IOT BASED SMART INHALER FOR CONTEXT-AWARE SERVICE PROVISIONING

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A project submitted
in partial fulfilment of the requirements
for the degree of
Bachelor of Science in Computer Science and Engineering

UNIVERSITY OF LIBERAL ARTS BANGLADESH
Dhaka, Bangladesh

May, 2020

DECLARATION

We declare that this report/ project entitled "*IOT BASED SMART INHALER FOR CONTEXT-AWARE SERVICE PROVISIONING*" is the result of our own research except as cited in the references. The report /project has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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CERTIFICATE OF APPROVAL

The project report/ project entitled "*IOT BASED SMART INHALER FOR CONTEXT-AWARE SERVICE PROVISIONING*" is submitted to the Department of Computer Science and Engineering at University of Liberal Arts Bangladesh (ULAB) in partial fulfillment of the requirements for the degree of Bachelor of Science**.**

Dated: May, 2020

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DEDICATION

To our lovely parents, and specially aunty (for Anindo) who gave us endless love, trust, constant encouragement over the years, and for their prayers.

To our mentors and peers for their patience, support, love, and for enduring the ups and downs during the completion of this thesis.

This report is dedicated to them.

ACKNOWLEDGEMENT

We wish to express my deepest appreciation to all those who helped us, in one way or another, to complete this project. First and foremost, we thank Almighty who provided us with strength, direction and purpose throughout the project.

Special thanks to our project supervisor Dr. Muhammad Golam Kibria, all his patience, guidance and support during the execution of this project. Through his expert guidance, we were able to overcome all the obstacles that we encountered in these enduring eight months of our project. In fact, he always gave us immense hope every time we consulted with him over problems relating to my project. We also thank "IoT Lab at ULAB", we attended a 3 days long workshop on IoT and learnt lot of thing about IoT.

My friends and family…

ABSTRACT

The evolution of information technology has allowed the development of ubiquitous, user-centered, and context-aware solutions. The overall goal with the project work is to localize user needs and discover ways to implement electronics into the inhaler in order to solve the needs and improve the user experience and service provisioning. It will look like a regular inhaler, but it will different than the regular inhaler by the option we are going to add here. By defining user needs and solving problems with today's asthma inhalers the design process is initiated. But this whole Research work is taken a good knowledge of sensor and connectivity. Our whole system is IoT based and our output will be giving an efficient system for the patients of Asthma. In this research work, different type of sensors and the connections between the sensors and server are the main base of this inhaler system. IoT is the main target to have a smart system where inhalers can do much greater work than the traditional inhalers that are available in the market. To realize smart inhaler vision in a prepared way, a few sorts of context-aware applications ought to be sent. To address these issues, in this project structural plan of a smart-inhaler context-aware service provisioning is proposed, which bolsters participation among application and IOT engineers. Context-awareness service provisioning, finding the inhaler and notifying via mobile devices in case of forgetting to carry inhaler, providing personalized feedback, increasing health awareness - all of these features are included in this smart inhaler. Different source of sensors will be used for the working process and for the base system SOC (system on chip) will be used. Most importantly, this system provides a good connection with the smartphone for context aware service provisioning. As asthma patients consider inhaler to be their lifesaver, it needs to be efficient and user friendly. So considering all the possible options, we are trying to deliver a smart device to those asthma patients.

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LIST OF ABBREVIATIONS

Note: This part should be completed if you have used any abbreviations in your write-up. Please ensure that the list is chronologically organized. Samples are as follows.

CSE	Computer Science and Engineering
ULAB	University of Liberal Arts Bangladesh
IoT	Internet of Things

CHAPTER 1

INTRODUCTION

Asthma is a kind of chronic disease that involves a patient's lungs airways. It is difficult for asthma patients to take breath in a normal way, that causes symptoms including coughing, chest tightness and breath shortness. Hence, inhaling medicine using Inhaler is a way for these patients. Inhaling the medicine in time is necessary for patients, sometimes the patients might forget to inhale. In that case, it is essential for the family members to remind the patients to inhale in time which is always not possible. Start-of-arts technology allows us to remind these patients to inhale.

This research identifies related problems, available start-of-arts technologies, proposed an IoT based Smart Inhaler for making the asthma patients life easier and much more worry free. By the selecting the main tool of their medication "Inhaler" and making it smarter for them. As those patients need the support of inhaler all the time, the project will give them a smart and technological solution so that they can have the opportunity of better medication. The main aim is to keep living as symptom-free as possible while ensuring the best potential impact on asthma. Many consumers who will use this smart inhaler should live a much happier and more efficient life. In fact, learning to recognize early signs of progress to enable adequate risk evaluations and to know when to change the medication products, if exacerbation happens, is critical for the patient. When those people get to learn more about their signs of asthma attack, they can be very vigilant and warn as the system's mobile app notifies them about their body's evolving state as well as the environment condition surrounding them.

It is not possible to cure asthma completely from anyone’s body, but the smart inhaler will give them the opportunity to upgrade their way of life. There will be several features like, finding their inhaler (in case they misplace the inhaler), Notify the user (giving warning to someone if they forget to bring the inhaler), Predicting their triggers (for the better medication they will have a prediction of their drug usage) and Contextual warning (giving them feedback of change in both environment and physical changes). All of these features will give those users the freedom to be free of most of their tensions regarding their asthma condition, in a word betterment of the asthma medication is main focus.

1.1 Background:

Asthma is one of the most severe lung-borne inflammatory diseases. It triggers closing down of the airway of the lungs, and very painful breathing method for those with this disease. Untreated asthma restricts the opportunity to lead a productive life [1], and many asthmatics have not as much power of their asthma as they should have. A common cause is that the recommended recovery program adheres very badly. To achieve the optimal result, the care program should be pursued consistently including on without signs days, which for many asthmatics is challenging for them & relate with [2]. This kind of disease required special treatment and focus. Asthma can be fatal to them when it's taken care of as soon as possible. Because these individuals may experience an asthma episode and they ought to bring an inhaler with the drug with them. Yeah, there are many pills and medications but the most popular type of their treatment is inhaler.

So, we are going to make a smart inhaler for the solution of this problem and give them much relief of tension.

1.2 Asthma & Inhaler:

Inhaler can treat asthma in three conventional forms, one is to inhale long-term drugs, the other is short-relief medications, or we may tell the drug that works very easily, and eventually the medication can use both long-term and rapid treatment, known as mixed drug. And diagnosis for asthma usually includes the awareness cycle of one's cause signs and the approaches to prevent such assaults. There are several triggers that may induce an asthma attack and all practitioners will be very familiar with those trends. We will stop those industries for their development next time [3]. An inhaler (also known as a puffer, pump, or asthma spray) is a prescription system used to administer medicine through the lungs through the bloodstream. It is used mainly in managing asthma and persistent obstructive pulmonary disorder (COPD) [4]. Today it is needless to claim inhaler is part and parcel and core function of an asthma patient's living cycle. Asthma patients use this tool by puffing out medicine from it for their treatment. Inhaler is like their life support, experiencing an asthma attack and not getting an inhaler as appropriate can be lethal for patients with asthma [5].

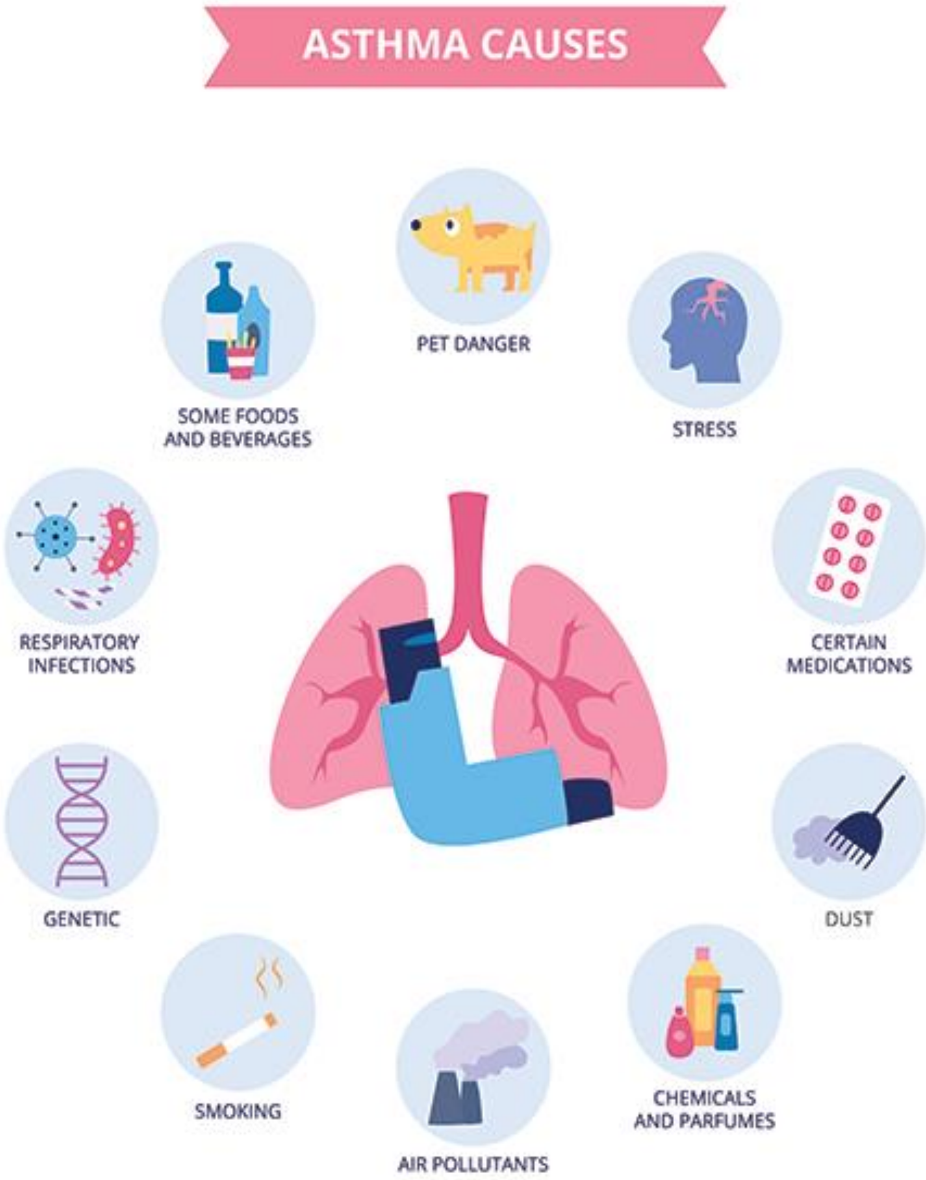


Figure 1. 1: Asthma Causes [80]

1.3 Smart Inhalers:

Smartly enhanced inhalers are also known as inhalers with upgraded with different capabilities – they can make communication to a smartphone application on users smartphones or tablets to help them and their doctors to have proper control or maintenance over asthma [9]. Some smart inhalers are fitted with sensors that can figure out whether you are in heavy contamination or heavy pollen region, some can give you helpful alerts and some can tell you whether you need to test your inhaler. They are all programmed to watch automatically how much you use your inhaler, so you don't have to maintain your own records [10].

Now for our smart inhaler, our system will have finding or tracking option, notification system, mobile App and monitoring option. Like if you lost your inhaler, there will be a buzzer system in the inhaler and that can be triggered through the mobile app. Then someone forgets inhaler in the home they will receive notification and maintained by our smart inhaler.

Figure 1. 2: Features and facilities [81]

1.4 Problem Statement:

The main goal of this project work is to give smart solution of the dangerous disease Asthma. Now there are several challenges considering this project like:

i. Traditional inhalers are like inanimate. Those can not act smartly with their users

ii. sometime serious asthma patients forget to carry their life-saver inhalers

iii. Inhaler should be a helpful companion for asthma patients [6]

iv. It is not possible for asthma patients to follow all their medication pattern, so the system keeps record of those medication

v. As per physiological conditions change, the amount of medication will be also changed, so we are going to overlook this section

The traditional inhaler doesn't cover those part, so our research work will try to include all this sections for the asthma patients for their betterment and much efficiency.

