successful change in alarm tone.

3.2.11 Set Emergency Number

This is the eleventh function identified of the project discussed below is the description and the functional requirements that are derived from this function.

3.2.11.1 Description

This feature shall provide the user with an option to set emergency of his/ her choice for SMS alert.

This function is of medium-high priority because if emergency number is not set it would not be able to send an SMS alert.

3.2.11.2 Stimulus/ Response Sequences

3.2.11.2.1 Select the setting option.

3.2.11.2.2 Select the set emergency number option.

3.2.11.2.3 Enter the emergency number in the text field or select from the list.

3.2.11.2.4 Press the save button.

3.2.11.3 Functional Requirements

REQ-4.11.3.1: The system shall be able get contact numbers form phonebook.

REQ-4.11.3.2: After pressing save button the system shall display the message that emergency number was successfully saved.

3.2.12 Open Help Document

This is the twelfth function identified of the project discussed below is the description and the functional requirements that are derived from this function.

3.2.12.1 Description and Priority

This feature shall provide the user with an option to open and read help document about the product functions. This feature is of medium priority since it allows the user to learn the different features of the system.

3.2.12.2 Stimulus/ Response Sequences

3.2.12.2.1 Select the Help option from menu.

3.2.12.2.2 The help document opens.

3.2.12.3 Functional Requirements

REQ-4.12.3.1: The system shall be able to get saved help file in database and open it for user's assistance.

3.2.13 Exit the System

This is the thirteenth function identified of the project discussed below is the description and the functional requirements that are derived from this function.

3.2.13.1 Description and Priority

This feature shall allow the user to exit the system or close the application.

This feature is of low priority.

3.2.14 Stimulus/ Response Sequences

3.2.14.1.1 Select one of the following options to exit the system.

3.2.14.1.2 Select "Exit" from the main menu.

3.2.14.1.3 Press the "←" button on to your phone while in main menu

3.2.14.1.4 Selecting either option shall shutdown the system.

3.2.14.1.5 Shutting the system down will disconnect from the sensors module.

3.2.14.2 Functional Requirements

REQ-4.13.3.1.: In case there is some unsaved data, the system shall ask the user if he wishes to save it before closing the application.

3.3 Non-Functional Requirements

Non-functional requirements are discussed separately under the headings of performance, safety, security and software quality attributes.

3.3.1 Performance Requirements

Performance requirements of the system are:

3.3.1.1 Response time

Bluetooth 2.1 has an average latency of 6ms. So approximate response time from sensors is 12ms (6ms×2).

3.3.1.2 Accuracy

3.3.1.2.1 90 to 95 percent of the readings shall be accurate, for an inaccurate reading may result in recording of false data.

3.3.1.2.2 Accuracy of the readings depends upon the placement of the sensor. Wrongly placed sensors may result in false recording of data.

3.3.1.3 Resource usage

Application requires a minimum of 500Mb of RAM and 128Mb of memory. Lower RAM may result in slow running of the application.

3.3.2 Safety Requirements

There is no possible loss, damage, or harm that could result from the use of the product. The application will not affect any other applications installed on the user's phone nor cause any harm to any components of the phone.

3.3.3 Security Requirements

The owner shall be able to add valid emergency number(s) of people who shall be alarmed in case apnea occurs.

The application shall have the security signatures embedded in the ".apk" file.

3.3.4 Software Quality Attributes

Software quality attributes to be achieved by the project are as follows:

3.3.4.1 Adaptability

3.3.4.1.1 The application is designed for devices using version 3.0 and can be used on any device using version above 3.0.

3.3.4.1.2 With the installation of a new release, the user records that were maintained in the previous version shall remain unchanged.

3.3.4.2 Availability

The application shall be available 24/7 provided that the user has installed the application and all the sensors are powered on.

3.3.4.3 Portability

The application shall be downloadable from the play store for all the devices using version 3.0 or above of android.

3.3.4.4 Usability

3.3.4.4.1 People, who are familiar with android, shall have no problem using the application. Even so people who are not familiar with android shall be able to use the application by their second attempt. 90% of the people shall be able to use the sensors and place them correctly by their third attempt in less than 10 minutes.

3.3.4.4.2 A helping document shall be available, assisting the user how to use the system.

3.4 Design and implementation constraints

Design and implementation constraints observed are discussed under two main headings, one under the architecture pattern and second under the design pattern.

3.4.1 Architecture Pattern

Architecture pattern that is used in this project is layered and the constraints observed are as discussed below:

3.4.1.1 Software Design Principles followed

We have followed the principles of software design such as the Information Hiding Principle, Single Responsibility Principle and the Open-Closed Principle.

3.4.1.1.1 Following Information Hiding Principle - Abstraction

Information hiding principle states that "Each module has a defined public interface through which all external access must occur and that a module's internal structure should be protected from external access". In our design we have ensured that each of our sub-components have a separate interface and other components will interact with the component using its interface.

3.4.1.1.2 Following Single Responsibility Principle – Modularity

Single responsibility principle states that "each class should have one responsibility". In our design this principle is kept in mind while drawing out our class diagram so that each class only perform one major task.

3.4.1.1.3 Following Open-Closed Principle

The open-closed principle states "that the modules are open for extension and modules are closed for modification". Let's take an example of adding more sensors in the system for accuracy, this will require the front-end layer to be extended to fit in the new sensor, no modification in the existing code will occur, new features will be handled by the new classes.

3.4.2 Using Layered architecture pattern

Layered architecture is used because the system is a pervasive system and secondly because the architecture of android is layered.

3.4.3 Design Pattern

The design pattern used for sleep apnea android application is Façade.

3.4.4 The FAÇADE Principle

Façade is a design pattern in which façade is a class that provide simplified user interface to user and hide all other logical complex details. User only interact with façade and façade control all the classes and sub components.

3.4.4.1 Why we used FAÇADE?

Façade pattern is useful when there is layering involved. As the architectural pattern is layered, so purpose is to hide complex details from user and provide user with simplified user interface.

A segment of the client community needs a simplified interface to the overall functionality of a complex subsystem.

3.4.4.1.1 Structure of Façade

This pattern involves a single class which provides simplified methods which are required by client and delegates calls to existing system class methods figure 3-1 shows the general class pattern of Façade pattern.

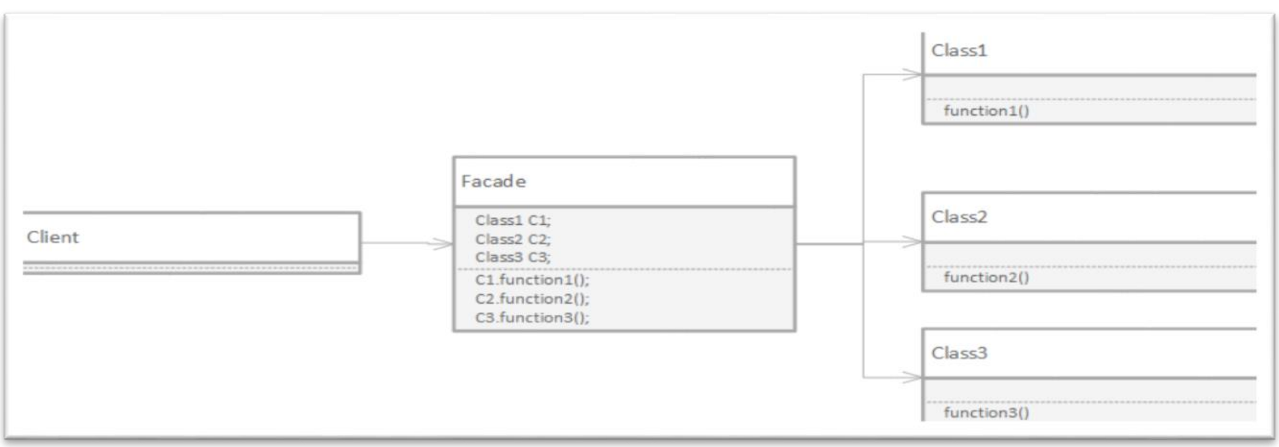

Figure 3-1 The general class diagram of the Façade pattern

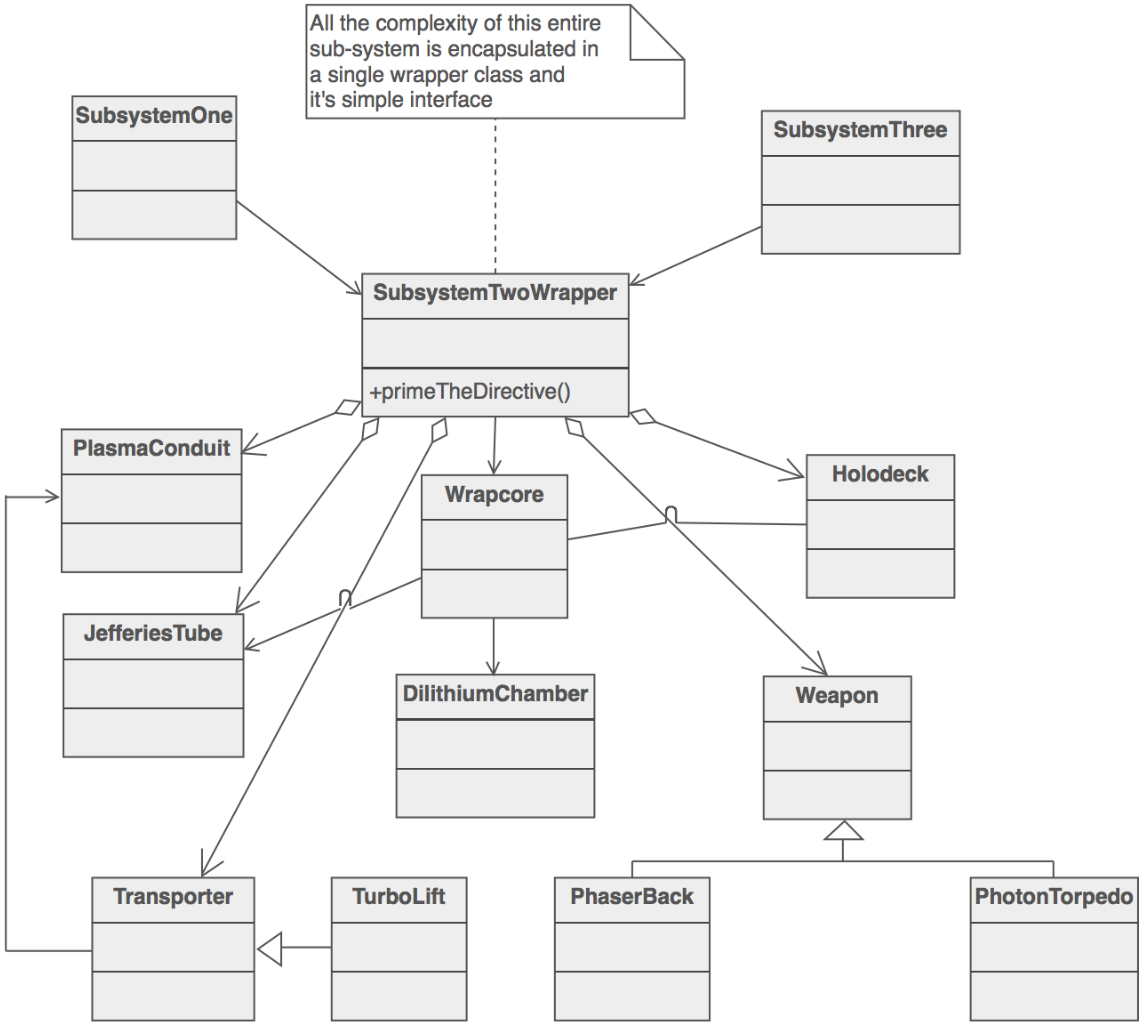

Figure 3-2 Façade pattern class diagram

The Class diagram is exactly according to this pattern MainActivity is the class that is acting as Façade, MainActivity then call to subsequent classes to perform tasks while providing simplified interface and hiding complexities. (Refer to Class Diagram).

Sequence diagram in façade pattern is such that the client interacts with Façade object and then façade object call other classes functions. As shown in figure 3-4.

In the sequence diagrams of the system exactly this is the scenario. User only interact with MainActivity object and then main Activity object call to subsequent functions figure 3-3 shows one of the sequence diagrams as an example.

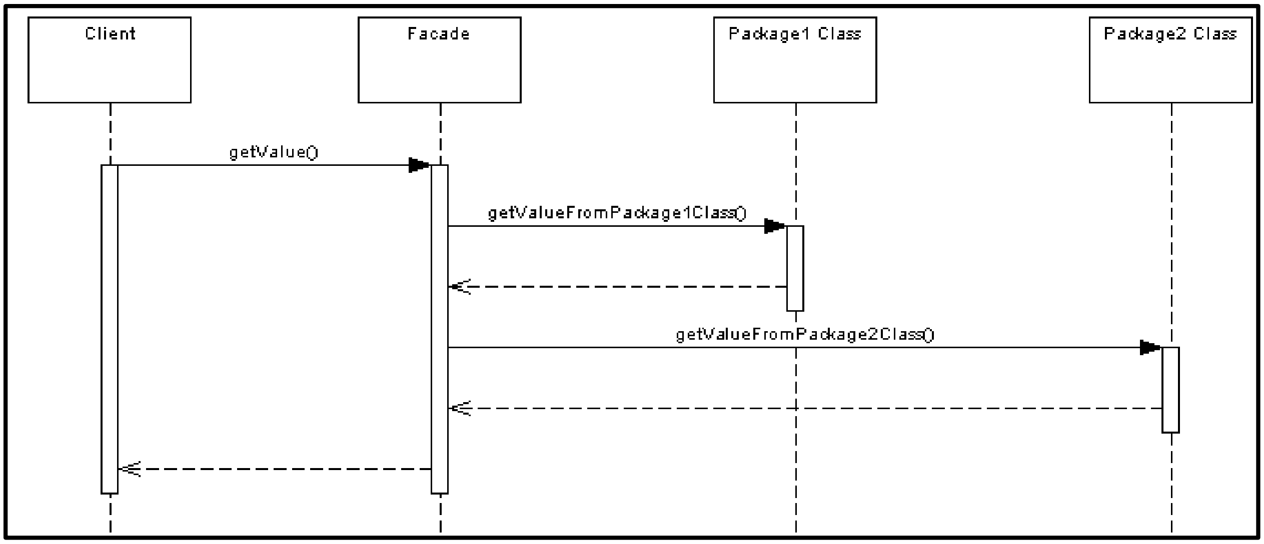

Figure 3-3 Sequence diagram showing the class interactions in a façade pattern

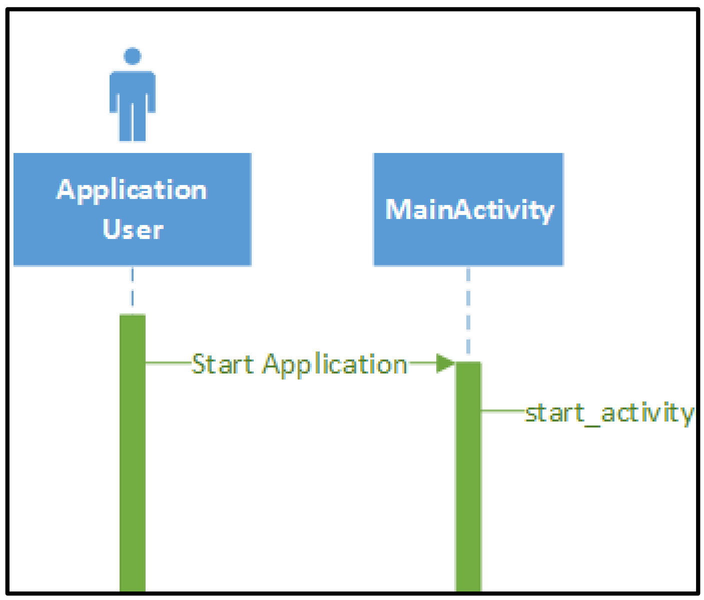

Figure 3-4 Sequence diagram of our system showing how it relates to façade

3.5 Conclusion

The functional and non-functional requirements of the project are discussed. Also the constraints on the system that are imposed by the architecture pattern and the design patter are discussed and how they affect the project.