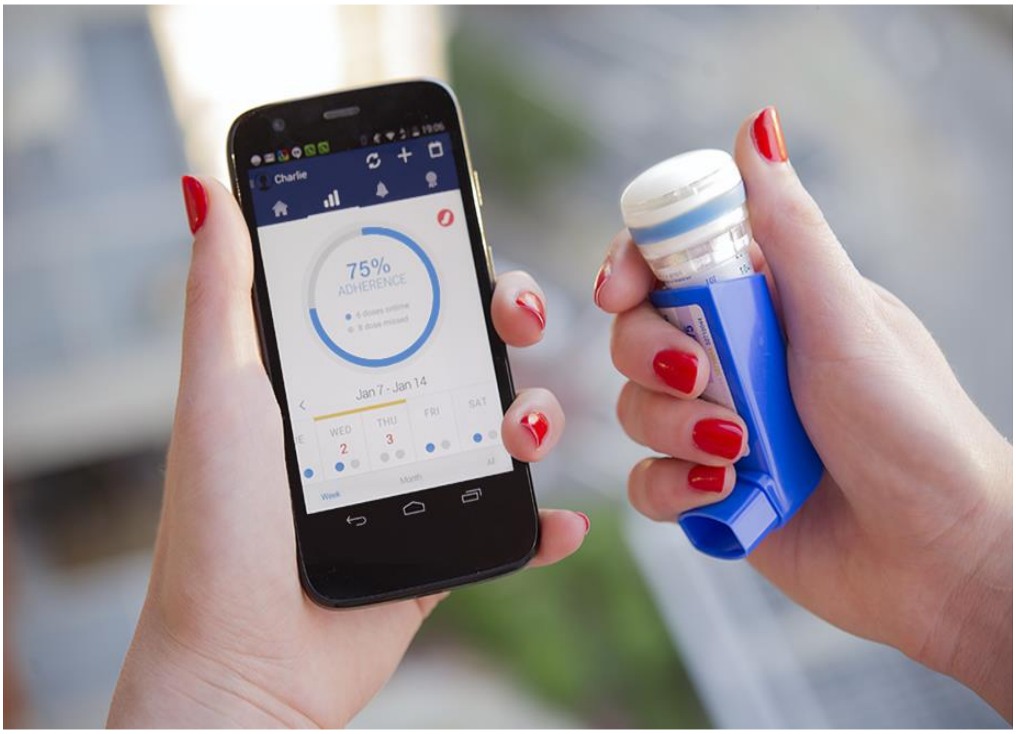


Figure 1. 3: Smart Inhaler [82]

1.5 Research Objective:

For achiving the main target, some important points that our reasearch work is going to follow:

i. There are some smart inhaler available in the market, but not in Bangladesh. So in this proposed idea we would like to introduce a smart inhaler in the market that will make the life of asthma patient easier.

ii. Also considering the other inhalers, our system will be different because, our system will have finding, Several context aware based notification giving part to the user.

1.6 Motivation of Research:

Considering this project wok, there are several motivations behind doing this project:

i. Asthma patients are always in risk of having an attack or forgetting their inhaler. So in this project, our inhaler system will give them freedom and efficiency in their medication.

ii. For the traditional inhaler, there is no way to alert the inhaler-user if they forget to keep the inhaler with themselves [7].

For gaining more **control over their problem** there are also few important points which should be followed and those are:

i. Monitoring their symptoms and their surroundings
ii. Medication time table
iii. Ways and times of asthma triggers and

iv. Finally, development of the whole process [8]

All of this items will be included in our smart inhaler and bringing those options to them is our main inspiration for the project.

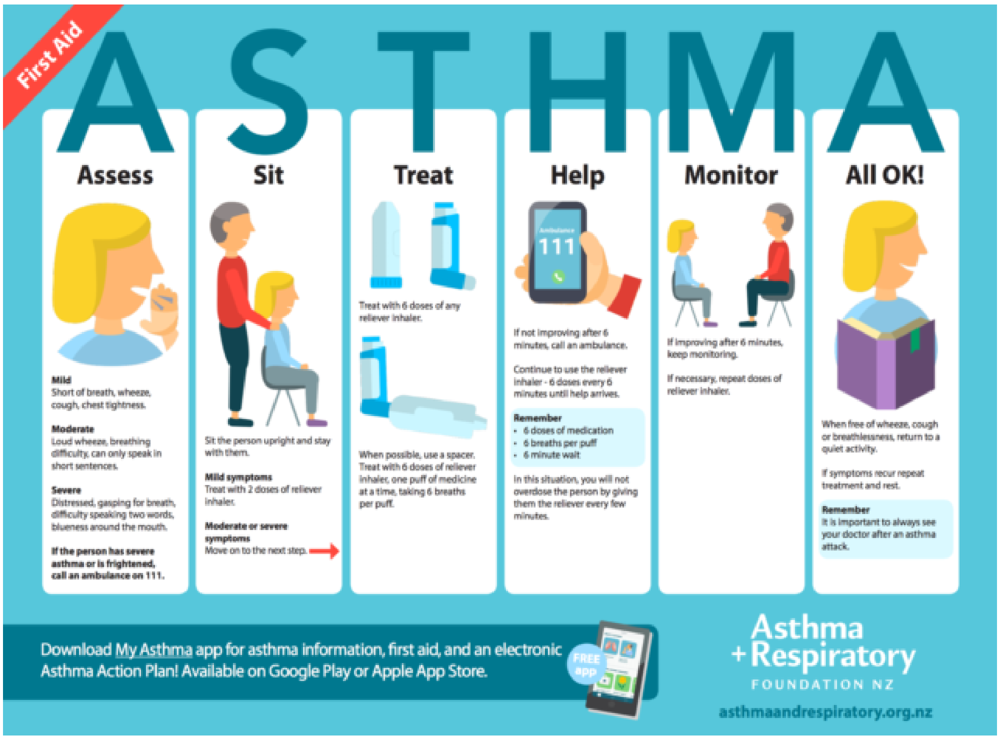


Figure 1. 4: Asthma medication [83]

1.7 Proposed Methodology:

The data obtained by the sensors can be transmitted through Bluetooth to a linked smartphone; the data can then be analyzed in the application server. To those without a device, data may be distributed through a health hub at home or by connecting directly to the machine [11]. Some points for Proposed Methodology, are:

i. connection with inhaler and user
ii. Patient provision for enhanced participation in decision-making
iii. Transparency
iv. Patient choice in deciding diagnosis

v. Customizing therapy and not generalizing

vi. Having achievable objectives

There are some crucial guidelines to pursue in order to have further influence over the problem, and these include: tracking their signs, treatment time scale, asthma causes forms and times, and eventually improving the entire cycle. It's sort of like the form of advice from the psychiatrist, but our approaches would be engineering alternatives. It method is not just easy to do. In spite of these reasons, E-Health is becoming rapidly popular and pro-active in offering alternatives to all those harmful aspects of asthma. Events generate more data than at any point [12].

IoT, in here physical machines has the capcity of gathering, sharing information, modern processing processes and digital technologies are increasingly emerging. Gartner, the consulting company, expects more than 20 billion linked goods will be usable in 2020 [13]. For IoT, the convergence of smart special devices, mobile technologies and cloud infrastructure provides the potential of storing, analyzing and sharing relevant data. Through this way, one may obtain information about the device installation, its utilization, how those functions Optimum or requires maintenance. It has been shown enormous potential to build a smart, IoT-based inhaler that will ease and enlighten life [14]. The tremendous potential for creating an inhaler focused on smart and IoT, that can enlighten certain patients and make life simpler.

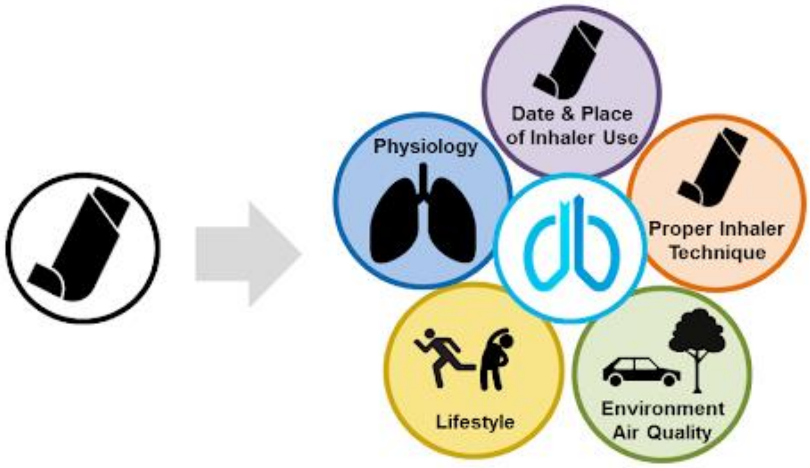


Figure 1. 5: Main targets of Smart Inhaler [84]

In the **figure** 1.5 we can see what are some main target for Smart Inhaler, Like:

i. Recording the date & time of the inhaler use
ii. Will be helpful in proper inhaling technique
iii. Delivery of updated life style
iv. Environment friendly
v. Physiological component of your health

The main purpose behind giving this figure was to understand this parts of Smart Inhaler in a picture.

CHAPTER 2

LITERATURE REVIEW

2.1 Smart Inhaler & related terms:

There are many health treatment providers that involve asthma patients with reliable high efficient facilities, such as Asthma UK. Also turn to GPs, which are like their 'personal physicians' high are qualified in clinical medicine. They help patients to control their general fitness and health [15]. They also detect and cure illnesses, and offer guidance and resources to help patients handle certain problems such as asthma to last a career. Many GPs undergo mild operation, too. GPs in the United Kingdom must obtain a license from the General Medical Council which regulates their practice [16].

Figure 2. 1: Health care Services [85]

IoT One of the core elements for our project and the current condition in this regard is IoT: Smart Inhaler is one such IoT-based approach that recently caught the eye. Asthma is a debilitating condition that has no treatment, and is thus forever widespread. The World Health Organization has reported that asthma triggers 250,000 deaths annually. Asthma prevention diagnosis and care consists of either entirely removing causes or controlling by regulation drugs, eliminating swelling in the airway; or halting spasms by relief medications, minimizing visits and fatalities in emergency rooms. An inhaler is a tool that offers a controlled and aerosolized dosage to a broad variety to medications that are administered [17].

Figure 2. 2: Smart Inhaler & IoT [86]

"context is any knowledge that can be used to describe an entity's condition. An entity is a location, individual or event deemed important to a user's contact with an application " [18, 19]. Information is of two kinds: low-level information concerning time, place, identification and behavior, the most commonly applied

Contingent knowledge and context on all other details that may be extracted from low-level types[19]. The context source is referenced to any computer that can generate contextual data. Typical sources of background are cell phone, monitor, thermometer, laptop, browser, network, site, etc. A context-conscious design often utilizes descriptive knowledge of the individuals concerned to modify the actions and offer context-conscious services. **Context-aware Middleware** seeks to promote **context-aware framework** architecture through the delivery of context control services. In general, context-aware middleware comprises the main system of smartphones, PDAs, PCs, servers, notebooks & also environmental computing tools as well as context management facilities [20].

Figure 2. 3: Context-aware [87]

Quick all the smart inhalers focused on IoT are **sensors** that function as a clip on established inhalers. It has a GPS feature that enables it to monitor where and when the patients take the puffs. Such sensors are linked to an app that the patient is expected to install on their smartphone. On the mobile or a plug-in device, sensors can easily converse this information to the app through Bluetooth. Which are also seen as part of the asthma treatment system, under the supervision of a practitioner. It is a wireless network consisting of a custom sensor that tracks and transmits the acquiescence data for the treatment [21].

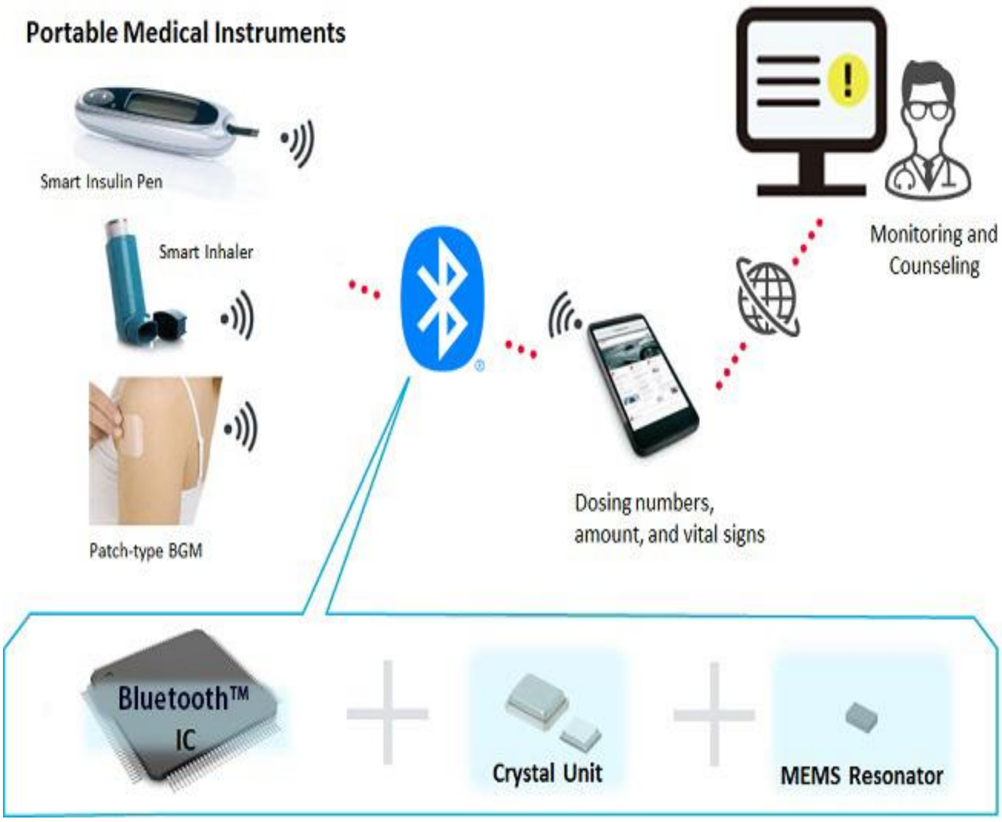


Figure 2. 4: Sensors for Smart Inhaler [88]

Smartphone Administration. The writer Krall, from Cone Health situated Greensboro and state of North Carolina, reported the findings considering expediency analysis to encourage patient interaction using a mobile device. Of 20 patients aged 63 years of age, 17 have completed the 12-week analysis. The maximum weekly conformity ranged from 68% to 84% for routine symptom evaluation; the weekly COPD performance check (CAT) indicated 53% - 100%. Reported medicines indicated 77% - 97%. All it took 1 person per hour a day to manage the database of patients[22].

Figure 2. 5: Smart Inhaler & Smart Phone [89]

2.2 Smart Inhalers:

Down below here are some examples related with the smart inhaler that are already present in the market:

A smart inhaler has been created by Cracow scientists. Through integrating the tool with a smartphone program, asthmatics can consider detecting and stopping assaults more quickly. In everyday usage **FindAir** (the name assigned to the invention) gathers details about the application of the medication and the safety of the user. It stores information regarding what usage and sends it to an application which uses different algorithms to analyze it. Using this basis, the patient may create a customized image of the path of the disease, as well as get aid-alert of the next assault [23].

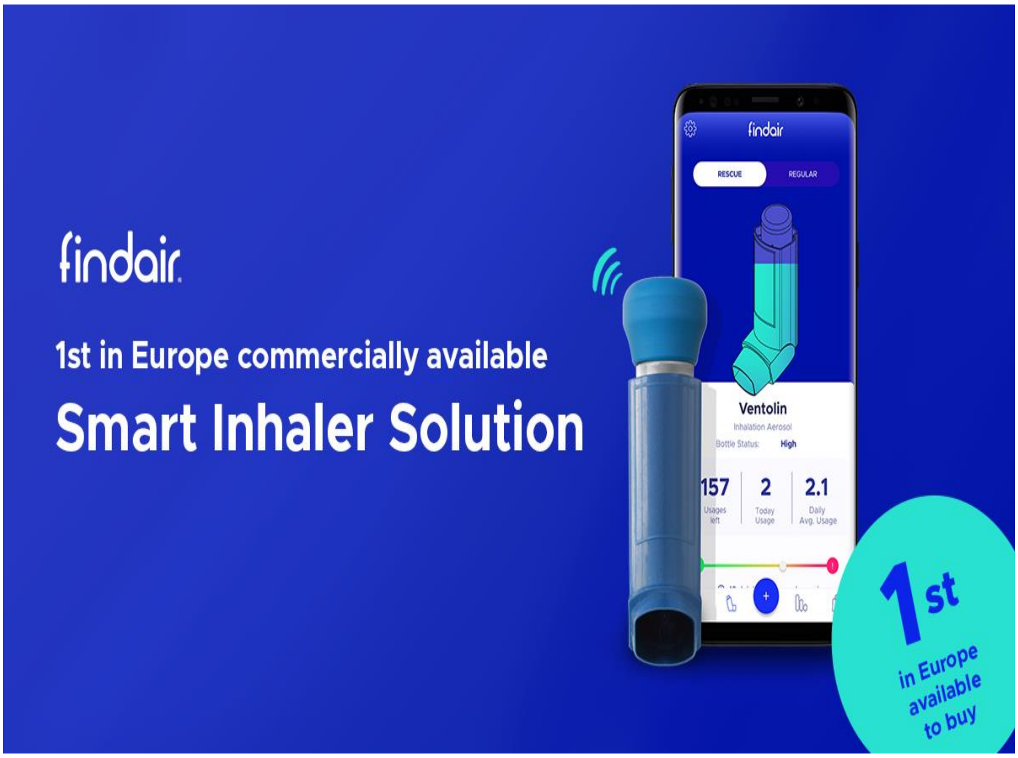


Figure 2.6: FindAir Smart inhaler [23]

i. Goal adherence tests are also critical because patient and parental adherence records are often off-base and appear to overestimate the amount of drug doses received [24, 25, 26]. Equally inaccurate may even be the subjective observations of a doctor's commitment to their patients [27, 28]. The Smart-inhaler (the name assigned to **Nexus 6**, Auckland, NZ) is a tool built for monitoring adherence to inhaled asthma medicines. The Smart-inhaler was a fairly modern tool, and had not been tested before. This research tested the Smart-inhaler's accuracy in a bench-top experiment and compared it to a previously established unit, the Dozer [29].

Figure 2. 6: Nexus 6 Smart touch Inhaler [29]

ii. In order to help patients, obtain better power, In a Master's Thesis paper written by Kent Ngo and Erika Axhed created a framework what will be the next-level of ICOres inhaler, which offers a sign of those patients of asthma condition with the help of capturing, showing details and documenting information when a dose has been taken [30].

Figure 2. 7: Next Generation ICOres inhaler [30]

2.3 Different Sensors Used in Smart Inhaler:

Measures such as the moment in time where the medicine is dispensed include details on the product being stored in the lungs. Furthermore, spirometer-like parameters relevant to disease course require useful observations, and the smart inhaler is an effective resource for treating asthma and COPD diseases.

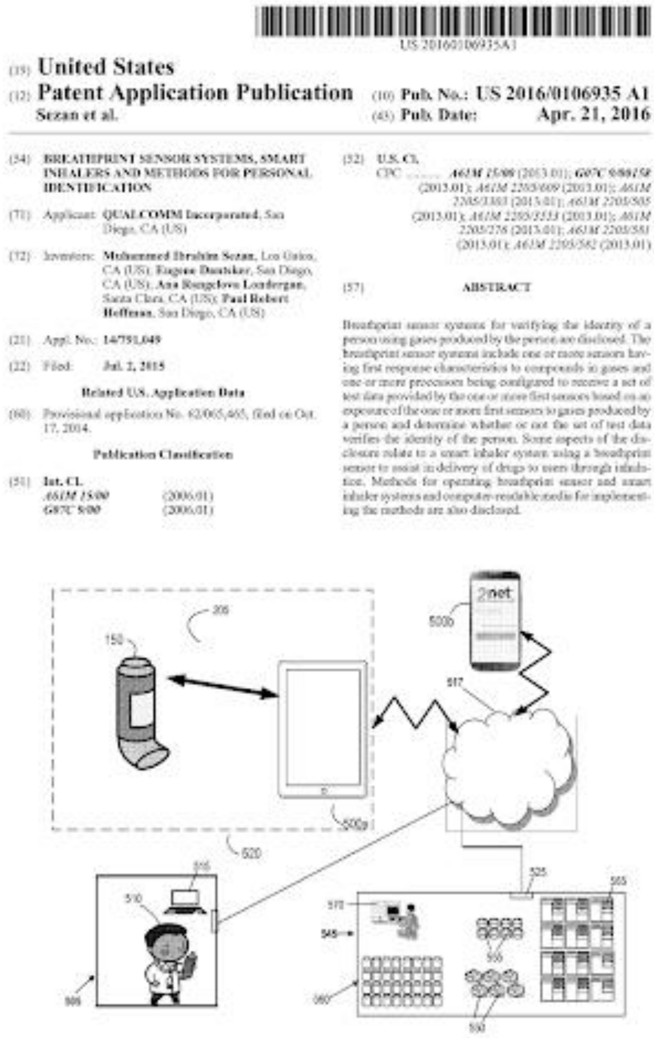
Through the **SDP3x flow sensor**, Sensirion allows applications that vary from basic inhalation flow activation to accurate flow profile characterization. This requires customer input on optimizing inhalation and diagnosis and benefits the health care professional. Sensirion would have the sensor solution customized to the unique product specifications. Using Sensirion's technologies to test modern e-health solutions effectively, and allow tomorrow's medical inhaler tool [31].

Figure 2. 8 : SDP3x flow sensor [31]

The inhaler's **GPS sensor** is a special function that constantly tracks when and when the puff has been administered, with this details over a span of time, it comes up with a trend, without the requirement for specific diaries or any aware knowledge entry. Time and position statistics for each application was related to a broad variety of variables from weather, spatial, traffic, to multiple neighborhood details, generating a chart of incidences of an asthma attack. Using this knowledge of where and where the rescue medication's prophylactic puff was administered, the cause of the assault may be removed entirely [32].

Figure 2. 9: GPS enabled Inhaler [90]

Breathprint sensor systems are disclosed for verifying a person's identity using the person's produced gases. The breathprint sensor systems contain one or more sensors with first reaction characteristics to gas compounds and one or more processors that are designed to accept a series of test data generated by one or more first sensors based on a person's exposure of one or more first sensors to gases and to decide whether or not the test data collection verifies the identification of the print. Any elements of the disclosure apply to a smart inhaler device that uses a breathprint sensor to help administer medications by inhalation to the patients [33].



US 20160106935A1

(19) United States
(12) Patent Application Publication (10) Pub. No.: US 2016/0106935 A1
Sezan et al. (43) Pub. Date: Apr. 21, 2016

(54) BREATHPRINT SENSOR SYSTEMS, SMART INHALERS AND METHODS FOR PERSONAL IDENTIFICATION

(71) Applicant: QUALCOMM Incorporated, San Diego, CA (US)

(72) Inventors: Muhammed Ibrahim Sezan, Los Gatos, CA (US); Eugene Dantsker, San Diego, CA (US); Ana Rangelova Londergan, Santa Clara, CA (US); Paul Robert Hoffman, San Diego, CA (US)

(21) Appl. No.: 14/791,049

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(57) ABSTRACT

Breathprint sensor systems for verifying the identity of a person using gases produced by the person are disclosed. The breathprint sensor systems include one or more sensors having first response characteristics to compounds in gases and one or more processors being configured to receive a set of test data provided by the one or more first sensors based on an exposure of the one or more first sensors to gases produced by a person and determine whether or not the set of test data verifies the identity of the person. Some aspects of the disclosure relate to a smart inhaler system using a breathprint sensor to assist in delivery of drugs to users through inhalation. Methods for operating breathprint sensor and smart inhaler systems and computer-readable media for implementing the methods are also disclosed.

Figure 2. 10: Breathprint Sensor [91]

The **HailieTM** approach is a software and app platform that lets patients and health professionals control respiratory problems and medicines.

The **Bluetooth** ® wireless technology-enabled HailieTM drug sensors wrap around current patient’s inhalers and transfer use details directly to their mobile. Using the HailieTM smartphone device, patient and health care providers can monitor adherence to medicine, set regular reminders and gain insights about the usage of medicine [34].