4 System Design and Development

4.1 Introduction

This chapter covers the design of the system it explains over a series of diagrams which is more important. System architecture is discussed then based on the basic architecture rest of the diagrams are drawn.

4.2 System Architecture

First the choice of architecture pattern used in explained then the component diagram based on the architecture diagram is discussed.

4.2.1 Architecture Diagram

For this project SAD, we used layered pattern for the architecture. The system is divided in three layers, presentation/front end layer, application logic layer and database layer. The figure 4-1 shows the architecture of the system.

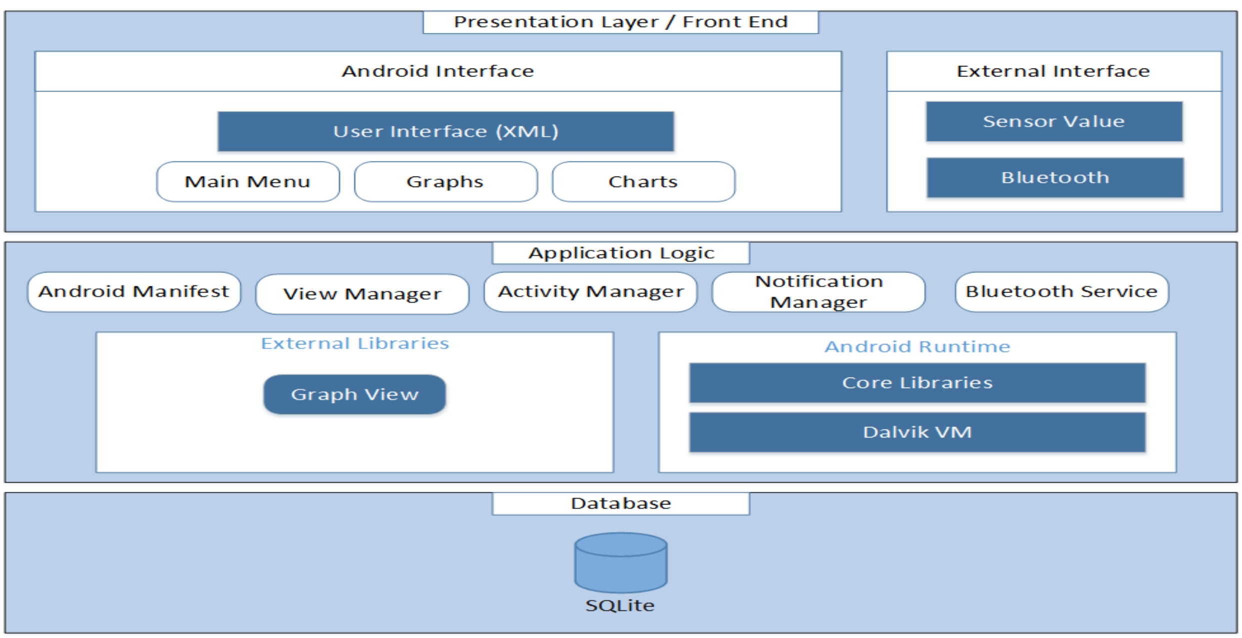

Figure 4-1 Architecture diagram of the system

4.2.2 Component Diagram

The three layers identified in the architectural pattern namely presentation, application and database are further divided into the components of the system. We have identified 5 sub-systems of the system and then divided the sub-systems into components.

Figure 4-2 is a diagram showing the major components of the system.

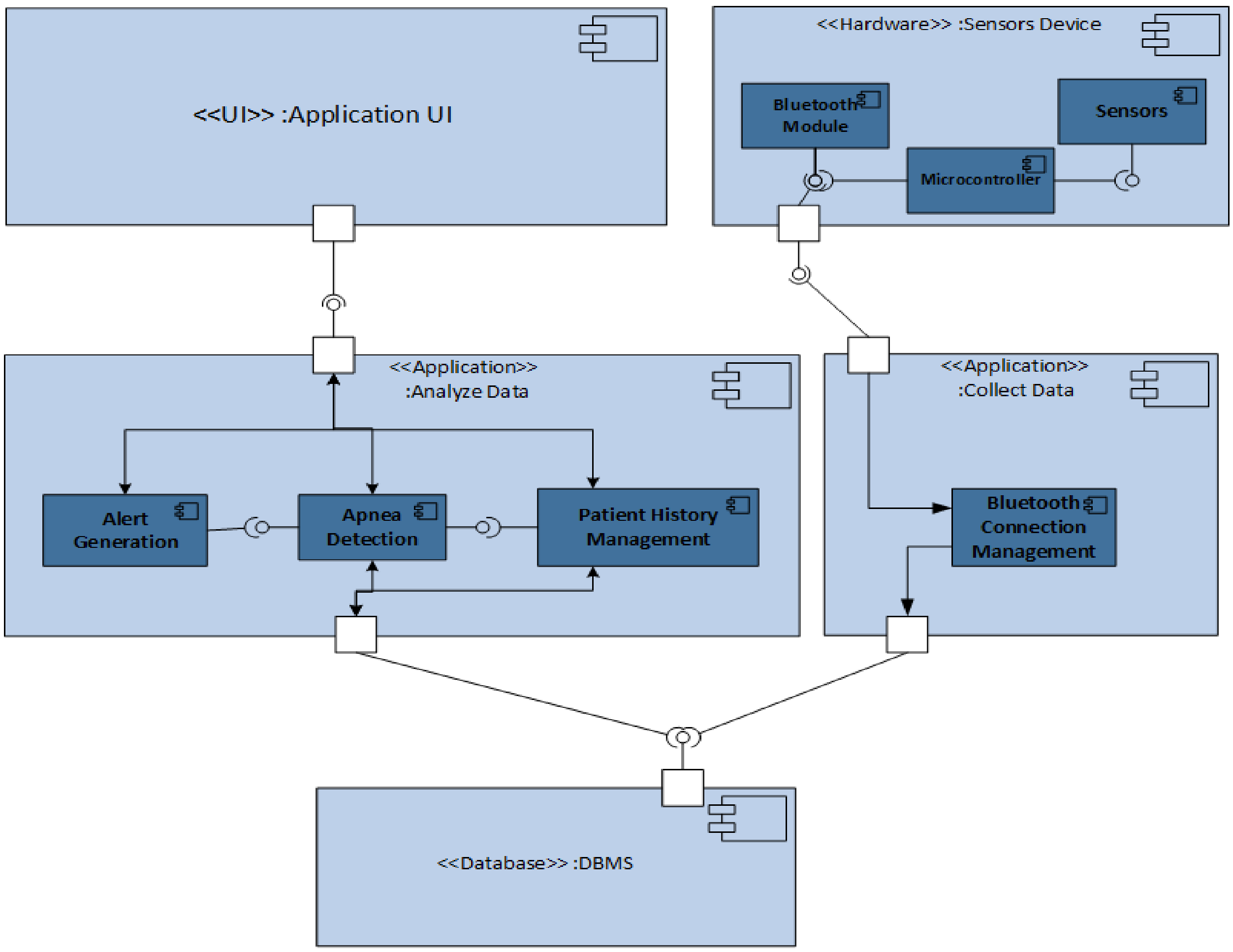

Figure 4-2 Component Diagram of the system

4.3 Structure and Relationships

Structure of the system is broken down and explained through the block diagram first then the use case diagram, next in sequence is the structure chart of the whole system. After the structure chart we can now break the system into classes and the class diagram is discussed. Then the major functions are discussed through the sequence and activity diagram.

4.3.1 Block Diagram

The Block Diagram below shows how the layers in which the system is divided are interacting with each other.

The external hardware is communicating with the external interface to provide the sensor readings, which are then communicated over Bluetooth to the application and then these values are displayed on the screen in the form of graphs. In case apnea occurs, values are also saved in the database. Figure 4-3 shows the block diagram of the system.

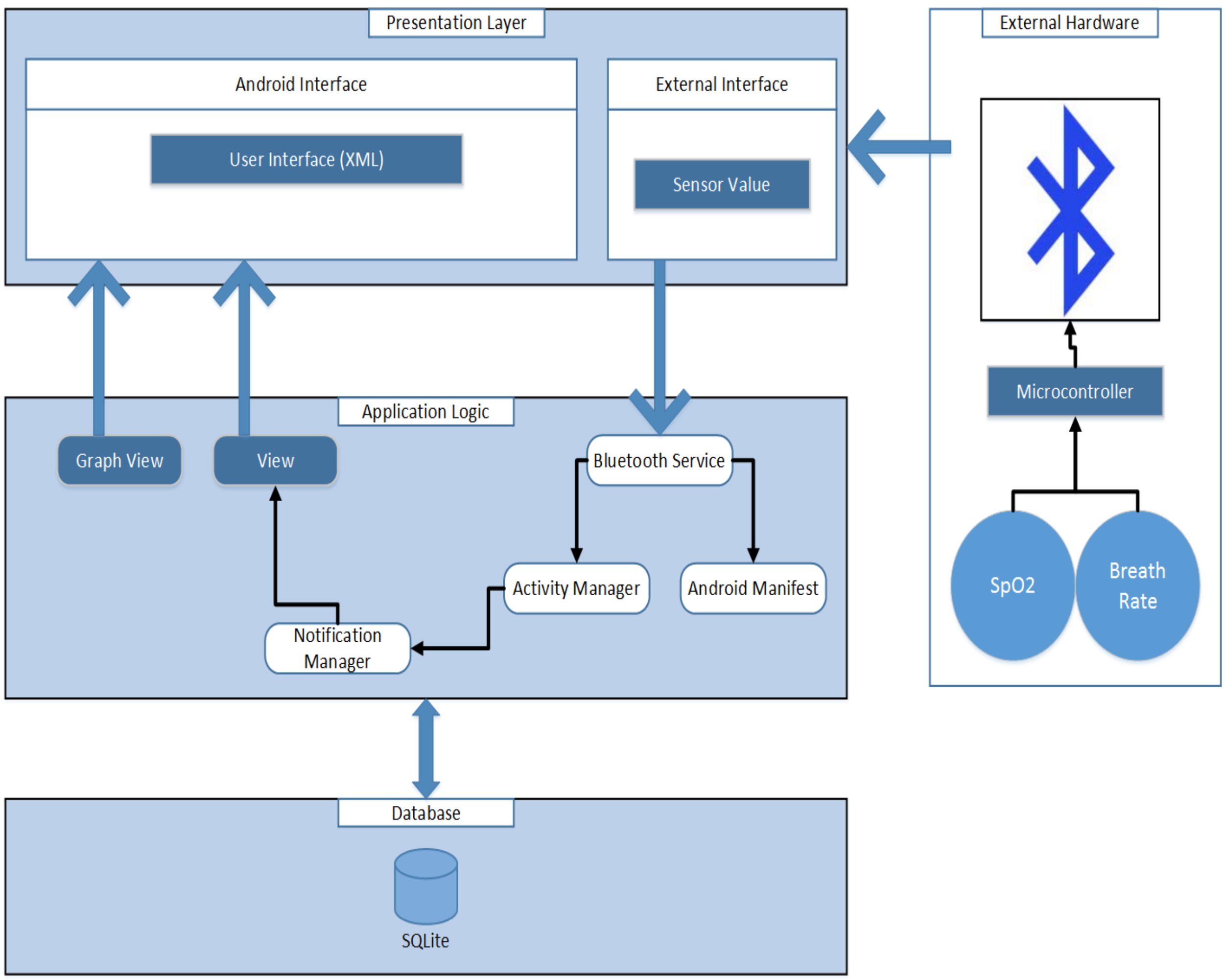

Figure 4-3 Block diagram of the system

4.3.2 Use Case Diagram

The user can perform the following 8 tasks which are depicted through the use case diagram shown in figure 4-4.

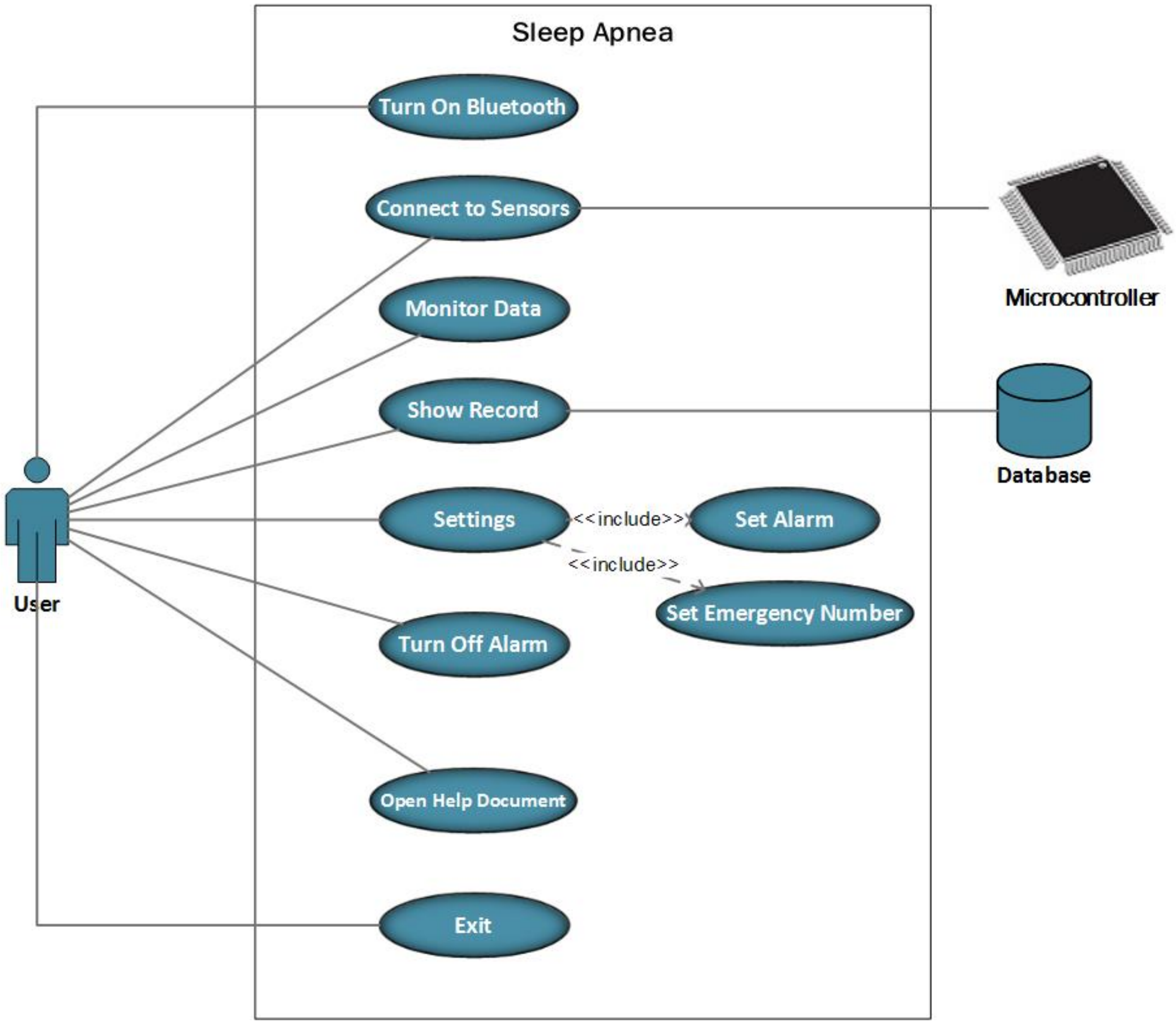

Figure 4-4 Use case diagram of the system

Following template discusses each of the above use cases in detail.