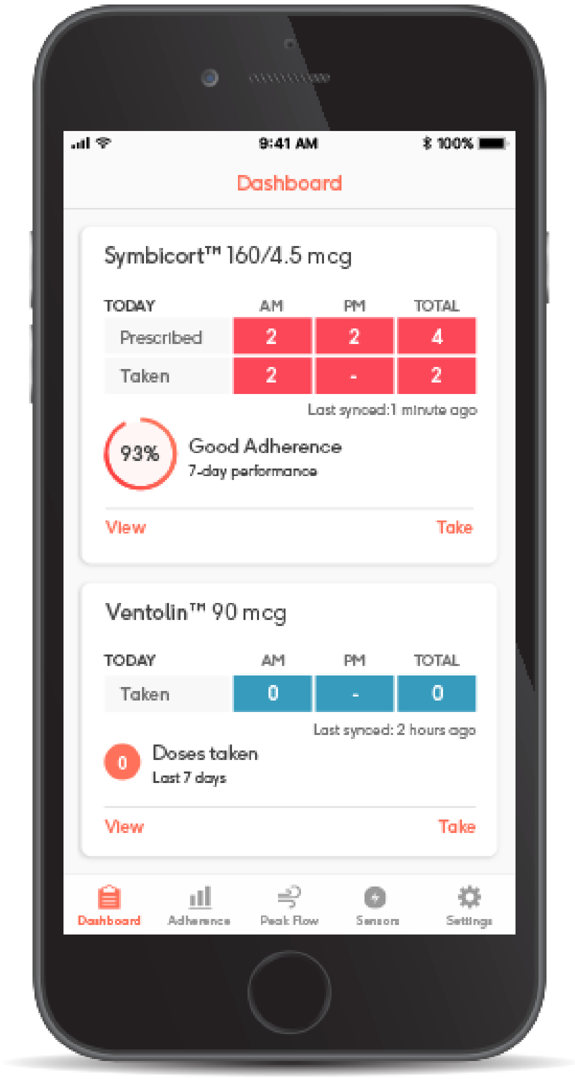

Figure 2. 11: HaileTM and Bluetooth [92]

Cohero manufactures the **HeroTracker** series of sensors that target MDI and Diskus inhalers to monitor conformity to the drug. The data is compiled and subsequently submitted by physicians, analysts or insurance providers to an electronic archive for access-while patients can check their data via a smartphone device. Also, they develop a smart spirometer [35].

Figure 2. 12: HeroTracker Sensor [93]

2.4 Getting the Basics Right:

Asthma victims use several forms of inhaled drugs: often use inhaled corticosteroids to diminish the illness-driving swelling and prevent attacks, and when problems such as weeping or wheezing begin, they use bronchodilators, known as outfielders or relief medicines. For now, just smart inhalers record actuation-a location and time stamp when a patient using an inhaler [36]. Many firms style devices that strap on existing inhalers; leading the charge is US-based Propeller Public health, and New Zealand-based Adherium. Both have data from clinical trials showing that their medicines can support patients [37].

A controlled observational trial of 495 patients showed that people have more relief-free days and improved management of asthma over 12 months utilizing Vertical fin's smart inhaler attach-on, and smartphone apps used fewer relief pitcher medication. In the meantime, a randomized controlled clinical trial of 220 classroom-age children showed that perhaps the Adherium intelligent inhaler increased responsiveness over a period of 6 months to prevent medication [38].

Such findings have whetted the curiosity of the medical industry and the promise of intelligent inhalers. GlaxoSmithKline, Boehringer Ingelheim and Pfizer signed cooperation arrangements with Turbine Health while AstraZeneca entered into a master service deal with Adherium. Pfizer is also working with US smartphone app maker Qualcomm for develop the first wireless smart inhaler they plan to deliver in 2019 [39].

Figure 2. 13 : Adherium Smart Inhaler [94]

2.5 The Importance of Technique:

Prospective smart inhalers can be of benefit by monitoring and adjusting a person's inhalation strategy. Research teams at the Dublin-based Royal College of Surgeons in Ireland headed by Richard Costello have developed a device that is linked to GlaxoSmithKline's popular Diskus Inhaler. To monitor the procedure, the device uses acoustic instruments and can detect errors both in the inhalation duration and the procedure. MyAirCoach, a mono-institutional study project sponsored by the EU, is examining how mobile health devices such as smart inhalers with sophisticated sensors will help patients cope with the asthma [40].

MyAirCoach launched patient work at two UK sites — Manchester University and Imperial College London — and also at the Institution of Leiden throughout the Netherlands in fall 2016. Analysis specialists are developing data collection and simulation software to make the findings obtained relevant to nurses and physicians [41].

Clinical chief responsible MyAirCoach named as Omar Usmani, a pulmonary physician working for Imperial College London. "More frequently than not you have a patient use their inhaler for the incorrect inhalation procedure, which indicates that they will not use it in other situations as well," he notes [42]

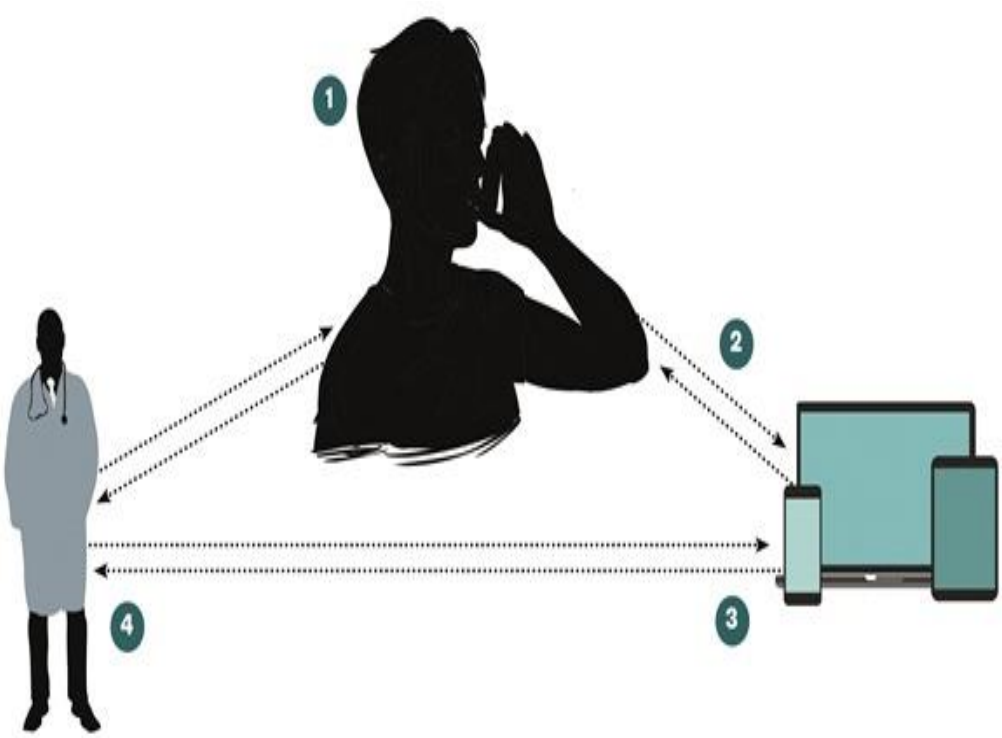

Figure 2. 14 : How Smart Inhaler Work [93]

2.6 Statistics of some flow rates of inhalers:

Patient inhalation is correlated with two significant and most severe mistakes in the usage of inhalers. Through monitoring the inhaled ventilation into the inhaler and thus tracking the moment in time when the medication is being dispensed for MDIs [43], it is important to reliably assess if the product has been delivered during the optimum timeframe of the inhalation period (Figure 2. 15). The timing of the dose-trigger versus flow association is one important parameter for knowing whether the medication carrying flow penetrated deep into the bronchia and obtained the required high lung deposition (Figure 2.16).

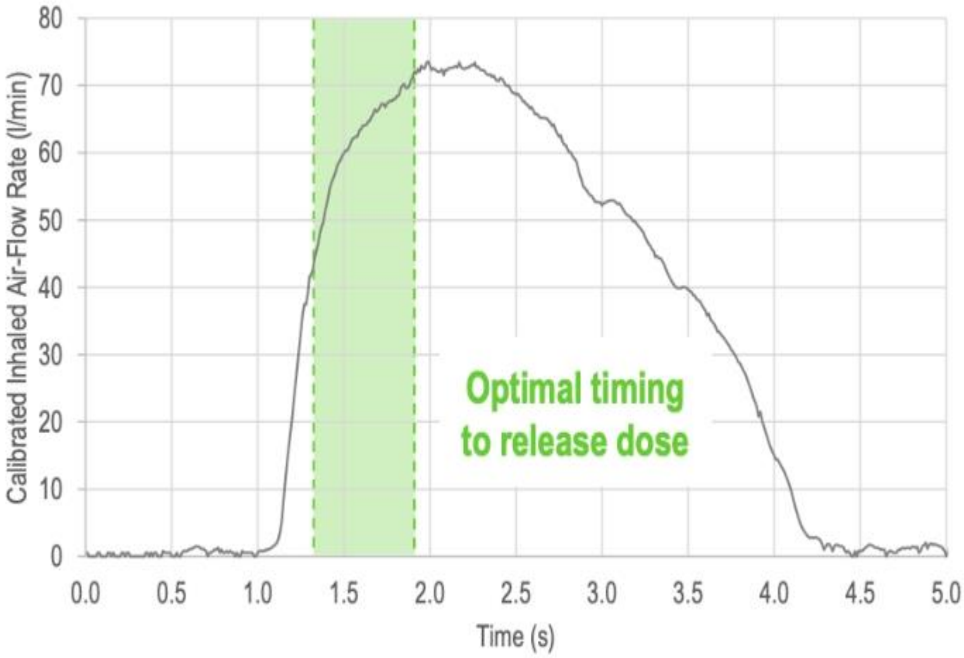

Figure 2. 15 : Calibrated flow rate versus inhalation time [95]

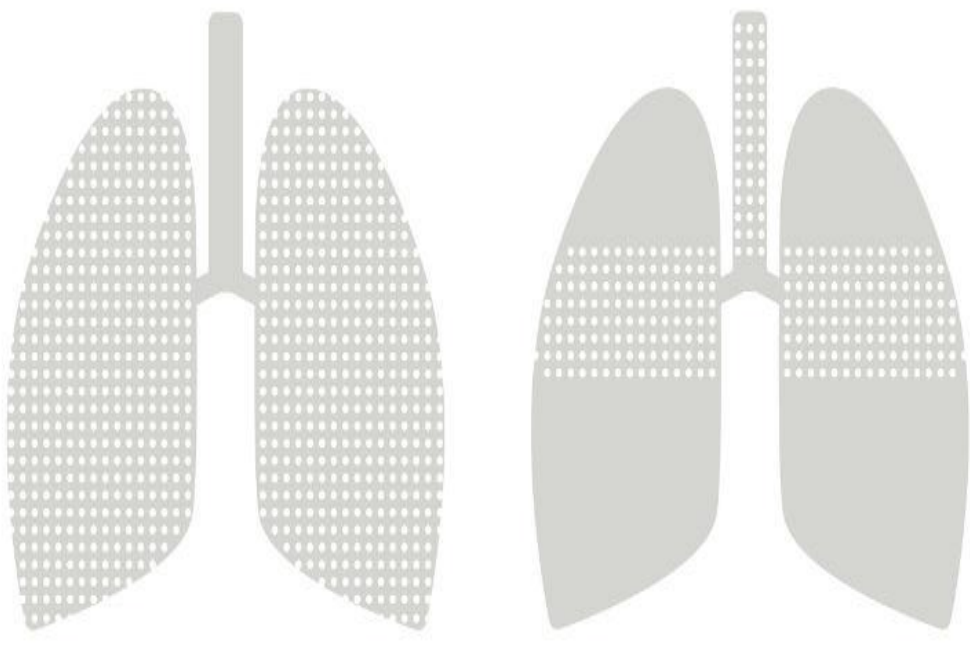

Figure 2. 16 : Drug deposition -optimal timing window (left), released too late (right) [96]

The knowledge above is given by precise and measured real-time measurements of the inhalation flow pattern, from which it can be established if the patient conducted the inhalation correctly and obtained a high lung deposition during inhalation. Certain parameters of concern include the inspired vital potential (IVC) and peak inspired flow rate (PIF) [44], along with the maximum characteristic of inhalation airflow as seen in Figure 2.17.

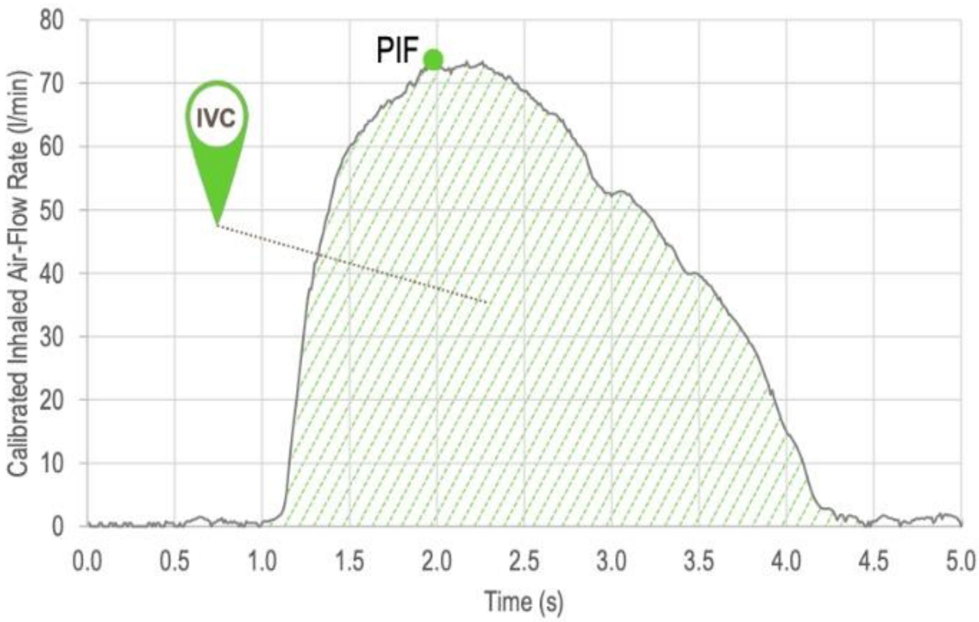

Figure 2. 17 : Inhalation airflow characteristic parameters [96]

The second important parameter is the airflow profile and is inhaled. Borrowing from spirometry, several parameters can be obtained from the inhalation airflow profile which provides insight into the inhalation of each patient:

i. Depth and duration of inhalation
ii. Full exhalation before inhalation
iii. Fast inhalation as per the directions Lung function and
iv. Its development over time

The inhalation airflow profile may also be used to evaluate subsets of parameters such as forced influenced volume within the first second of inhalation (FIV1) [45], or airway resistance (RAW). The following derivation is represented in Figure 2.18.

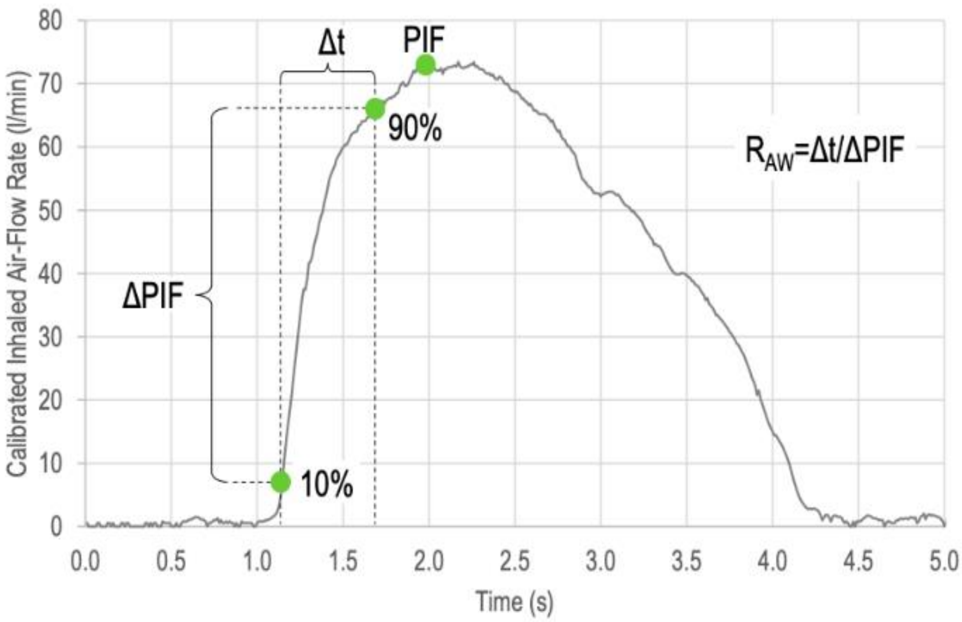

Figure 2. 18 : calculate the airway resistance (R_{AW}) [96]

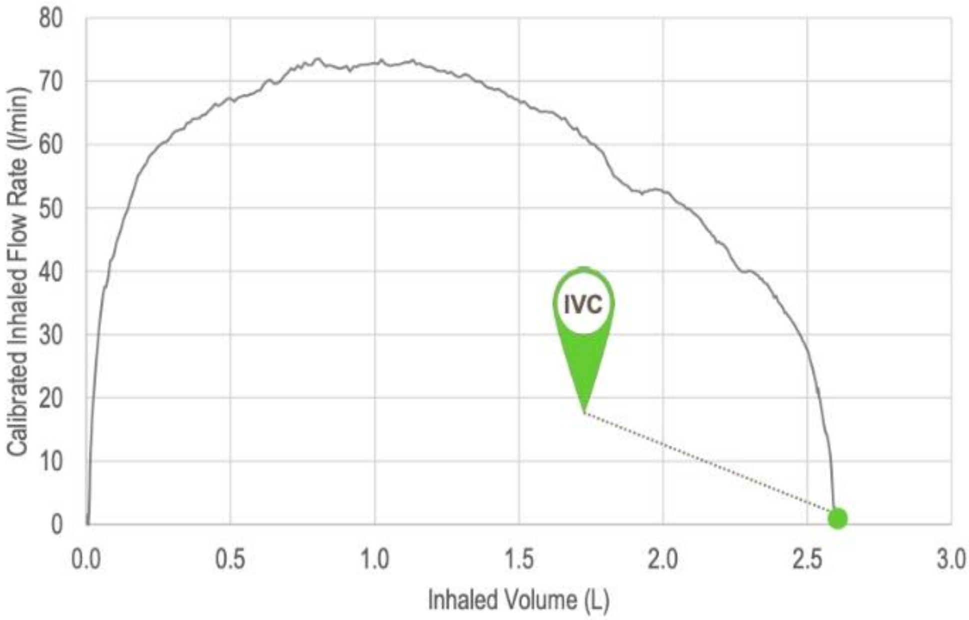

Figure 2. 19 : The flow rate at the conclusion of the inhalation drops to 0 [96]

Figure 2.20 displays the PIF, IVC, and RAW schematic actions against the period. It visualizes the beneficial impact of beginning therapy, the safe period of care during daily administration, and the detrimental effect of medication interruption [46].

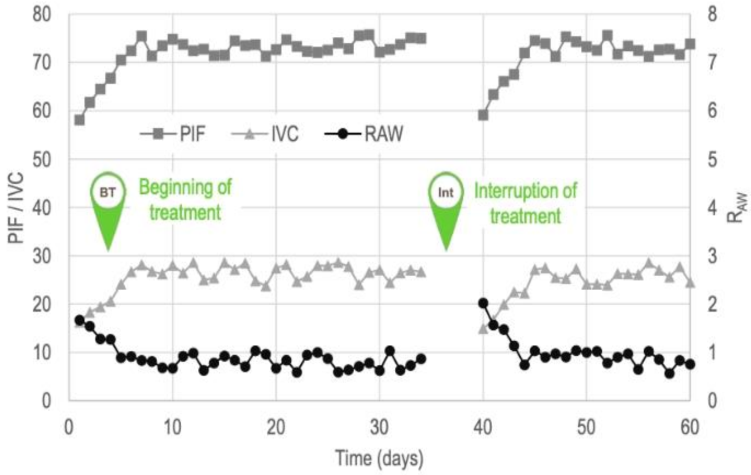

Figure 2. 20 : the beneficial impact of beginning therapy to patients [96]

By incorporating the monitoring flow functionality to the inhaler drug delivery system, it is not only possible to track patient compliance and proper usage of the inhaler, but it is also possible to examine the efficacy of the treatment and the progression of the disease over time using spirometer-like lung function measurements [47].

New generation inhalers — naturally integrating airflow calculations into their design — will enable automated dosage release at the optimum point in time, adjusted uniquely to the patient and to their particular diagnosis.

2.7 Context Awareness:

In a report published in January 2017, 'Smart Asthma,' Asthma UK outlined its concerns about the necessity for healthcare providers to plan appropriately so that the full benefit of smart inhaler technology can be realized [48]. Modern inhalers may alert patient about potential atmospheric hazards and, if used widely enough, may help researcher answer key questions. This will involve managing the competition between drug makers in order to make the goods and the information they produce standards compliant.

But there are several smart inhalers in the market that have the ability of sensing the environment and give you notification according to its user.“Find out what triggers your asthma” this is one of the moto of **FindAi**r and they give the facility of sensing the environment as they are saying: Now you may browse at all the details gathered in the **FindAir App** and it will tell you what to watch out for! Is it the grass pollen that triggers most of your symptoms, poisonous air quality or harsh winter weather in your area? This are some of their features or analytic part related with context awareness of the inhaler.

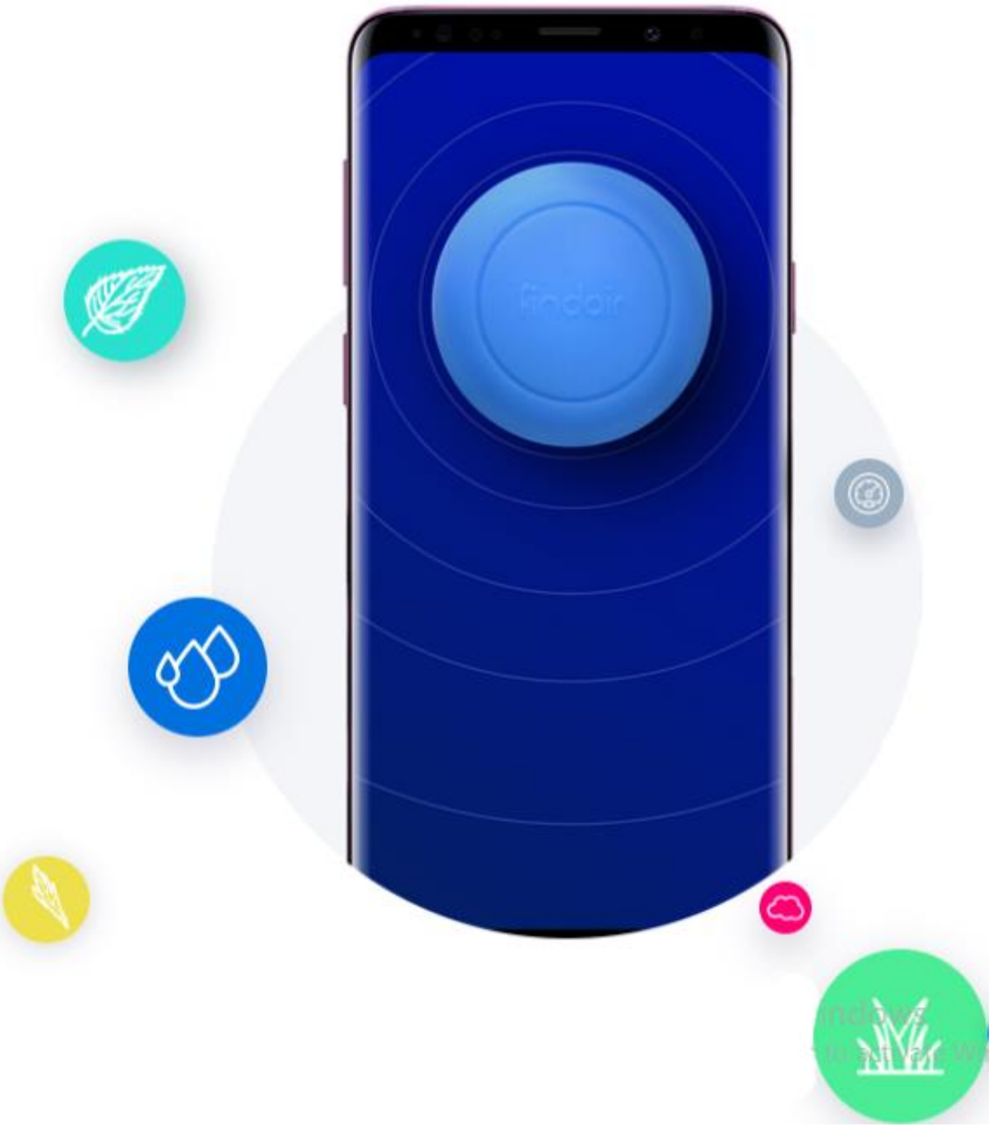

Figure 2. 21: FindAir Mobile App **[96]**

They determine whether a bio monitoring device that incorporates an atmospheric sensor — like nitric oxide, particulates, other atmospheric monitoring dimensions — can be beneficial to patients in providing them with tailor-made information of how they could respond to an assault.