Table 4-1Connect to Bluetooth use case

Use Case ID:	**UC-1.2.1.**
Use Case Name:	**Connect to Sensors.**
Primary Actors:	Application User
Secondary Actors:	-
Description:	This use case will be used when the user wants to select which device the sensors will connect to.
Trigger:	When the user wants to connect the sensors with the application so that the system will start detecting apnea.
Preconditions:	The user will have searched for the available Bluetooth devices.
Post conditions:	The user will have connected to the desired device.
Normal Flow:	1. User will be displayed with a list of devices to be connected to. 2. User will select the desired device to be made connection with. 3. Connection will be made to the device the user selects.
Alternative Flows:	In case of normal flow 1, there might be no connections available for the system to display. In that case 1. The system will display error message that no Bluetooth devices are found.
Includes:	-
Special Requirements:	-

Table 4-2 Turn on Bluetooth use case

Use Case ID:	**UC-1.2.2**
Use Case Name:	**Turn on Bluetooth**
Primary Actors:	Application User
Secondary Actors:	-
Description:	User will turn on the Bluetooth for connecting with device to make the flow of data to be possible.
Trigger:	User needs to send data to the application.
Preconditions:	The microcontroller will have data from the sensors and have it processed to be sent to the application.
Post conditions:	Application will have data to be saved, displayed and for further processing for detecting apnea.
Normal Flow:	1. User will look for the Bluetooth option. 2. User will turn the Bluetooth on. 3. System will show the available Bluetooth devices. 4. User will choose the device to be connected with.
Alternative Flows:	-
Includes:	-
Special Requirements:	-
Assumptions:	User will use a Bluetooth supported device with the system.
Notes and Issues:	

Table 4-3Read sensors data use case

Use Case ID:	**UC-1.2.3**
Use Case Name:	**Read sensors data**
Primary Actors:	Application User
Secondary Actors:	-
Description:	The microcontroller will use this use case to get data from the sensors that they sensed.
Trigger:	Sensors would have data to be passed to the microcontroller.
Preconditions:	Sensors have taken the readings and have to pass the readings taken to the microcontroller.
Post conditions:	The microcontroller will have the data from the sensors and will process the data to be in an application accepted format.
Normal Flow:	1. Sensors will pass the readings to the microcontroller. 2. Readings will be received by the microcontroller. 3. Microcontroller will transform each of the sensors readings into numerical form for passing them to the application.
Alternative Flows:	-
Includes:	-
Special Requirements:	This use case will generate our performance requirement of accuracy.
Assumptions:	• It is assumed that the sensors will provide with the correct and accurate readings. • It is assumed that no loss of information will occur over the transfer.

Table 4-4Table for monitor data use case

Use Case ID:	**UC-1.2.4**
Use Case Name:	**Monitor Data**
Primary Actors:	Application User
Secondary Actors:	-
Description:	This use case will be used by the system to keep check if the apnea has occurred or not.
Trigger:	When the application will receive the data, then this use case will be used by the application to constantly keep check of the patient's condition.
Preconditions:	Application will have readings taken by the sensor.
Post conditions:	Based on the readings taken by the sensors the application will keep checking if the apnea has occurred.
Normal Flow-:	1. Application will get the readings from the database. 2. Application will compare the readings of last 5 seconds to calculate their difference. 3. Based on the calculations the application will determine whether to sound an alarm or not.
Alternative Flows:	-
Includes:	-
Special Requirements:	This use case will generate our performance requirement of response time and for having the quality attribute of availability.

Table 4-5 Table for show record use case

Use Case ID:	**UC-1.2.5**
Use Case Name:	**Show record**
Primary Actors:	System.
Secondary Actors:	Database
Description:	The use case will be used when the user wants to access his records.
Trigger:	User will touch the history button on the user interface to view the history.
Preconditions:	Application will have apnea detected at least once for the user to view it.
Post conditions:	The user will have viewed the frequency with which apnea has occurred with details.
Normal Flow:	1. User will open the history maintained by the system. 2. The application will access the database for the records. 3. The application will display the records on the screen with all the details.
Alternative Flows:	In case of normal flow 2 if the system might not have any history to display. In that case the normal flow 1. User will open the history maintained by the system. 2. System will display error message that no records have been made using the system.
Includes:	-
Special Requirements:	

Table 4-6 Table for settings use case

Use Case ID:	**UC-1.2.6**
Use Case Name:	**Settings**
Primary Actors:	Application User
Secondary Actors:	-
Description:	The user will be able to open settings of the application using this use case.
Trigger:	The user wants to modify how the system alerts in case sleep apnea occurs.
Preconditions:	The user must have application installed in the system.
Post conditions:	The user will be able to change the settings available in the application.
Normal Flow:	1. User will open the application. 2. User will tap the settings button. 3. User will be able to view the settings of the system.
Alternative Flows:	-
Exceptions:	-
Includes:	Set Alarm Set Emergency Number

Table 4-7Open Help Document

Use Case ID:	**UC-1.2.7**
Use Case Name:	**Open Help Document**
Actors:	Application User
Description:	The user will use this use case in case he is unfamiliar with how the application works or how he can modify or use the application or connect the hardware.
Trigger:	The user will need information how to operate the system.
Preconditions:	The user will have application installed to access the help document.
Post conditions:	The user will have opened the help document.
Normal Flow:	1. User will open the application. 2. User will open the help document by touching the
Alternative Flows:	-
Includes:	-

Table 4-8Set alarm use case

Use Case ID:	**UC-1.2.8**
Use Case Name:	**Set Alarm**
Primary Actors:	Application User
Secondary Actors:	-
Description:	The user will use this use case when he wants to change how the alarms sound when apnea is detected.
Trigger:	User wants to change the duration of the alarm.

Preconditions:	The user has the application installed.
Post conditions:	The user will have modified the alarm according to him.
Normal Flow:	1. User will open the application. 2. User will open the settings. 3. User will choose the alarm settings. 4. User will change the duration of the alarm. 5. User will save settings. 6. User will exit settings.
Alternative Flows:	-
Includes:	-
Special Requirements:	-

Table 4-9Table for Set Emergency Number use case

Use Case ID:	**UC-1.2.9**
Use Case Name:	**Set Emergency Number**
Primary Actors:	Application User.
Secondary Actors:	-
Description:	The user will use this use case to add the number of the user to send a message to in case apnea has occurred.
Trigger:	The user wants to add a number in the application to be notified on in case apnea has occurred.
Preconditions:	The user will have application installed.
Post conditions:	The user will have added a number to be sent a message to in case of apnea.

Normal Flow:	1. User will open the application. 2. User will open the settings. 3. In the settings, user will open add emergency number. 4. User will add the emergency number and emergency message. 5. User will save the settings. 6. User will exit settings.
Alternative Flows:	-
Includes:	-
Special Requirements:	-

Table 4-10Table for Turn off alarm

Use Case ID:	**UC-1.2.10**
Use Case Name:	**Turn off alarm**
Primary Actors:	Application User
Secondary Actors:	-
Description:	User will use this use case to turn off the alarm when he wakes up in case apnea has occurred.
Trigger:	The system will have detected apnea and sounded an alarm for the user to wake up and user has to turn off the alarm.
Preconditions:	The system would have sounded an alarm after detecting apnea.
Post conditions:	The user will have turned the alarm off.
Normal Flow:	1. The system will detect apnea and sound an alarm. 2. User will touch the dismiss button to turn off the alarm.
Alternative Flows:	-

Includes:	-
Special Requirements:	-

4.3.3 Structure Chart

The chart in figure 4-5 shows the breakdown of our system.

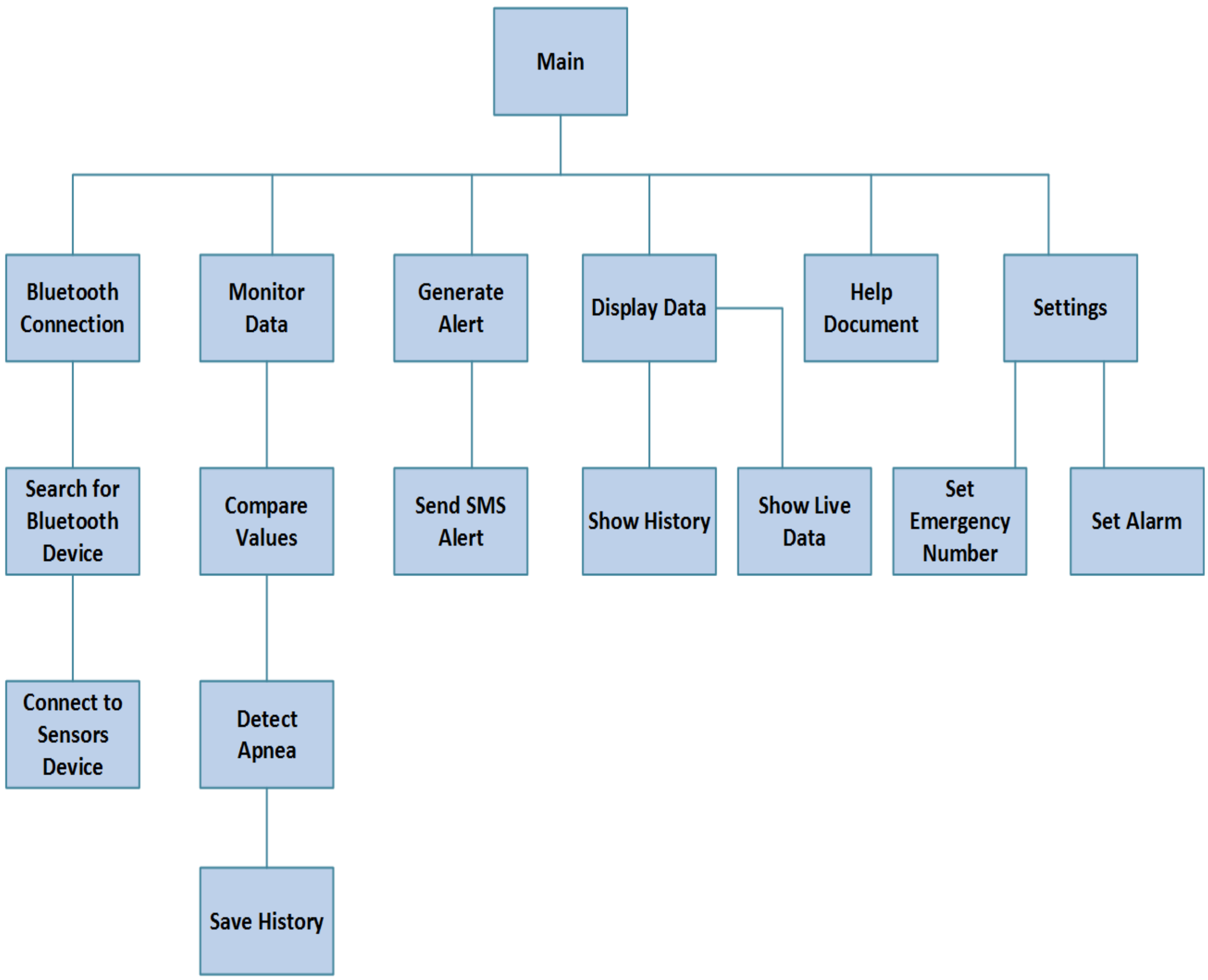

Figure 4-5Structure chart of the system

4.3.4 Class Diagram

Following classes are identified for our system shown in figure 4-6.