Figure 2. 22: ProAir Digihaler [97]

ProAir ® DigihalerTM contains built-in sensors which sense inspiratory flow when the inhaler is used. This inhaler data is then sent to the accompanying smartphone device using Bluetooth ® Wireless Technologies to enable patients to monitor their data over time and exchange it with healthcare professionals if needed. This smart inhaler can also sense the environment and give update to the user, what should they do or what are condition is going to be. According to its environmental updating option, it will notify the user.

Figure 2. 23 : MyAirCoach [98]

The aim of myAirCoach project is to support asthma patients manage their disease through mHealth. New management strategies coupled with the creation of modern devices can create a framework that tackles patients' needs on a regular basis. Analysis, simulation and analysis of signs of illness may help to inspire patients to participate in health care, as well as to improve awareness about the possibilities mHealth will offer to treatment of asthma. They also provide environmental sensing, which allows their user for a better solution for their asthma problem.

2.8 Smart Phone:

Smartphones have become an essential part of life, and mobile healthcare systems (mHealth) are innovative devices that might revolutionize self-management of asthma. There are more than 200 smartphone apps for asthma and additional portable and inhaler-based applications are commonly available [49]. A 'Virtual nurse' also let people navigate their medical details and provides guidance about how to treat their sickness. The app helps doctors to set guidelines that will give specific patients auto-notifications. For example, if the patient's blood pressure increases above 120, a doctor can set a guideline that determines they must get a prescription to take medicine.

The systems attach over Bluetooth to smartphones. Maker appears to offer corresponding mobile applications where you can look at your data or alter memory settings, which might not be possible on any mobile form. The intelligent inhaler applications that have appeared to date appear to operate on both the iPhone and Android.

Figure 2. 24: Connecting with Smartphone [84]

2.9 Connecting, Saving Data & Analyzing:

As per we have seen, smartphone or other electronic devices are connected through Bluetooth or Wi-Fi or other type ad on devices and the main reason for this connection is transferring data from inhaler to device then to cloud or server.

Most of the smart inhalers' large-picture vision includes their ability to have comprehensive data so experts may study to understand more about the disorder and prepare for new approaches. For example, the MyAirCoach project is seeking to know about the process how all those data could have been transmitted back to patients to help them to recognize their causes easier and eliminate them.

The data may also be used for care personalization. "If a clinician goes to a patient who, say, is 40 years old, has smoked ten cigarettes a day for ten years, is married to three daughters, at an income point of none," says Ryan, "if you can go to the cloud to see maybe 10 or 15 people with a common background to see what therapy has performed for them, you will clarify it to the patient to suggest 'Let's do this.'"

One form of contact, the user flips the Main rotor sensor on the inhaler as well as the new device's sensors streamline the data collection process by monitoring the signal and capturing precise information regarding the symptoms and substance usage on the patient's smartphone and company list. The health care professional of the patient gathers the data generated in the control panels and the doctors may ask questions that are informed by evidence. "If patients miss a critical dosage of preventive medication, the applications track substance usage date and time and give consumer audio and video warnings," Adherium explained in a press release[50]. "The devices send the data directly to a smartphone device, presence detection center or Laptop using the SmartinhalerLive wireless contact program, and then sending to company **cloud-based server**.

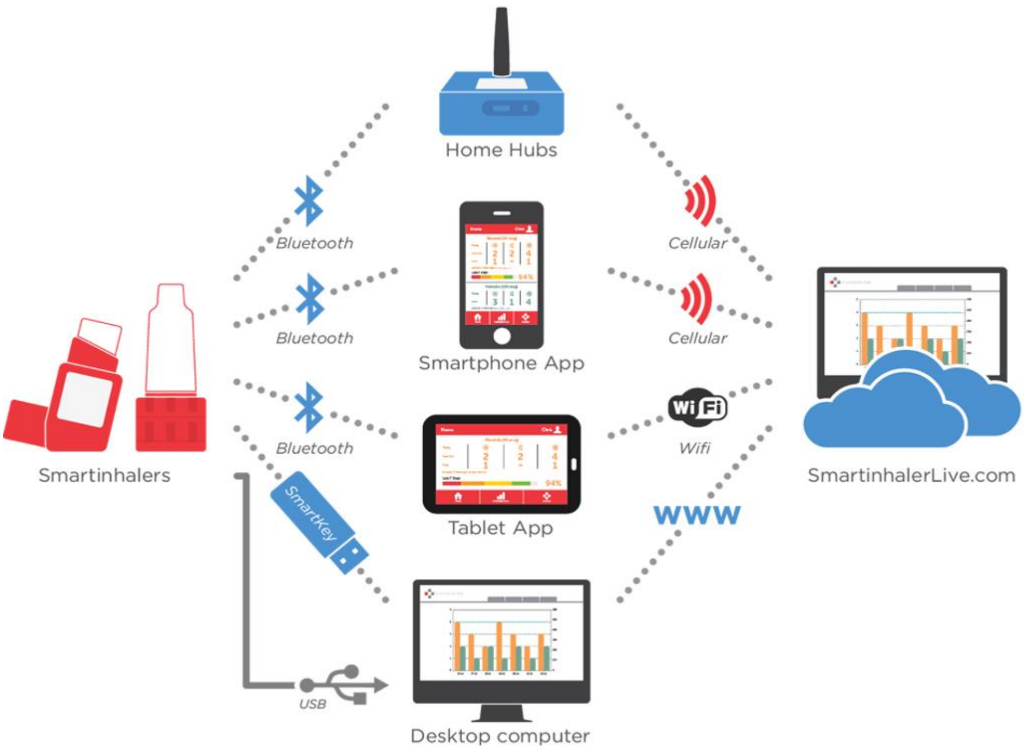

Figure 2. 25 : Connecting & Data flow of Smart Inhaler [99]

If consider this picture, there is a smart inhaler connected to different types of electronic devices through Bluetooth, WIFI or other kind of devices. The data is flowing through those connections and transferring to those devices.

Now finally those data are traveling through cellular data or WIFI to the cloud server to be saved or to be analyzed. And most of the smart inhaler that are available in the market follows this pattern of connectivity and finally saves the data in cloud server. This server can be of the organization or the doctors or the user itself.

CHAPTER 3

IOT BASED SMART INHALER SYSTEM

3.1 Introduction

Asthma is a clinical condition that affects about 300 million individuals worldwide [51]. This is projected that by 2025 [52] there could be an extra 100 million individuals with asthma. Asthma accounts for about 1 of every 250 dies worldwide [53], while existing prevention, which naturally requires patient care, will avoid 80 percent of these death [54]. Further than 100 million people experience coughing and chest tightness in Bangladesh. Nevertheless, citizens are seeking unplanned care and consuming unscientific, natural and often dangerous goods in order to receive relief.

Inhaled drug is as the main therapy for asthma had contributed to major changes in the management of asthma [56,57]. Unchecked asthma, nevertheless, is still widespread and poses a significant burden on clinicians and society [58,59]. IoT dependent context-aware intelligent inhaler program has now been introduced to concentrate on this issue and conventional inhaled medicine.

3.2 Description of Smart Inhaler system

Now considering a person, User is a male asthma patient and he has our smart inhaler for his medication. Considering the features in our smart inhaler, down below some some key points related to this system has been discussed:

Features & Options: Suppose, user is a busy guy, he needs to travel different place and obviously the environment for those places won’t be same his regular work places. Now different environment can trigger Asthma attack, suppose his body may not get enough oxygen while he is walking, biking, driving or performing any other things at high altitudes.

Altitude sickness may be caused by shortage of oxygen. Altitude sickness typically arises at altitudes over and below 8,000 feet. People that are not used to these altitudes are more susceptible. Symptoms contain fatigue, and sleeplessness. Altitude vomiting shouldn't be taken lightly. The situation is extremely harmful. Altitude sickness is difficult to foresee — anyone will catch it at high altitude.

Altitude sickness symptoms can start up instantly or gradually. Symptoms of illness at altitude include:

i. Fatigue
ii. Migraine
iii. Exhaustion
iv. Vomit
v. Fast heart rate
vi. Shortness of breath (with or without exertion)

Figure 3. 1: Altitude Sickness & Asthma [101]

The disease asthma doesn't only depend on the height also depends on weather, amount of carbon dioxide and other gases mixing in the air, temperature etc. and according to environment and patient's physiological condition also. Every time when user change his location area, according to environment and physiological condition user gets notifications about his current environment and physiological condition through his smartphone app.

This app will let him know that, he should take puffs immediately or not, for prevent sudden asthma attack in an intelligent way. Basically our main goal is to give early notification for upcoming danger, so the user can prepare himself with the changing environment or the changing weather. Having that context awareness feature, the system has been propossedare also looking forward to add other features like:

Notification: This option will give notification to the user when they accidently forget to take their inhaler when they are going outside. After 100-200m distance from the inhaler, the system will give them a notification in the smartphone and remind them to bring their inhaler back. So the inhaler will be acting smartly in this part, because forgetting their inhaler can cause to major damage and can create emergency situation for the user. This is one of the key & lifesaving feature if weconsider the amount of danger an asthma attack can bring to the user.

Figure 3. 2: Tracking & Finding Inhaler [102]

Tracking: Now suppose the user can’t remember where they have put or left the inhaler for the last time. Here the system has been proposed have the tracking option that will give the simplicity of finding the inhaler through the smartphone application. Basically they can click the find button in the mobile app and a buzzer sound will come out from their inhaler and they will be able to find the lost inhaler. Imagine someone having an attack and they can’t find their inhaler, that situation is not good by any means. So having this tracking feature a user can have much relaxed life and will be safe from losing their precious inhaler, also they can find the inhaler in the time of their.

Prediction: Now it is common that, the asthma attack and it medication can change concurrently. Also the physical condition of the user can change in different period of time. As the conditions are changing the user can take less or more amount of drug according to their situation. With the help of the mobile application, user will find it easier to predict and prevent attacks and guess what sort of medication they will take for that particular phase. From collected data on the use of the drug and the user's craniological conditions during everyday use. It will save information on each use and send it to an application that will analyses the data using special algorithms. On this basis, user can be created a personalized image of the course of the disease, as well as will get notify - warning of the coming attack. Also this prediction can make the job the doctors easy, because doctors can also see those data and give updated medication to the user. Like how much drug or gas they are inhaling can sum up the result of their future attack.

Health Awareness: As the users will be updated every time about their physical & environmental situation, they will be much aware of their health issues. The smartphone app will give them notification if the situation changes. Like rise in their heartbeat or oxygen level. If their heartbeat is rising they can take pre-cautions right before they go through an asthma attack. Not only their physical conditions, their environment can also trigger their asthma attack, like high temperature, less or more humidity, rise in carbon dioxide level etc. All of this can engage a trigger in their asthma attack. As our smart phone app will notify the user, they can be self-conscious before they face an attack. Considering all this parts, Asthma patients can be much more health conscious by using our smart inhaler system

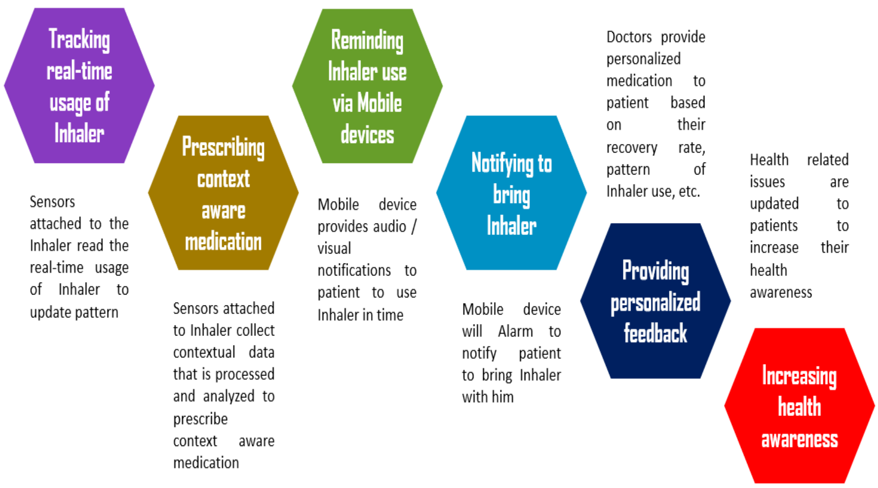

Figure 3. 2: Features of the smart inhaler

3.3 Proposed System Architecture

The proposed system has an architecture for our how the system will try to combine them with context provisioning and making the medication of asthma patients much more digitally controlled than the traditional way through this smart inhaler system. This system architecture is designed such a way to collect all that data from context (environmental or physical changes) and make them in a useful output for both patient and doctor for better prediction and medication.

First of all, various sensors will have attached to the user's body for measuring his physiological data which are directly connected to the asthma such as heart-beat rate, oxygen level in his blood, body temperature and so on. Other sensors will collect the contextual data which also are directly connected to the disease asthma such as temperature, humidity, the amount of carbon dioxide mixed in the air, quality measurement of air which causes the shortness of breath and so on. These environmental and physiological data and also some other data from inhaler will pass through a gateway to the local server. Inside the server some analyzing will be going to take place and using advanced analytical techniques such as machine learning to take decision for the user in that situation, which is better for the medication of his asthma. Because, As decision-making circumstances are more difficult, sophisticated analytical approaches are becoming increasingly common in solving a broad range of issue types (explanatory, descriptive and proscriptive) in many sectors, including health care and medication; [57]. The taken decision as form of a report will send to the user's smartphone app as notification if it is important for the user, and the user also can check his physiological and his context status by his smartphone app whenever he wish. These analysis report will send to the cloud server through internet for storing and further analysis the data. The cloud server can also communicate to the user using telecommunication. If the user wants to find the inhaler where he kept his inhaler in indoor area, and if the inhaler is inside the Bluetooth range from his smartphone he can trigger the buzzer attached to the inhaler by the smartphone app which will more easy to find his inhaler in emergency.

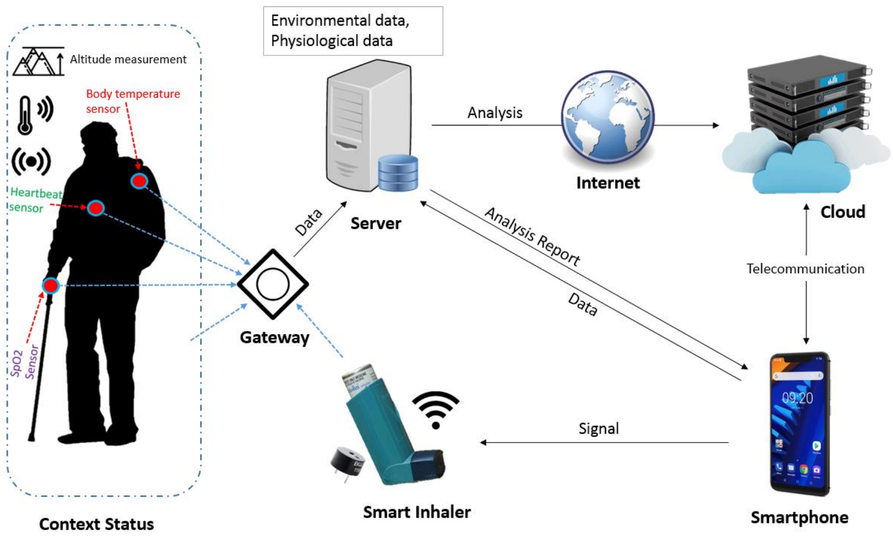

Figure 3. 3: Proposed System Architecture

3.4 Proposed Context-aware system architecture

Context-aware option allows smart Inhaler systems to make decisions on current context-aware services and also based on user's surrounding context.

From context status of the user and inhaler, the data will be passed to the server. Then inside the server specialized algorithms will analyze these the data coming from sensors and then the server will send report to the patient's registered devices application such as smartphone app. This registered app notifies the patient about the information of important changes in his context. Like their environment is changing or their physical condition is changing. Like there is change in the humidity, temperature, Carbon Dioxide level etc. Also can notify if their heart beat is changing, those source of situation that triggers their asthma attack. If in case the system is unable to communicate to the registered app via internet in a worse case, server will communicate to registered phone number through tele-communication. Inside the server all of these data would be saved in an analytic data storage and by considering the user registered app they can recall those data anytime from the analytic data storage to check the overall condition for the better understanding about his asthma. Also their doctor can work with this data and provide them with better medication for their situation. They can have a look of data of their month or week or even daily basis.

From High-level Architectural point of view, this system has 3 parts which will directly interact with users. There are: Context aware middleware, inhaler and smartphone App.

Context-aware middleware:

Context-aware middleware is essentially the combination of two elements in our analysis work, they are-the Context Management System (CMS) [60], and the Knowledge and Notification System (ANS) [61]. The Context Control system facilitates the usage of context-aware software and resources to publish their contextual knowledge. The Knowledge and Messaging system is a rule-based facility that enables customer applications to apply to regulations that include meaning-based requirements and to provide notice when the framework has been established. The suggested unified middleware design of the links to client applications and information sources [62]. So in this case there will be a gateway and that is our context-aware middleware which will be connection bridge between ANS & CMS of our system. The repository includes a list, which has the responsibility for preserving a normal viewing of the domain context types. And we need to look at points as well, sign in and get out.

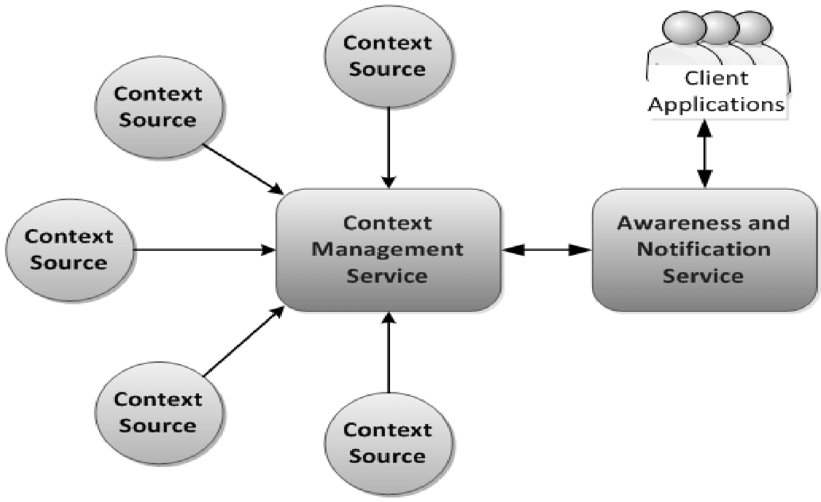

Figure 3.4: Context-aware middleware architecture

For the categories, there are Context source, Context provider, Server, Context consumer. Different type of work will be done in these categories and for the efficiency of the development, this proposed system has derived into these four parts [63]. Their descriptions are:

Context Source: The sensors will be our main source from which the system will take the information about the context and through the information provided by this sensor, we will make decisions.

Context Provider: Microcontroller or SOC (system on chip) will be the provider here, basically context provider does the work of connecting or gathering information from the context source and in this case Arduino board or Raspberry pi will be that device.

Server: Now there will be some analysis of those data that comes from the context provider using specialized algorithm and some data to be saved or be used later, so the system has been proposed will need a server for this purpose. We will intend to use the microcontroller or SOC as our server and save the taken data that comes from the context provider.

Context Consumer: So after saving the information and analysis report, the user can ask to view the information which is saved. In this case, proposed system will need an interface or device to show that information's to the users. And here the plan is to use a smartphone as a context consumer, by showing the information through the mobile app.

The repository includes a table of context-aware middleware, that is important for preserving a general opinion of the context forms accessible inside the domain. The suggested method would also therefore accept marks, recording and retrieving.

Register (title of the object, form of meaning, point of access): This approach is used by meaning suppliers to monitor their conceptual ability. It gets contextual sort, object description, context provider access point and inserts the respective checklist into the chart [64].

Retrieve (title of object, form of information): Program developers leverage these approach to locate their necessary information. It gets the related object context form and description, and recovers the device(s) point of access supplying this context feature. Initiated context extraction techniques are often known as context supplier for gleaning complicated information forms. Context providers that reside on any computer or server with computations. They will message one another through their address at the entry point [65].

Title-of-Object	form of information	Context: Connection point for provider

Figure 3. 4: Schema of the Table

In this project work, Context-Aware System will play an important role for making the traditional inhaler smarter. The system has proposed a Context

Aware System Architecture which will work the over-all system architecture. There will three layer in the Context Aware System Architecture – physical layer, data pressing layer and knowledge layer. In physical layer, from context sources (various sensors which will collect physiological and contextual data) physiological and contextual data will pass to data processing layer for further processing. In the data processing layer there will be two modules – one is Physiological status measurement module for processing the physiological data and second is Environmental context measuring module for processing the contextual data, which will process the data coming from context sources. In the Physiological status measurement module, the data from activity monitoring (various data coming from physiological context) will pass to asthma action plan monitoring module for data processing. And in the Environmental context measuring module sensor data collector will collect the sensor data which coming from environmental context then pass these data to the clinical modeling and prediction and then with data security pass these data to doctor decision support system. In the knowledge layer, the processed data which has come from data processing layer will be analyzed along with the previous collected data to generate reports about the current contextual status. The knowledge layer and physical layer can be communicating with each other sending messages about contextual status. In Physical layer there will be user, smart inhaler and smartphone app. From physical layer User could have access to the knowledge layer for viewing the analysis report. Figure 3.5 shows Context Aware System Architecture of this project work.

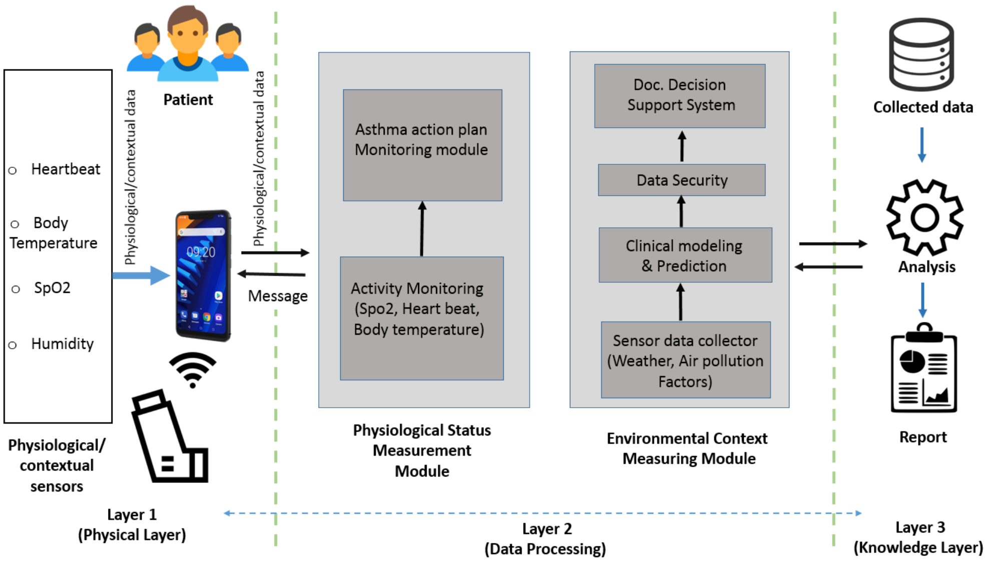

Figure 3. 5: Proposed context-aware system architecture

The evolution of information technology has allowed the development of ubiquitous, user-centered, and context-aware solutions. This context-aware system will determine how much the system will be interactive with the outside world and current physiological condition of user. In a word, use of different sensors and collect data from various sources are the part of context-awareness. To understand better, the research work has been divided into two different modules of this context-aware middleware and those are:

3.5 Physiological status measurement module:

As per the name says, it will collect physiological data of the user’s body. Sensors attached to human body for reading oxygen level in blood, heart-beat rate, body temperature and then send these data to the server for further work. Sensors are used here:

i. Spo2 sensor (measures the oxygen saturation of a patient's blood)
ii. Heart beat sensor
iii. Body temperature sensor

The proposed system will save those data for providing better healthcare services. Data will come directly from the context source through context provider and saved in storage in the server, they will be analyzed and shown and notify to user by his registered smartphone application. For asthma patient oxygen level indication will make difference between usages of inhaler. Heart beat up down is directly connected with asthma, like a patient is having an attack, his/her heart beat rate will automatically rise. As the time and change in the heartbeat will be recorded in the storage, doctor can recall those data to have a close look of patient's cardio logical conditions. Body temperature can differ in various situations, so this smart inhaler system is considering this part also in this work.