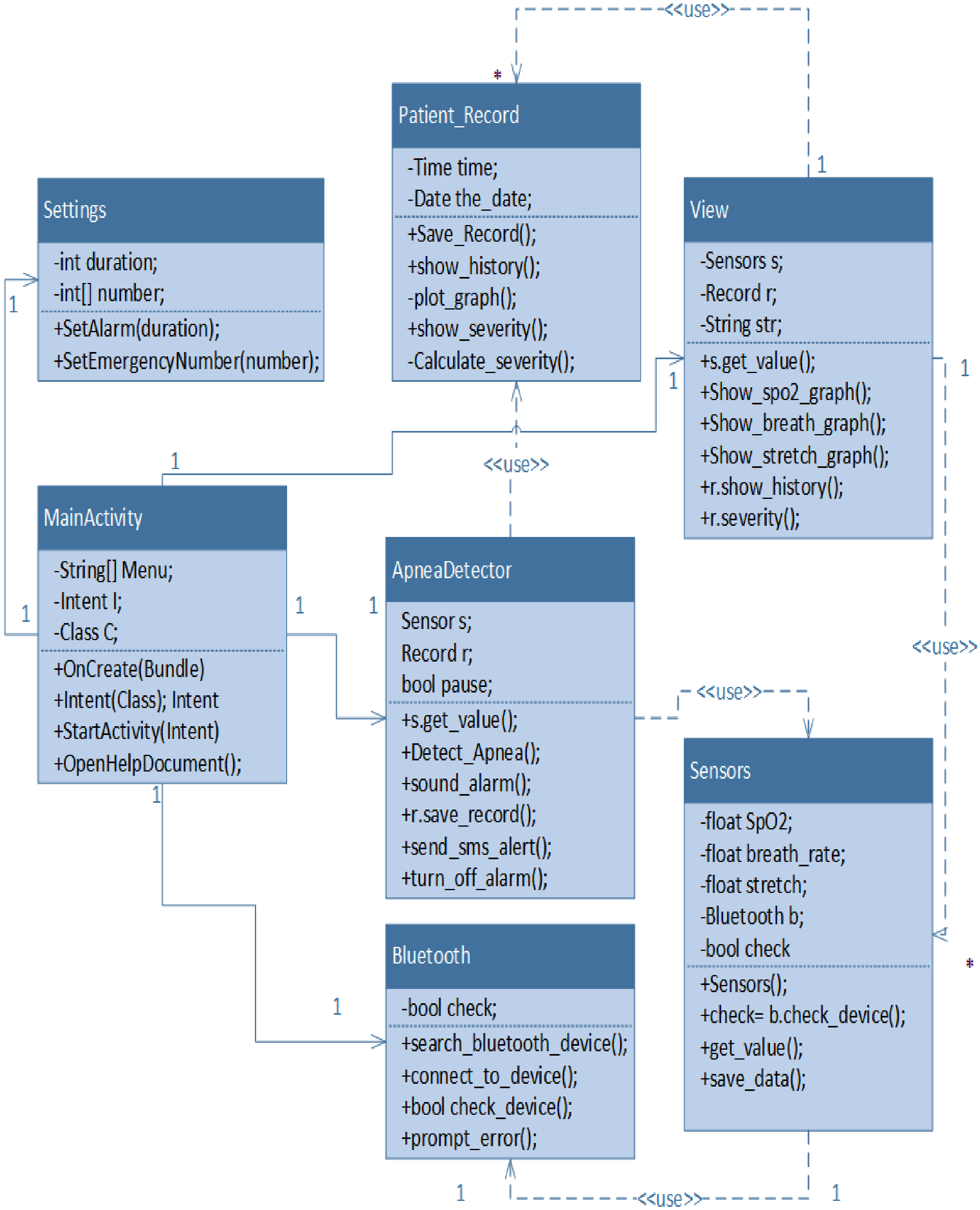

Figure 4-6 Class Diagram of the system

Table 4-11Table with descriptions of classes

Class Name	Description
Patient Records	This class maintains the records of how many times apnea has occurred. It will maintain the time, day and the readings of the time that apnea occurred.
View	This class is used for displaying all the sensor values and displaying the graphs of each type of sensor reading. As well as for displaying the history of the patient and the severity with which the apnea has occurred (if it occurs).
Settings	This class is used for changing the settings (available to the user) of the application.
Main Activity	This class is the main class in android and all other functions will be called form this class.
Apnea Detector	This class gets the values from the sensors and detects if apnea has occurred or not. It also provides with the functionality of sounding an alarm and sending message in case apnea has occurred.
Sensors	This class contains all the sensor readings which are converted into numerical form sent by the microcontroller. It will send these readings to other classes like View and Apnea Detector for further processing.
Bluetooth	This class is use for connection between the hardware interface and the application. This will get all the values from the sensors for processing and also provide the user with the option of available Bluetooth devices for connecting.

4.3.5 Sequence Diagram

Sequence diagram of each of the major functions is discussed separately under each of the following sub-sections.

4.3.5.1 Sequence Diagram for Connect to Bluetooth

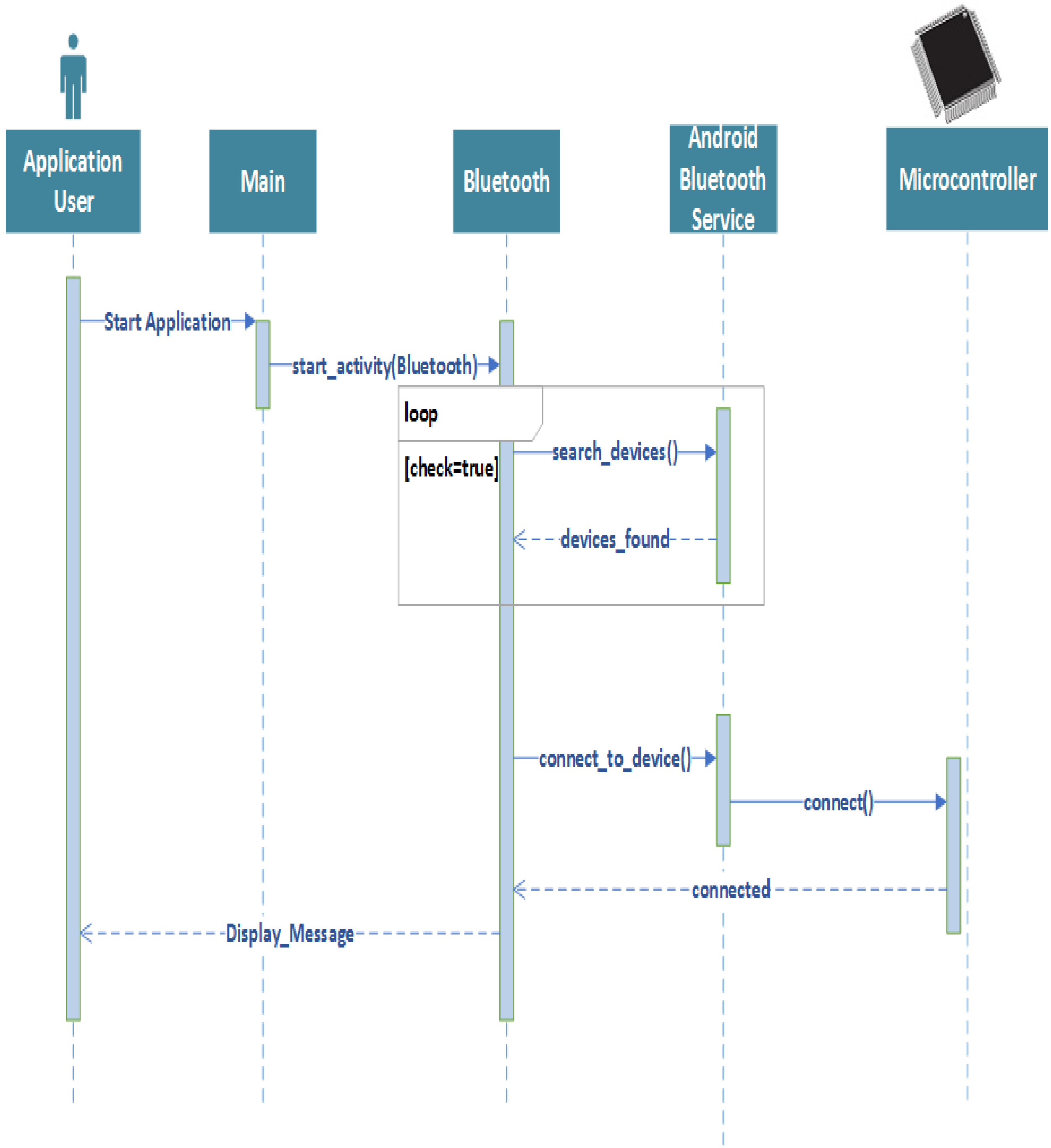

Figure 4-7Sequence diagram for connect to Bluetooth

Figure 4-7 shows the sequence of actions that will be performed when the function connect to Bluetooth will be performed. As the diagram shows the action will be initiated by the user and will interact with the Main, Bluetooth, Android Bluetooth Service and Microcontroller class.

4.3.5.2 Sequence Diagram for Monitor Data

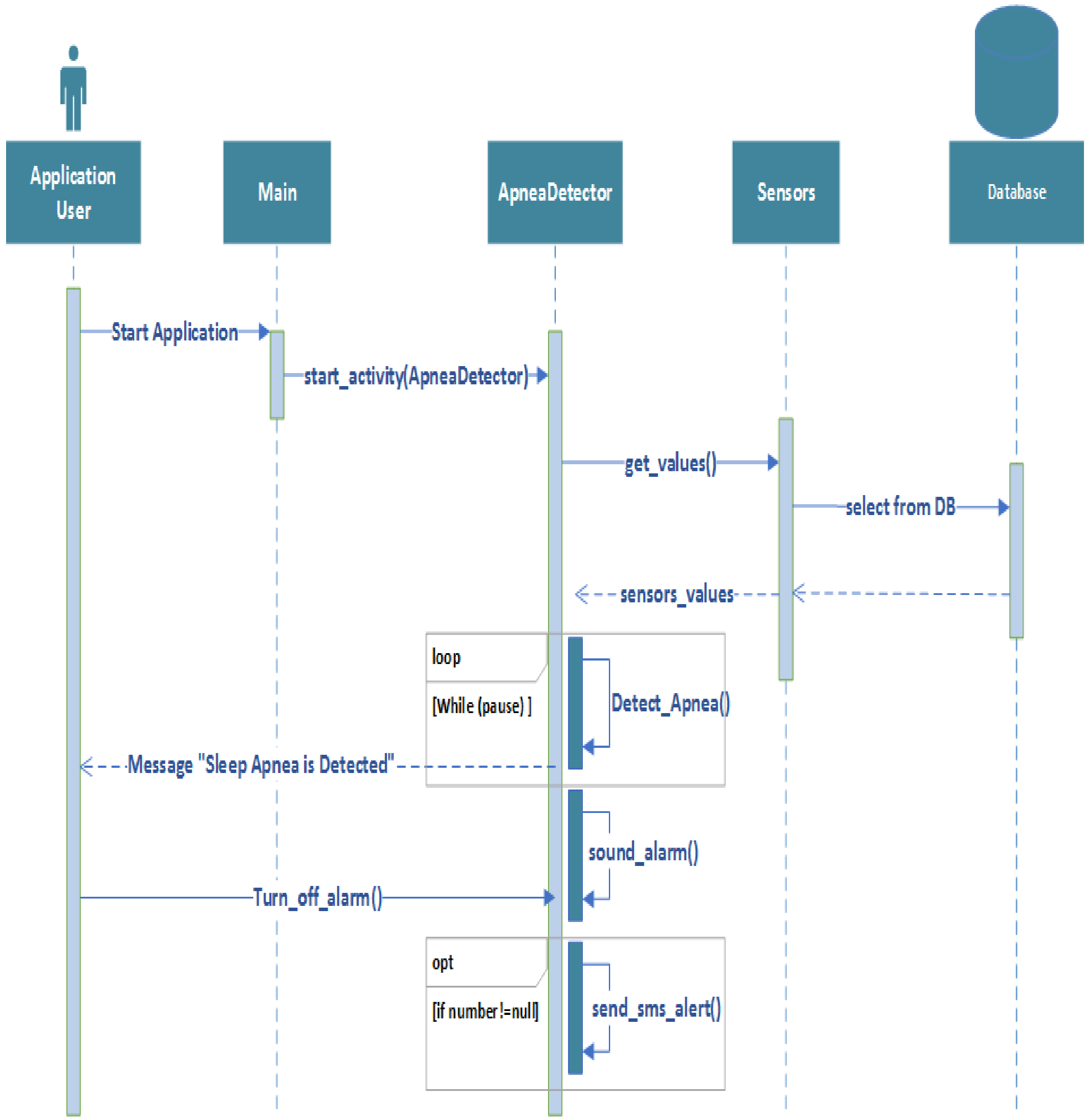

Figure 4-8 Sequence diagram for monitor data

Figure 4-8 shows the sequence of actions that will be performed when the function monitor data will be performed. As the diagram shows the action will be initiated by the

Application user and will interact with the Main, apnea detector, sensors and the database class.

4.3.5.3 Sequence Diagram for Settings

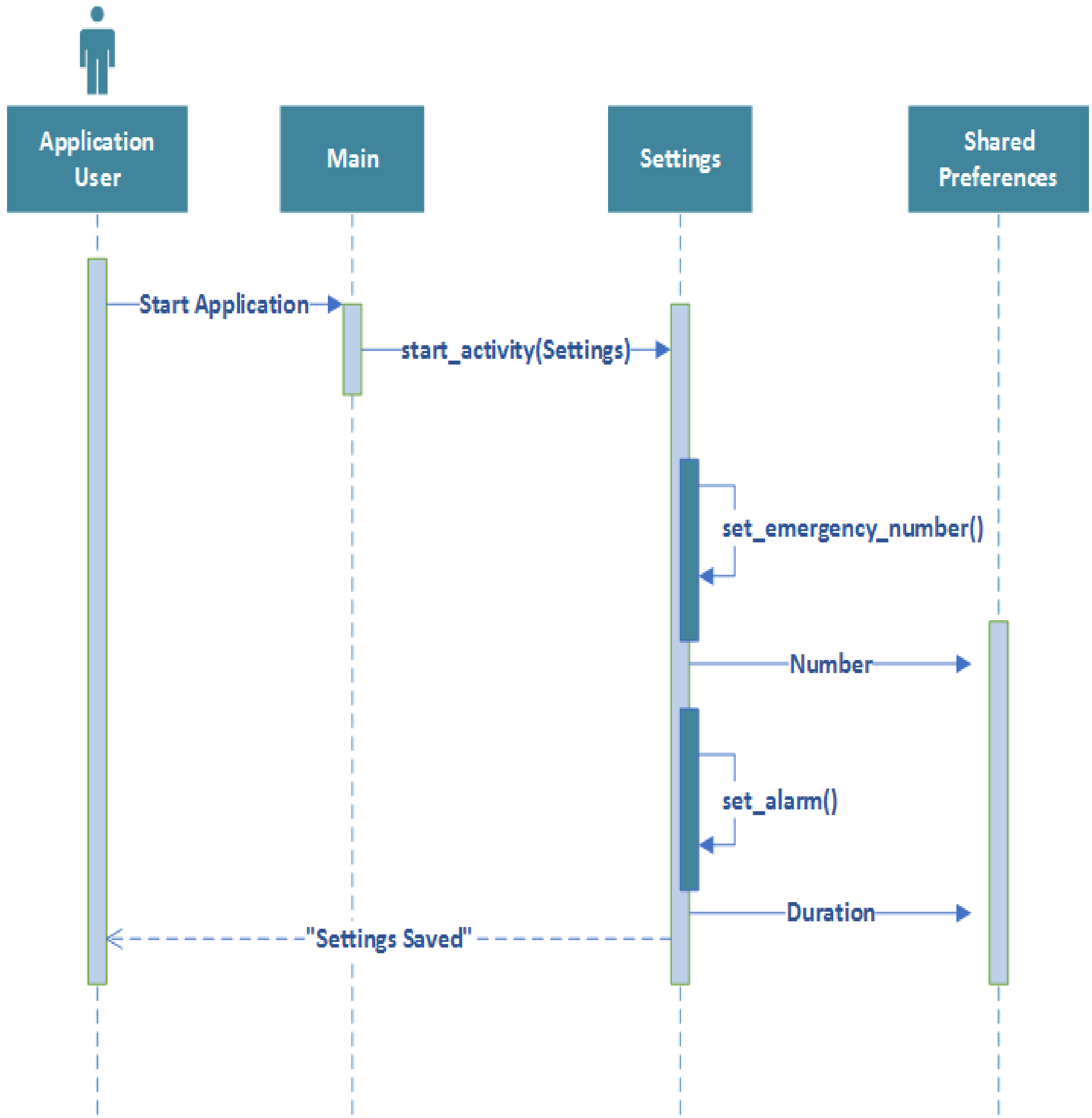

Figure 4-9Sequence Diagram for Settings

Figure 4-9 shows the sequence of actions that will be performed when the function Settings will be performed. As the diagram shows the action will be initiated by the Application user and will interact with the Main, Settings, Shared preferences class.

4.3.5.4 Sequence Diagram for Show Live Graphs

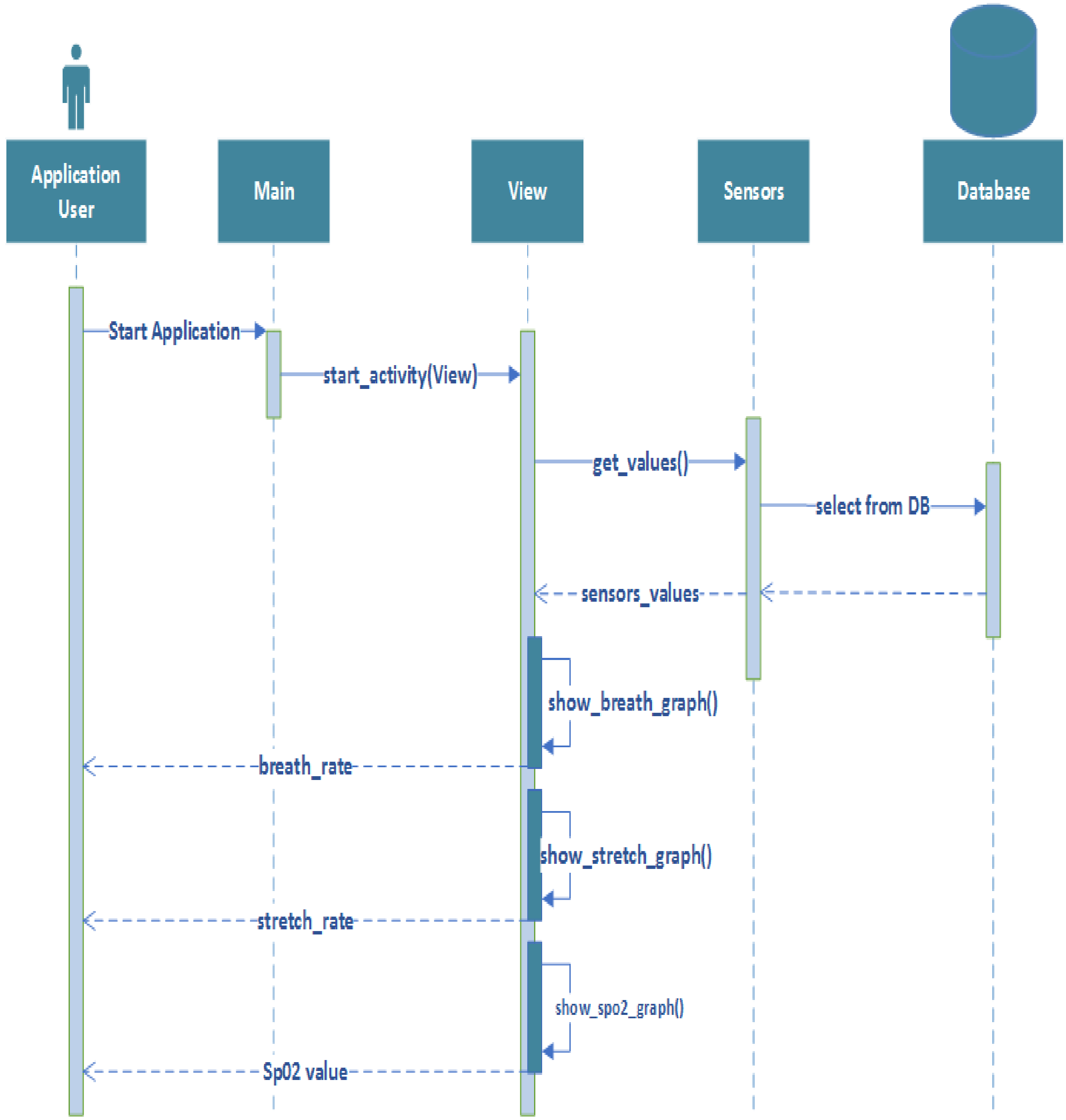

Figure 4-10Sequence diagram for show live graphs

Figure 4-10 shows the sequence of actions that will be performed when the function Show Live Graphs will be performed. As the diagram shows the action will be initiated by the Application user and will interact with the Main, View, Sensors, Database class.

4.3.5.5 Sequence Diagram for Show Record

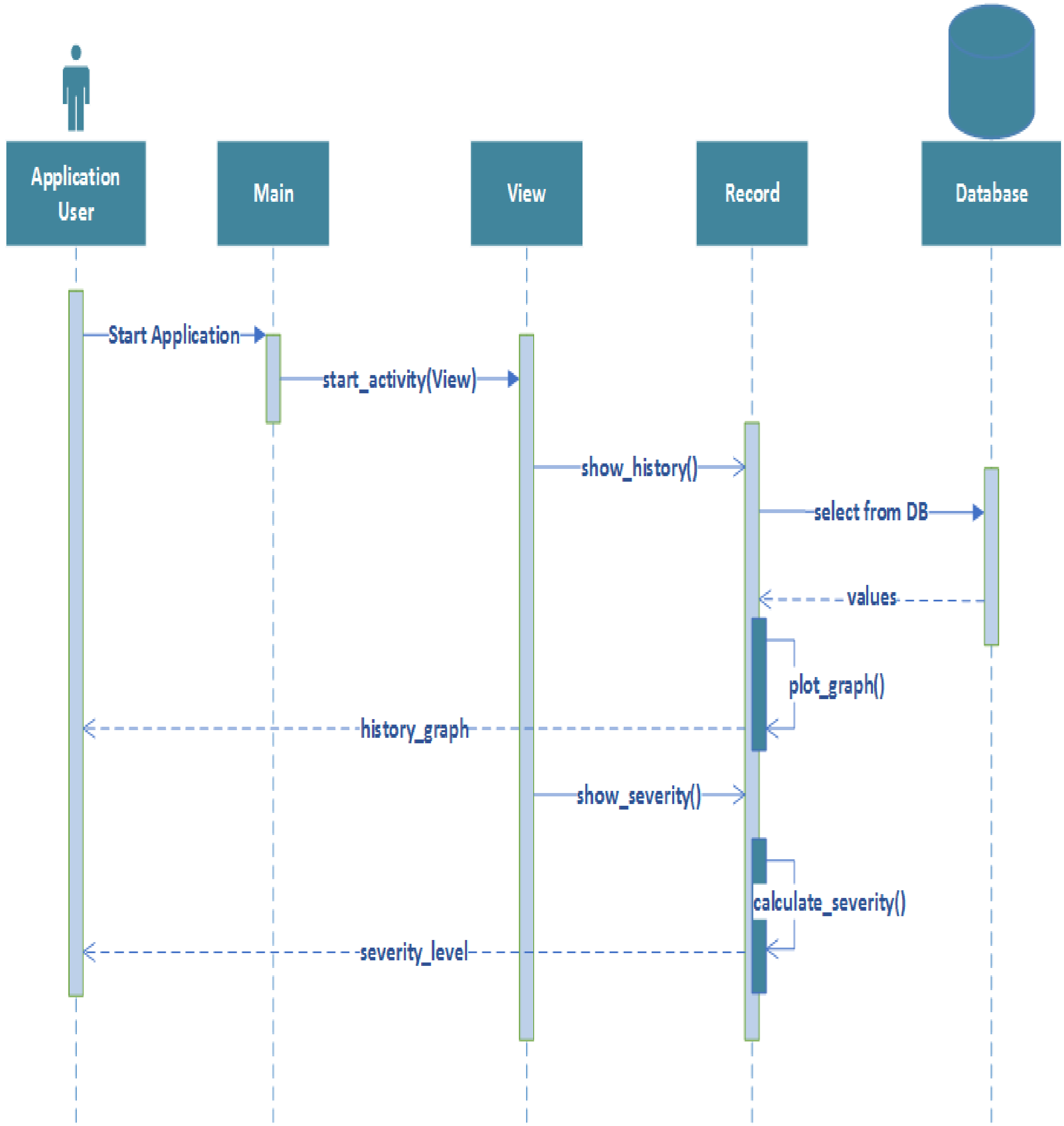

Figure 4-11Sequence diagram for show record

Figure 4-11 shows the sequence of actions that will be performed when the function Show Record will be performed. As the diagram shows the action will be initiated by the Application user and will interact with the Main, View, Record, Database class.

4.3.6 Activity Diagram

4.3.6.1 Activity Diagram for Bluetooth Connection

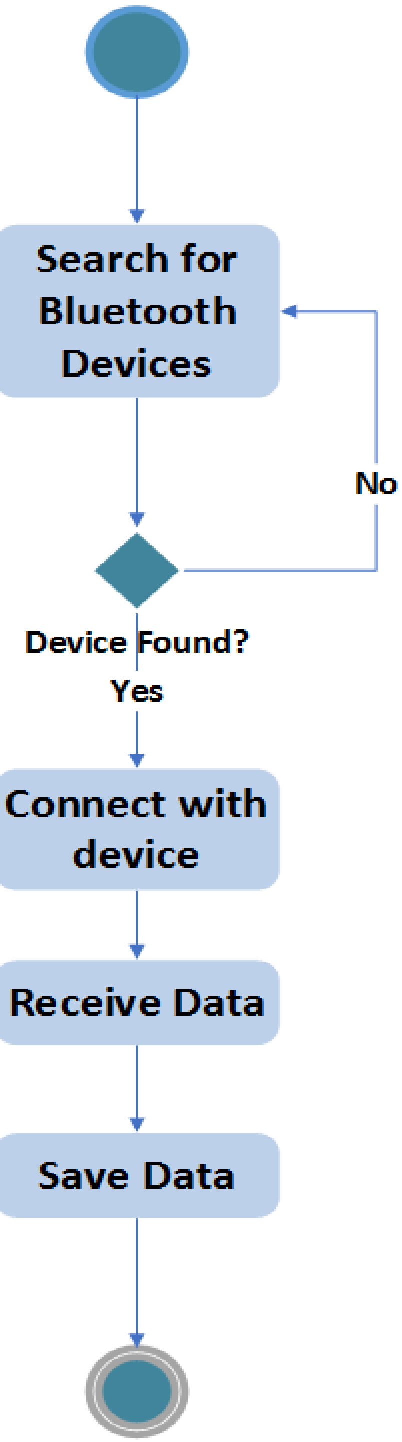

Figure 4-12Activity diagram for Bluetooth connection

4.3.6.2 Activity Diagram for Detect Apnea and Update History

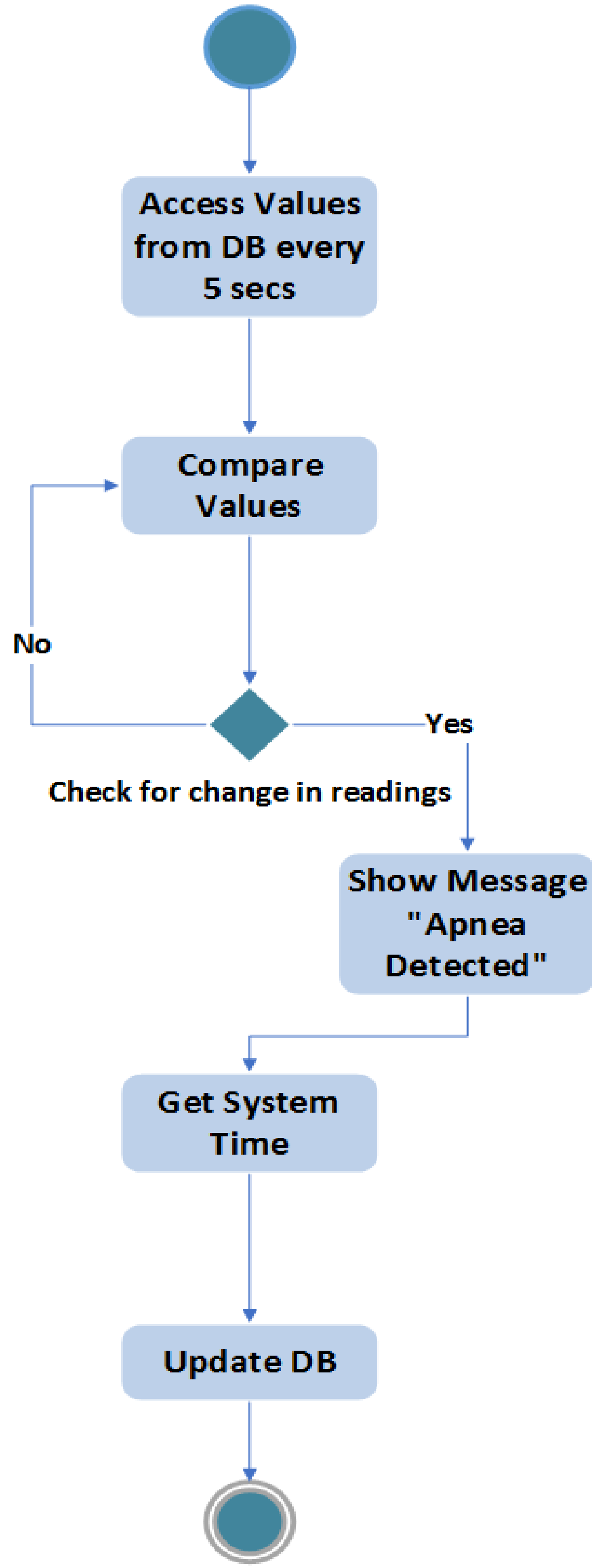

Figure 4-13Detect Apnea and update history

4.3.6.3 Activity Diagram for Display Data

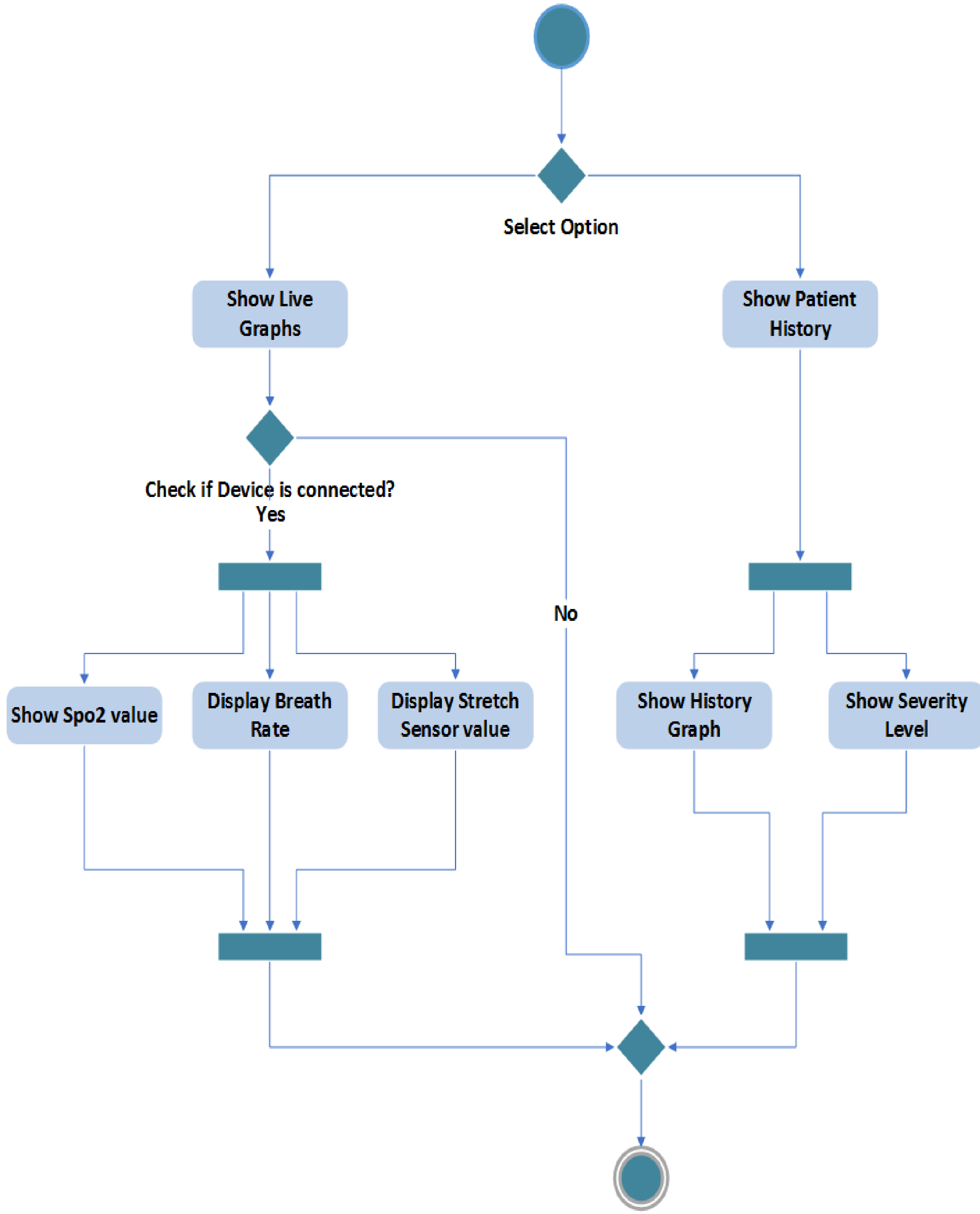

Figure 4-14Activity diagram for display data

4.3.6.4 Activity Diagram for Generate Alarm

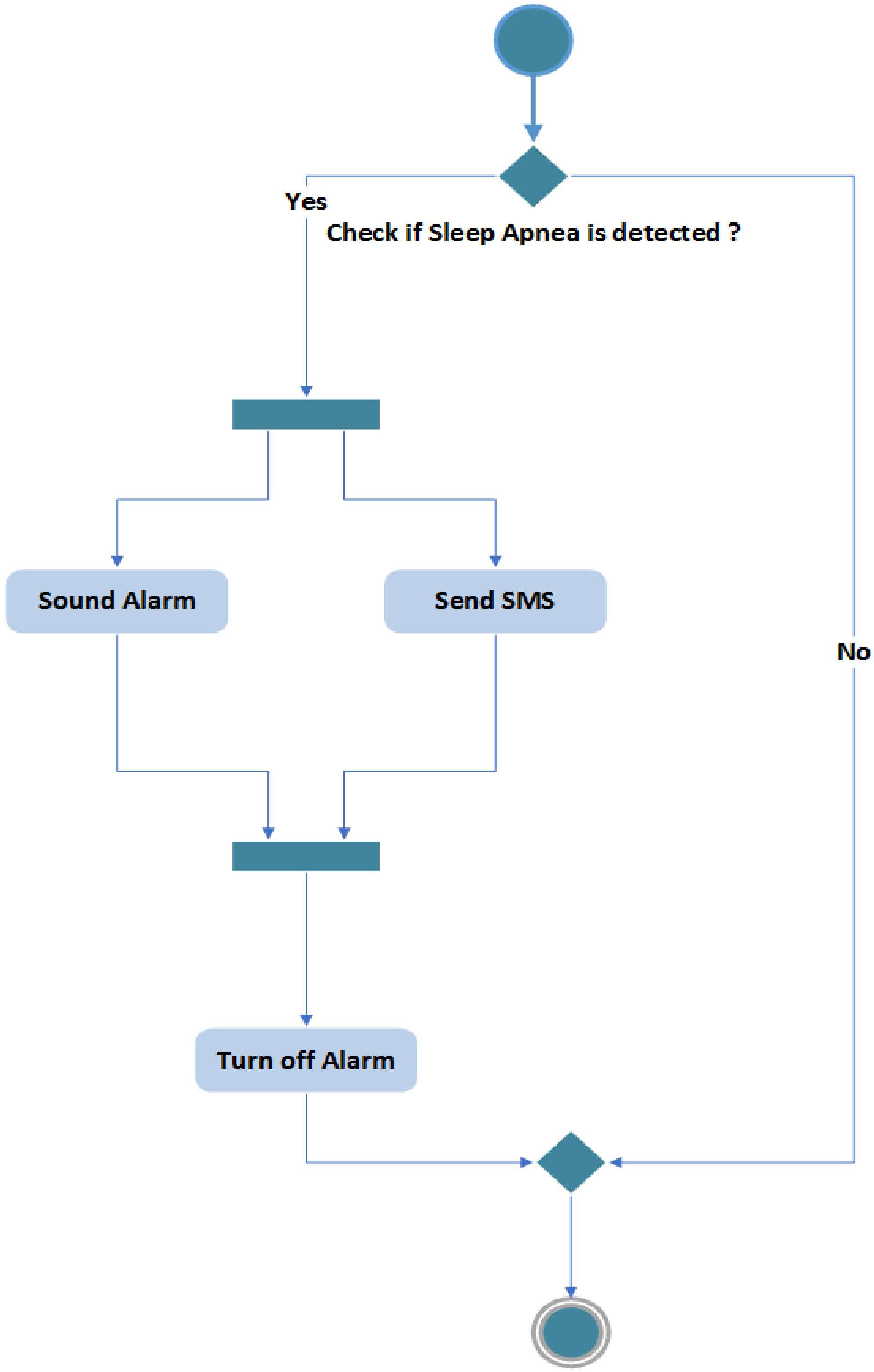

Figure 4-15Activity diagram for generate alarm

4.3.6.5 Activity Diagram for Hardware

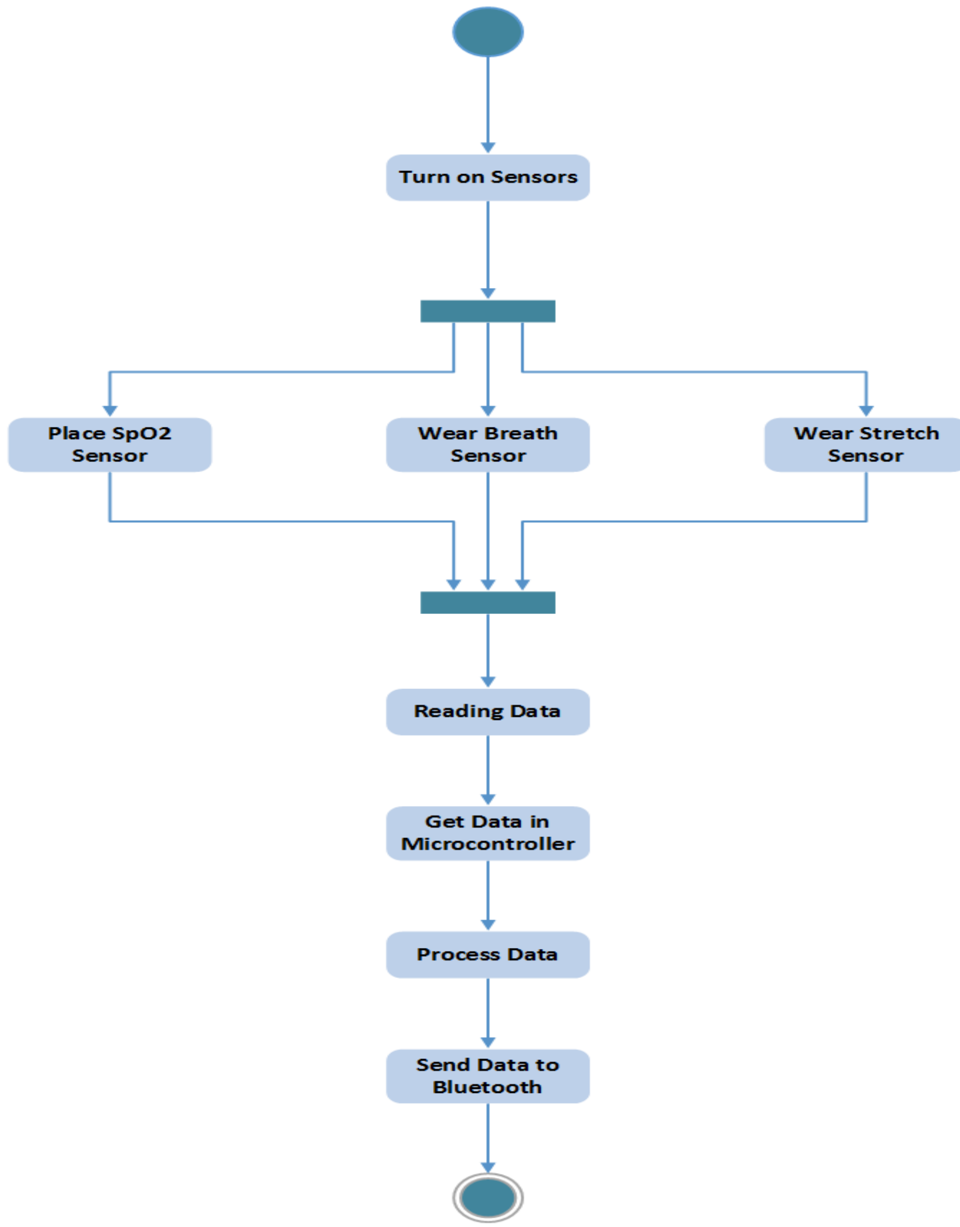

Figure 4-16Activity Diagram for hardware

4.4 Conclusion

Breaking a system step by step as broken above is quite effective as above, started with the architecture diagram then component diagram, then the block diagram and then the relationships between all of these classes are highlighted using class diagrams. Then the interactions between the classes are depicted through sequence and activity diagrams.

5 Project Analysis and Evaluation

5.1 Test cases

Test cases of the system for testing are as follows:

Test Case 1

Table 0-1Table for test case 1

Test Case ID	**01**
Test Case name	Sleep Apnea Application button testing
Input(s)	Press Sleep Apnea Application button
Output	Opens the Sleep Apnea application
Sequence of Action(s)	Press Sleep Apnea Application button from menu of mobile screen.
Result	Success

Test Case 2

Table 0-2Table for test case 2

Test Case ID	**02**
Test Case name	Bluetooth connection.
Input(s)	The Bluetooth of mobile is switched on Arduino was connected.
Output	Bluetooth connection established.
Sequence of Action(s)	Press Bluetooth button in the application and then connect the devices with it
Result	Success

Test Case 3

Table 0-3Table for test case 3

Test Case ID	03
Test Case name	SMS Alert Generation
Input(s)	Dummy SPO2 and flow sensor values provided
Output	SMS was forwarded to the number which was provided in the settings.
Sequence of Action(s)	1. Dummy Sleep Apnea values are given to application. 2. When it detects sleep apnea it will automatically send SMS
Result	Success

Test Case 4

Table 0-4Table for test case 4

Test Case ID	04
Test Case name	Save Records
Input(s)	Dummy values coming from sensors
Output	In database all the values were being updated.
Sequence of Action(s)	Software system will be connected to the sensors and it will automatically update database
Result	Success

Test Case 5

Table 0-5Table for test case 5

Test Case ID	05
Test Case name	Show Graph

Input(s)	Dummy values coming from sensors
Output	Graph shows all the values in graphical manner. When sleep apnea is detected its values change drastically.
Sequence of Action(s)	1. In main menu click on graph and then on live graph. 2. Graph appears.
Result	Success

Test Case 6

Table 0-6 Table for test case 6

Test Case ID	**06**
Test Case name	Set Alarm
Input(s)	Clicked on the Set Alarm option in the settings
Output	Alarm selected
Sequence of Action(s)	In setting went to the alarm setting then choose the alarm.
Result	Success

Test Case 7

Table 0-7Table for test case 7

Test Case ID	**07**
Test Case name	Set Emergency Number
Input(s)	Clicked on the Set Emergency Number option in the settings
Output	Field appeared where number was provided by user
Sequence of Action(s)	In setting go to the set emergency number setting and give

	the number.
Result	Success

Test Case 8

Table 0-8Table for test case 8

Test Case ID	**08**
Test Case name	Open Help Document
Input(s)	Clicked on the Open help Document in the main menu
Output	Document appeared showing all the help a person can get from the application.
Sequence of Action(s)	In main menu went to the open help document and document appeared.
Result	Success

Test Case 9

Table 0-9Table for test case 9

Test Case ID	**09**
Test Case name	Exit the System
Input(s)	Clicked on the exit button
Output	System closed
Sequence of Action(s)	In main menu clicked the exit button
Result	Success

Test Case 10

Table 0-10Table for test case 10

Test Case ID	**10**

Test Case name	Actuators functionality
Input(s)	Dummy drastic graph values
Output	Actuator activates and a SMS is sent
Sequence of Action(s)	Function detects the drastic values from the graph, actuator activates, alarm generated on phone.
Result	Success

Test Case 11

Table 0-11Table for test case 11

Test Case ID	**11**
Test Case name	Show patient record
Input(s)	Dummy values were updated in the database
Output	Show value of each sensors of respective patient.
Sequence of Action(s)	1. Dummy values were provided to the system 2. Database was updated 3. Data appeared on screen
Result	Success

Test Case 12

Table 0-12Table for test case 12

Test Case ID	**12**
Test Case name	Clear Record
Input(s)	Dummy values were updated in database
Output	Dummy data disappeared

Sequence of Action(s)	1. In main menu press clear record button 2. The record will be removed
Result	Success

Test Case 13

Table 0-13Table for test case 13

Test Case ID	**13**
Test Case name	Disconnect Bluetooth
Input(s)	Device is connected with mobile
Output	No device connected
Sequence of Action(s)	1. In Main menu click on Bluetooth setting 2. Then click on disconnect devices 3. Devices disconnected
Result	Success

Test Case 14

Table 0-14 Table for test case 14

Test Case ID	**14**
Test Case name	Stop Alarm
Input(s)	Dummy values were given which triggered the Alarm
Output	Alarm off
Sequence of Action(s)	1. Sleep apnea was detected and on screen alarm stared sounding 2. Then at left bottom of screen stop button appeared 3. By clicking it alarm stopped
Result	Success

Test Case 15

Table 0-15 Table for test case 15

Test Case ID	**15**
Test Case name	Sensor disconnected
Input(s)	Sensors was removed from Arduino
Output	No sensor was found.
Sequence of Action(s)	1. Sensors from Arduino board were removed manually. 2. Dialog box will appear displaying “No sensor found”.
Result	Success

Test Case 16

Table 0-16 Table for test case 16

Test Case ID	**16**
Test Case name	Sleep Apnea Alert
Input(s)	Dummy values in which minor sleep apnea was present
Output	Sleep Apnea about to occur Alert
Sequence of Action(s)	Dummy values were given in which sleep apnea is not critical It detected it and gave us the warning dialog box.
Result	Success

Test Case 17

Table 0-17Table for test case 17

Test Case ID	**17**
Test Case name	Show Duration of Sleep apnea occurrence
Input(s)	Dummy values were continuously given for 15 second
Output	Sleep Apnea occurred 15 second
Sequence of Action(s)	In Sleep Apnea database time for the occurrence was stored

	By clicking on duration it will show a dialog box showing sleep apnea occurred for XYZ time
Result	Success

Test Case 18

Table 0-18 Table for test case 18

Test Case ID	**18**
Test Case name	Sleep Apnea Severity
Input(s)	Dummy values with high and low severity were given
Output	in graphical pattern its level for each high and low was show
Sequence of Action(s)	1. In graphical view severity button was clicked 2. Which displayed the severity of the patient.
Result	Success

Test Case 19

Table 0-19Table for test case 19

Test Case ID	**19**
Test Case name	Volume adjustment for alarm
Input(s)	New alarm ring tone was selected
Output	“How much volume do you want?” message box will appear.
Sequence of Action(s)	While setting the tone in setting for alarm when volume was selected it gave us the option to set the volume.
Result	Success

Test Case 20

Table 0-20 Table for test case 20

Test Case ID	20
Test Case name	Show patient history graph
Input(s)	Dummy values were entered in the database. And then application was closed and again opened
Output	The graph appeared which showed the history of the patient for previous 2 nights
Sequence of Action(s)	1. Dummy values were updated in the database. 2. Application was closed after some time it was again open. 3. The graph showing patient history and graphical view of patient apnea will appear.
Result	Success

Test Case 21

Table 0-21 Table for test case 21

Test Case ID	21
Test Case name	In runtime sensors were removed
Input(s)	While application was saving data in database suddenly sensors were removed incidentally
Output	Dialog box telling us to reconnect the sensor
Sequence of Action(s)	1. While in runtime the sensors from the Arduino were removed incidentally 2. Then dialog box appeared and told the user to reconnect the sensors
Result	Success

Test Case 22

Table 0-22 Table for test case 22

Test Case ID	**22**
Test Case name	In runtime Bluetooth was disconnected
Input(s)	While application was running and suddenly then Bluetooth went off
Output	Dialog box telling us to reconnect the Bluetooth
Sequence of Action(s)	1. While in runtime the Bluetooth was disconnected 2. Dialog box showing us to reconnect the device and application stopped.
Result	Success

6 Future Work

6.1 Almost pervasive to pervasive

A pervasive system or an Ambient Intelligence (AmI) environment is ability of the electronic and digital devices to be everywhere shown in figure 6-1 is an example.

A medical device in a pervasive environment performs the three basic functions one is to gather the patient’s readings using multiple sensors, second is to pass these readings over the internet to some base computer of a hospital or a health care center and third is to save these readings on a server or cloud.

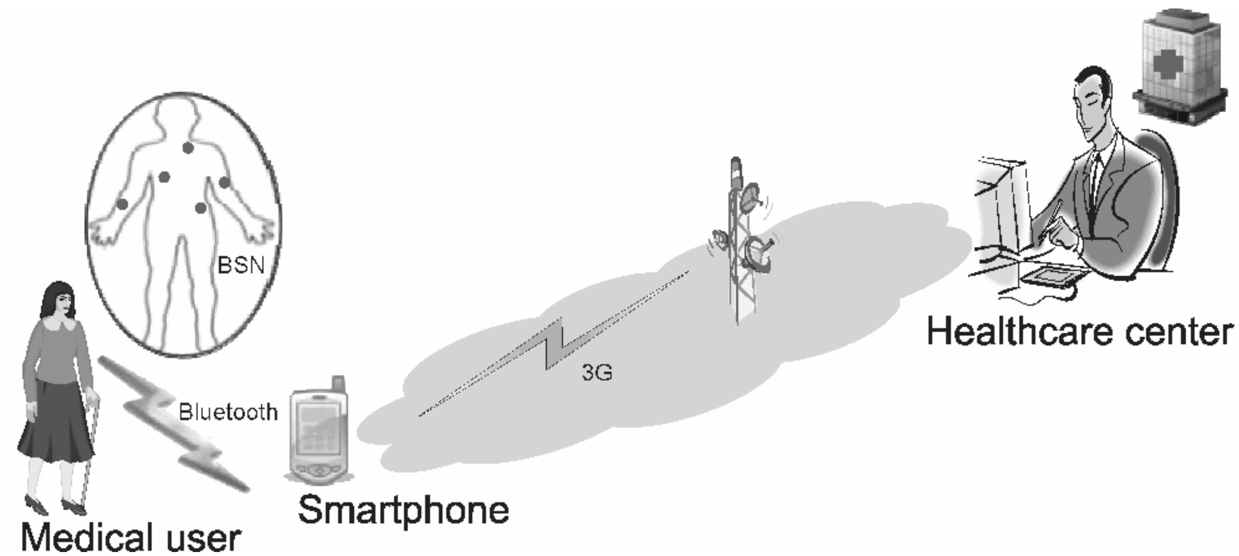

Figure 6-1 Pervasive system

Since our device saves these readings on a local device, it can easily be modified to send the patient readings using the internet to the patient’s doctor where these readings can be monitored live by him.

6.2 Reuse in other products

SAD (Sleep Apnea Detection) device can be re-used in many other application, either the whole system can be used as sub-system of another larger application or each of the sensors can be re-used individually in another application which might need to take the readings of the patient's current condition.

7 Conclusion

Sleep Apnea Detection serves as a replacement of the polysomnography, a sleep study conducted to detect if a patient has sleep apnea or not. It senses the drop in oxygen level, the compressions and stretches of the abdomen and the breath rate of the patient using three sensors and processes these readings to display the graphs showing the current condition of the patient.

The device will sound an alarm if it detects apnea and can also be customized to send a SMS alert in case apnea is sever. These readings will also be saved on the device in case these need to be shown to the doctor and also to detect the severity of the apnea.

The device serves as an alternate to the hospital visits and can be used at home easily by the patient.

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9 Appendix

USER'S MANUAL

Sleep Apnea Detection

Military College of Signals

May,2015.

Revision Sheet

Release No.	Date	Revision Description
Rev. 0	11/5/2015	User’s Manual Template and Checklist

User’s Manual

Authorization Memorandum

I have carefully assessed the User’s Manual for the Sleep Apnea Detection. This document has been completed in accordance with the requirements of the Computer Software Engineering department, MCS.

MANAGEMENT CERTIFICATION - Please check the appropriate statement.

______ The document is accepted

______ The document is accepted pending the changes noted.

______ The document is not accepted.

We fully accept the changes as needed improvements and authorize initiation of work to proceed. Based on our authority and judgment, the continued operation of this system is authorized.

NAME DATE

Project Leader

NAME DATE

Project Supervisor

10.0 GENERAL INFORMATION

10 GENERAL INFORMATION

10.1 System Overview

The system serves as a replacement of Polysomnography **(**PSG), which is a manual technique used for sleep monitoring. **PSG** is a complex technique only carried out by experts to monitor sleep apnea. The proposed system introduces a way of viewing, recording, analyzing sleep study patterns by the patient himself. The system displays all the information with help of graphs, charts and tables for easy reading of the patient as well as the doctor.

Three sensors are used for making the device, a SPo2 sensor, which determines the blood oxygen level in the body of the patient, an air flow sensor which determines the rate of flow of air and a stretch band sensor which determines the compressions and stretches of the abdomen. The readings from all three sensors are used to detect of sleep apnea has occurred. In case of emergency the application also sounds an alarm.

The system is a medical application and has a layered architecture and is completed as a final year project for the year 2015.

10.2 Organization of the Manual

The user's manual consists of four sections: General Information, System Summary, Getting Started and Using the System. General Information section explains in general terms the system and the purpose for which it is intended.

System Summary section provides a general overview of the system. The summary outlines the uses of

the system's hardware and software requirements, system's configuration, user access levels and system's behavior in case of any contingencies.

Getting Started section explains how to get Sleep Apnea Detection and install it on the device. The section presents briefly system menu. Using The System section provides a detailed description of system functions.

11.0 SYSTEM SUMMARY

11 SYSTEM SUMMARY

11.1 System Configuration

Briefly describe and depict graphically the equipment, communications, and networks used by the system. Include the type of computer input and output devices.

Fig 2-1 shows the general diagram of the system.

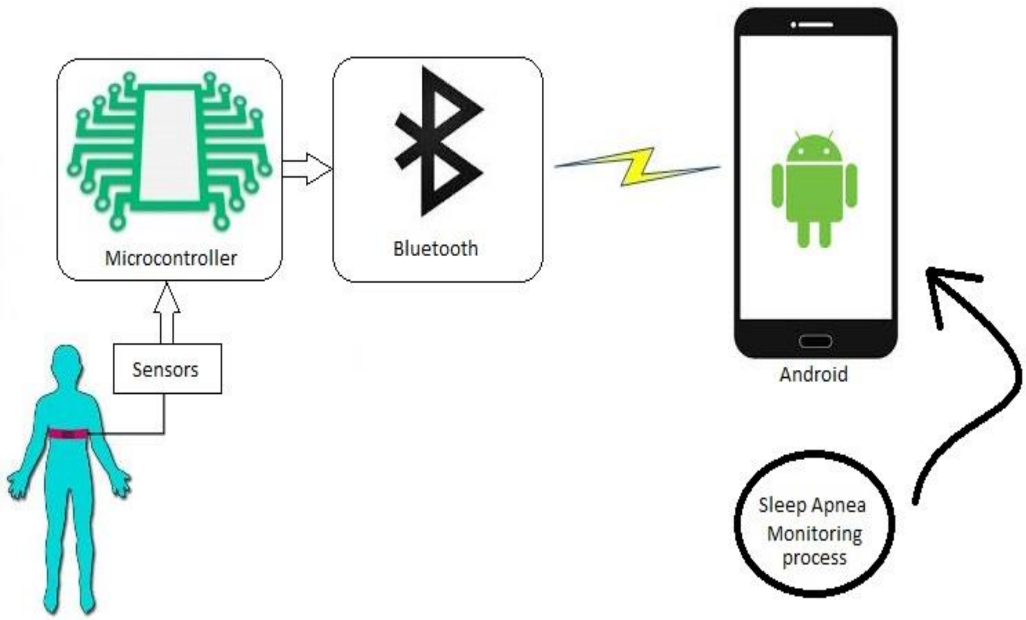

Figure 11-1General Diagram

11.2 User Access Levels

User has only one access level, as this device is built for monitoring the patient.

11.3 Contingencies and Alternate Modes of Operation

In case that the Bluetooth is disconnected or out of reach the system will stop detecting apnea. It is crucial for the patient to stay in the range of the Bluetooth.

12.0 GETTING STARTED

12 GETTING STARTED

Getting Started section explains how to get Sleep Apnea Detection and install it on the device. The section presents briefly system menu.

12.1 Installation

The application can now be purchased from the developer team, which is an .apk file and will be installed on the Android device when clicked easily. There is no log in module so no log in credentials are needed the user can get straight to using the application.

12.2 System Menu

Sleep Apnea detection consists of two sets of tabs as shown in the figure 3-1 .One is the Bluetooth set which has two tabs one for turning on the Bluetooth and one for turning it off. Second set of tabs is the Menu which has five tabs in it. One is start monitoring which will start monitoring the patient, second is the show history tab which will display the saved history of the patient, third is the help tab which will provide help to the user, fourth is the Settings tab which will be used for adjusting the application according to user and fifth is the exit tab which will be used to exit the application.

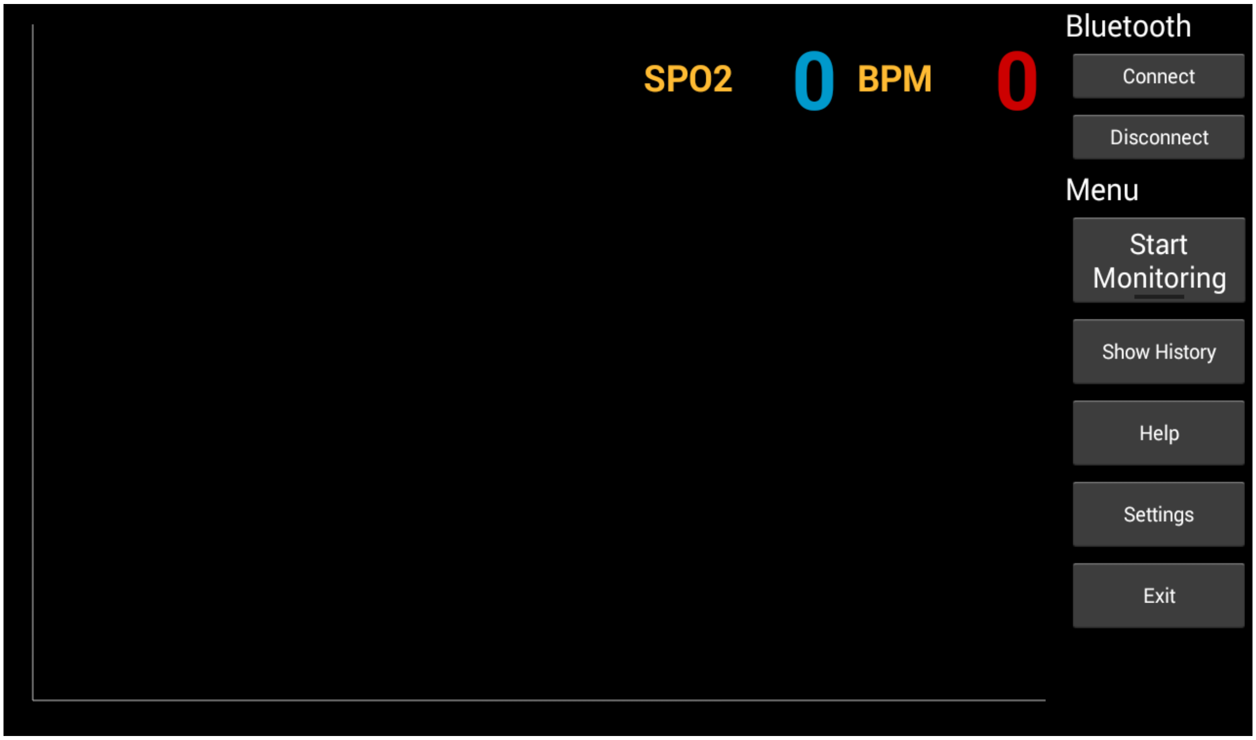

Figure 12-1 Main screen of the system

12.3 Connect Tab

The connect tab will display the next screen where the application seeks permission to turn the Bluetooth on. As shown in figure

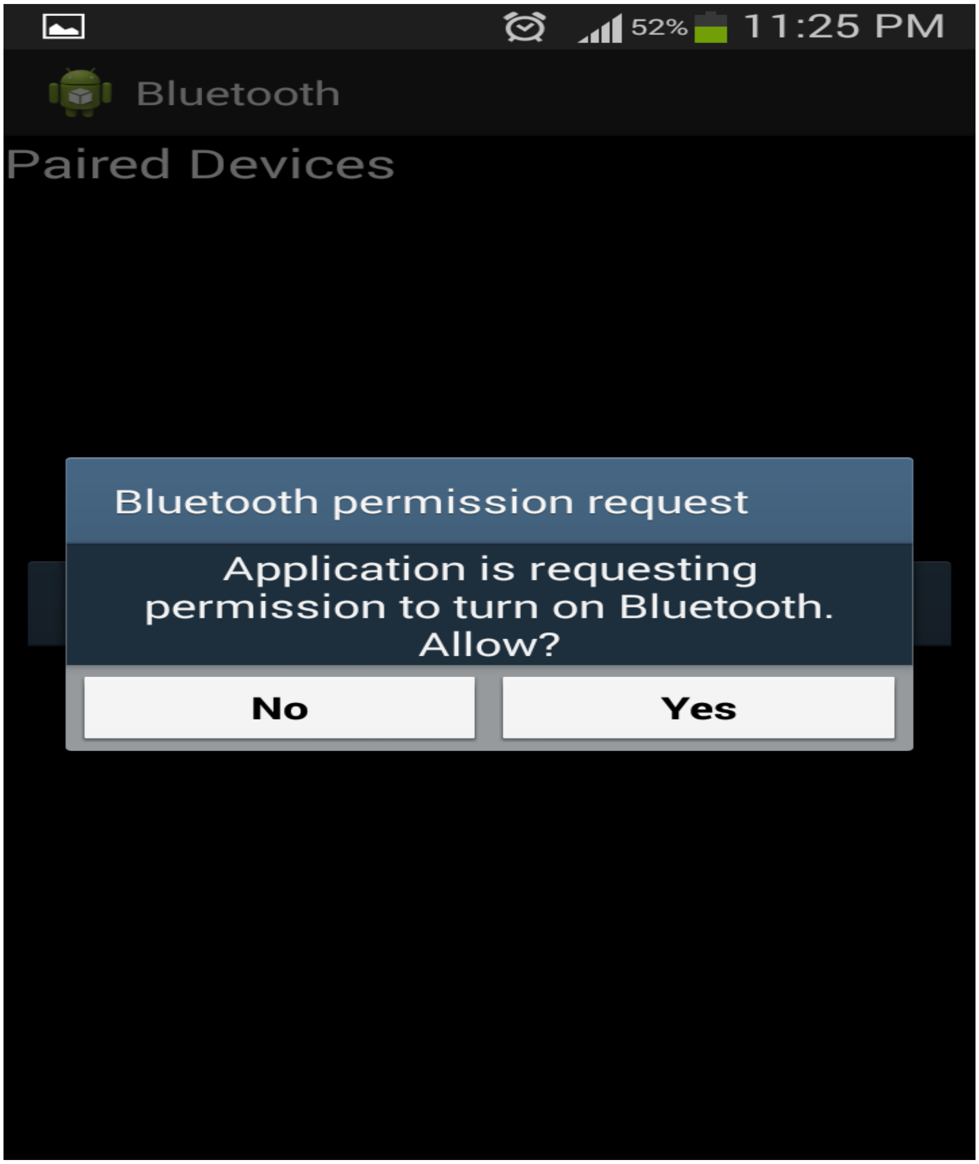

Figure 12-2 Allow Bluetooth to connect to external device

This will turn on the Bluetooth and a pair of devices that are available for Bluetooth connection will be displayed on the screen as shown in the figure 3-3. Tap on the device name that you want to connect to and the you will be connected to that device.

Figure 12-3 screen showing available Bluetooth devices

12.4 Disconnect Tab

For disconnecting the device you only have to tap on the disconnect button in the main menu and the connection will terminate as indicated by the arrow in figure 3-4.

Figure 12-4 Figure showing the disconnect tab on the main screen

12.5 Start Monitoring Tab

After the patient has his sensors on as soon as he presses the start monitoring tab it will start monitoring the patient's readings and display a live graph of these readings as shown in the figure 3-5.

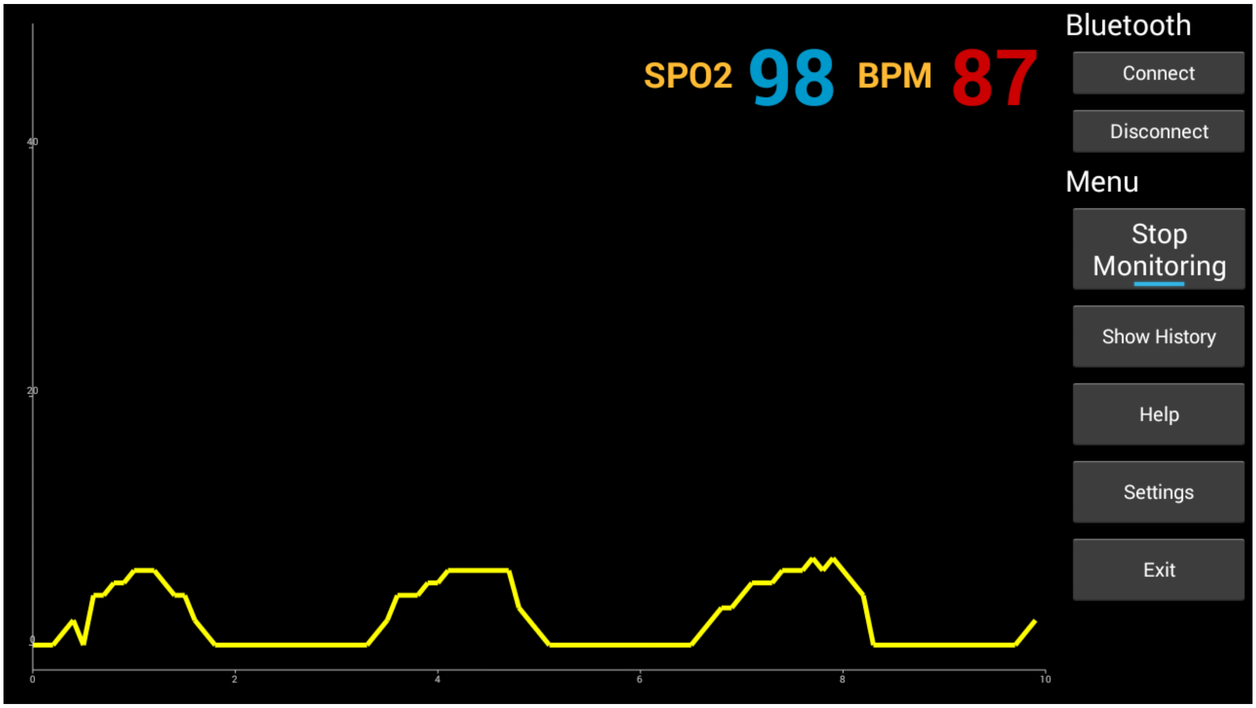

Figure 12-5 Figure showing the screen while the system has started taking readings

Now if apnea is detected the application will sound an alarm (if customize settings for alarm is set) and the apnea will be detected as shown in the figure 3-6.

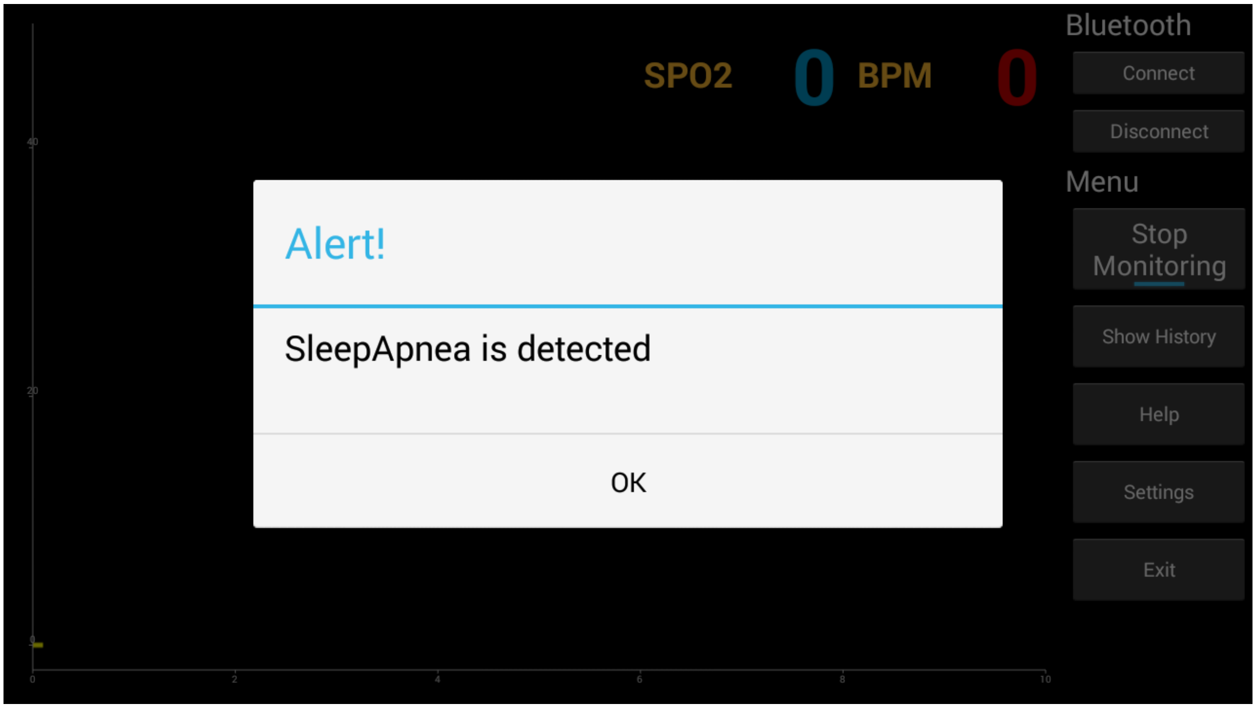

Figure 12-6 Screen showing apnea is detected

12.6 Stop Monitoring Tab

If the patient wants to stop monitoring the apnea it can simply be achieved by pressing the stop monitoring tab as shown and underlined with blue color in the figure 3-7.

Figure 12-7 Screen showing the stop monitoring option

12.7 History Tab

The history of the patient can be checked by pressing the history button the main screen as was shown in the fig 3-1 and that will display a screen with the patient's history as shown in figure 3-8.

Figure 12-8 Screen displaying the patients' history

12.8 Exit System

For exiting the system the user will have to only press the exit button on the main menu where upon the application will exit as shown in figure 3-9.

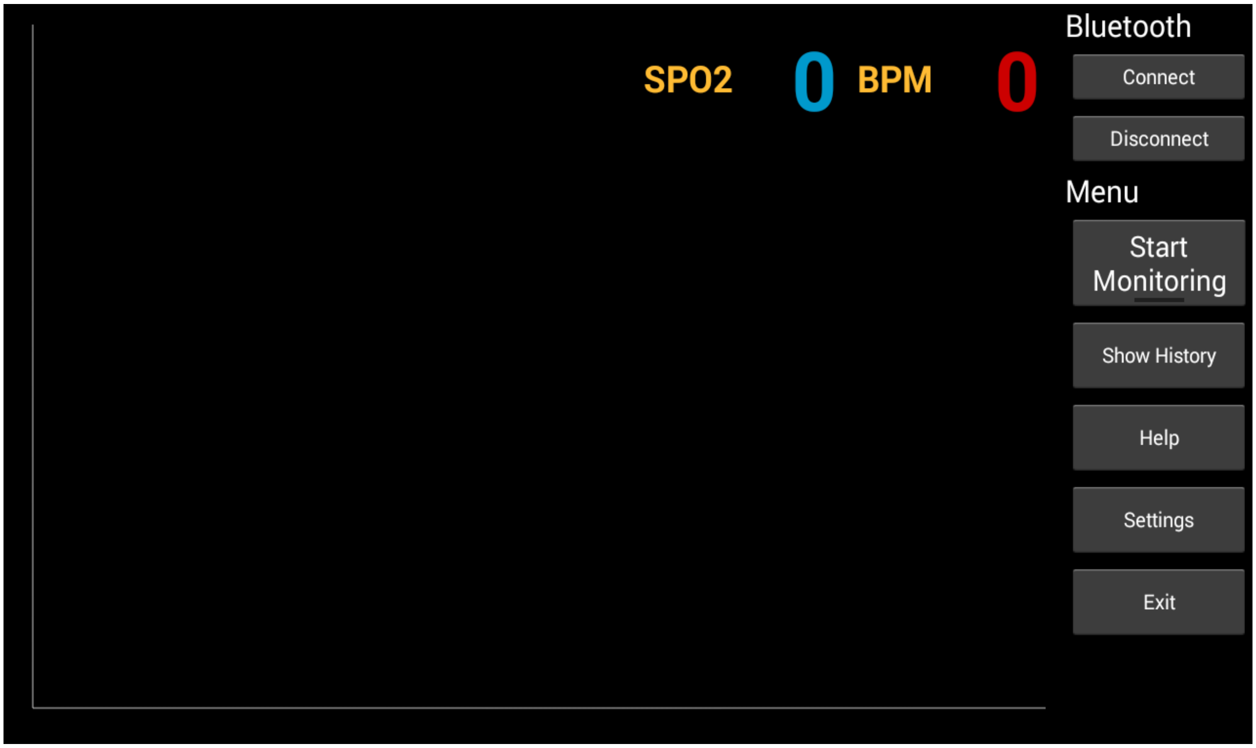

Figure 12-9 Screen showing the exit