3.6 Environmental context measuring module:

Previous module was dealt with the physiological condition of the user, but this module will be related with the environment. Asthma trigger can change according to the change in environment around a patient. So considering this part, our works will be like: Sensors attached to human body for reading Environmental status such as humidity, temperature, amount of carbon dioxide and other gases mixing in the air and then send these data from context source through context provider to the server for the analysis and further work. Sensors are used here:

i. Multi-Pixel Gas Sensors SGP
ii. Humidity sensor
iii. Temperature sensor
iv. Co2 Sensor

Now those sensors will collect data from the context and analysis of these data will have determined certain environmental condition for the user. Like the level of carbon dioxide, Humidity, Temperature, oxygen etc. are very important to the level of taking medication of an Asthma patient. All of this data will saved in storage in the server and the doctor can suggest batter to the patient by seeing those data. Not only doctor, the user can also predict the future of his medication usage. As the level of all those factors will be directly connected to the usage of drug, user can have large/medium/small drug canister as per his need. And doctor as well as user will know for the next time, how much drug they are using in those situations.

3.7 Smart Inhaler:

In a traditional inhaler, there are two-part actually: canister (Aluminum can) and Actuator. Inside the canister, there has a gas phase and drug formulation. When the canister pressed, the gas phase pressured the drug formulation part and the drug comes out from the metering chamber to the expansion chamber. Through the actuator nozzle, the drug from the expansion chamber comes out as aerosol (high-velocity spray). All of this process are what a normal inhaler is made of or user normally looks forward to have.

But in this Smart Inhaler, there will be a sensor to count the use of medication as per puffs. How much drug a user is inhaling will be recorded and this data will be transferred to server through context provider or this can be said as cellular data or WIFI. Adding context awareness to this system, by giving it the capability to be smarter in different situation. Like there is change in the environment or in the physical condition of the user, the system will warn the user about those changes. There will be also an attached buzzer to inhaler which can trigger by the smartphone Application for finding the inhaler easily or in a word tracking option will be added. And finally last but not least notification giving part, and this part will give notification to the user inhaler in case they forget their inhaler in home and goes outside with their inhaler.

Considering all this parts, making a traditional inhaler into smart and efficient life partner for the asthma patient. Not only user but also the doctors will get the scope of giving better health care advice to those patients. As there will be record of all their drug usages, ups & downs in health, all of this and more will have a greater opportunity for their healthy and risk free life. This will be there helping hand and updated level of medication for their own good.

3.8 Smartphone App:

Now a day all most everybody has a smartphone, so it is appropriate to say that this smart inhaler system must have a smartphone application by which the user will interact with the inhaler smartly. Smartphone app will give them the freedom of having all those options in the palm of their hand. They can easily access those options and make their selves free from several tensions. As said earlier, there will tracking, notifying, predicting & context awareness parts in this smart inhaler, all of this features and to make a bridge way between this features and the smart inhaler - here the system has a smartphone application for all this options to come to life.

This registered smartphone app will be the only platform of our system which directly communicate with the user mostly. An Android application will be used for user notification and view. Through this Android app user can see context-awareness (physiological and environmental) status, can notified of bring or keep the inhaler with themselves, click an option in the app and trigger the buzzer to find the inhaler easily and finally they can also see the overall report of their medication process which can help them and their doctors to take better decisions about their asthma.

For developing this android app, java platform has ben used. First of all, jdk11 need to be installed in the developing system. It is must to have jdk in machine to work on it. Android sdk help to create the interface of his application. It gives the app proper shape. We used Android studio IDE for the development of this application [66]. For designing purpose of this app we used xml. The main responsibility of this unit is to notify the user as early as possible with best possible correct information and create a platform for the user to interact with the smart inhaler.

All of this for better experience of the user and giving them the opportunity to be able to use those features that designed for the smart inhaler system. In a word here the smartphone app will give the users the proper support they need in their way of medication and smart health care services.

CHAPTER 4

IMPLEMENTATION AND DISCUSSION

4.1 Introduction:

The basic impetus behind this research projects is to create better instruments for conventional inhalers. The idea is that the more it will have user assistance the more a system learns about its user, its context and the circumstances in which it is being used. The aim is to arrive at a proper solution to render inhalers smarter and to incorporate recognition technologies – both hardware and software – the methodology of the proposed system follows.

4.2 Implementation Architecture

İn the system figure 4.1, various sensor will collect data from the physiological and contextual status. All the collected data will be sent to the application server through a gateway for analyzing the contextual data. The application server will collect those data and those would be examined using advanced analyzing algorithm in physiological module and contextual module and take decision about the context which is suitable for the user. Then send this decision as form of report to the android app. The whole application server will ensure the data security for prevent the outside attack from hackers. The analyzing report will send through network gateway for storing and further analysis. The cloud server can communicate with the user via telecommunication in an emergency case. User could view his current physiological and contextual condition by his android app accessing in the application server. To find the inhaler user can trigger the buzzer by sending Bluetooth signal through his android app.

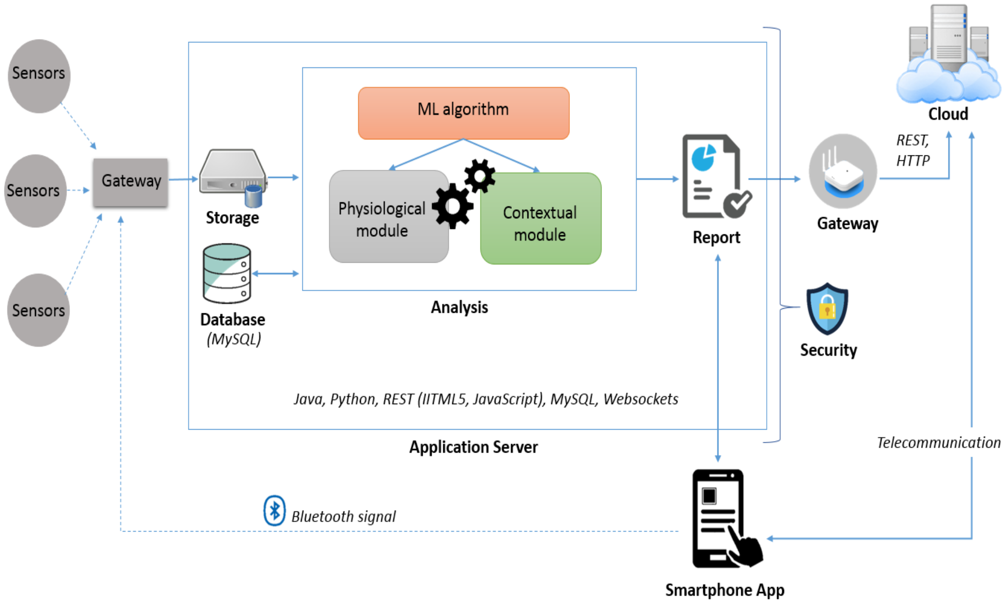

Figure 4. 1: Implementation of system Architecture

This architecture shows how the whole system will work. Figure shows overall works that needs to done for this project. It shows that the sensors, that will collect data. Basically those sensors are the main data collector which will be both in the inhaler and user body. Those sensors will submit data and through getaway the data will go to the storage to the application server. Application server has database that store data and use it for further analysis. After analysis of this the data, there will be some particular decision regarding the decision that our system will get. Finally, after the data aggregation and decision making using ML algorithm, send it to the user's app and to cloud server. This information will be the final outcome of the computation of those data. All this terms are described below more briefly:

Technological Concepts:

i. Integration of various sensors (i.e. Multi-Pixel Gas Sensors SGP, Humidity sensor, Temperature sensor, Co2 Sensor, heartbeat sensor etc.) to gateway, Gathered for multi-sensor data purchase, autonomous of any specific application and module.

ii. Multi-sensor Information Relationship of Condition and the user's physiological conditions in which the inhaler is used.

iii. Implementation of software and algorithms (here we are implementing machine learning algorithm), i.e. methods for computing contextual and physiological analysis from sensor data along with the previous *MySQL* and prolog database for better decision making, in application server and generate a result report.

iv. Sending the report to smartphone app as notify the user using *Java* and also cloud for storing that report in the server for further analysis through the network gateway using *REST* API and *http*.

v. Sending digital signals to the gateway to accomplish any particular task such as sounding the buzzer attached to the inhaler (if needed) by pressing button on the pre-registered smartphone app which will be connected via Bluetooth with the inhaler.

vi. If application server is unable to sending report to smartphone app in a critical condition (pre-programed condition for worse emergency physiological and contextual situations) and the application server is connected to cloud service, then through telecommunication the report will send from cloud to the user's registered sim card as form of massages.

4.3 Required Devices and Sensors

IoT's innovation has brought Sensor development to a new stage. IoT systems operate and use a range of sensors to provide different kinds of information and data. They help to gather info, drive it and distribute it to a whole network of similar gadgets. This collected data allows it possible for the devices to work autonomously, and every day the whole world turns out to be "smarter." By integrating a collection of sensors and a connected contact network, systems exchange knowledge and enhance their performance and usability [67].

Sensor actually collects data that is used for classification of different parameters in context and user's physiological condition. A brief description on the sensors are stated below. Also **Raspberry pi 0 W** has been used for the Project. The description of the whole things is given below:

Raspberry Pi Zero W:

The Raspberry Pi 0 is indeed a wonderful, mini version of the Raspberry Pi which decreases the board down to about size of a gum stick, however the absence of wireless functionality is one issue. The Raspberry Pi 0 W is a new edition that offers a twice the price of the previous Zero in Bluetooth and Wi-Fi. The Raspberry Pi Zero W arrives with all of the same functionality as the standard Pi Zero, but adds that same 802.11n Wireless LAN and Bluetooth as the Raspberry Pi 3. Cpu and RAM are identical to regular Pi 0, and is exactly the same as the earliest Raspberry Pi 1 versions.

Figure 4. 2: Raspberry Pi 0 W

4.4 Sensors used for the physiological condition measurements:

i. MAX30100 – Oximetry and Heart-Rate Monitor Sensor

A heartbeat oximeter is essentially a gadget which can gauge one's heartbeat and oxygen immersion in his blood. Generally, this sensor comprises of two LEDs discharging light: one in Red range (650nm) and the other one in Infrared (950nm). This sensor is put on your finger or ear cartilage, basically anyplace where the skin isn't too thick so both light frequencies can without much of a stretch infiltrate the tissue. When the two are radiated through your finger for instance, the retention is measure with a photodiode. Furthermore, contingent upon the measure of oxygen you have in your blood the proportion between the assimilated red light and IR drove will be unique. From this proportion it is conceivable to "effectively" calculate your oxygen level in your hemoglobin [68].

Figure 4. 3: MAX30100

ii. MLX90614ESF AAA - Human body temperature sensor

The sensor community MLX90614 uses resistive element thermal indications to assess the heat of items without disturbing them. This detector can tolerate ambient conditions from-40 to 85 ° C, and operates from-70 to 382.2 ° C for surface temperatures. It provides a calculation resolution of 0.02 ° C at room temperature and has an accuracy of ±0.5 ° C. The device comes in a package of modest TO-39 and weighs only 0.03 oz. (0.9 g), and it emphasizes filters which give the adjacent IR and daylight swiftness [69].

Figure 4. 4: MLX90614ESF AAA

4.5 Sensors used for the contextual condition measurements:

i. SGP30 Gas Sensor - Multi Pixel Indoor Air Quality Measurement Sensor

The SGP30 is an innovative multi-pixel gas detector developed for fast incorporation into systems such as air purifier, supply-controlled ventilation and IoT. SGP30 is a metallic oxide gaseous system with several sensors on a single device. It is incorporated with four gas sensing components and has a completely adjusted air quality output signal. In addition, SGP is easy to integrate and can coordinate metal oxide gas sensors into mobile devices, opening up additional opportunities for ecological observing in smart homes, household appliances and Internet of things applications [70].

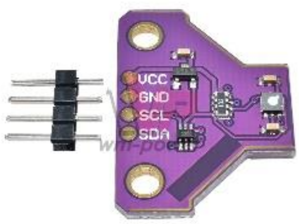

Figure 4. 5: SGP30 Gas Sensor

ii. DHT11 - Temperature and humidity sensor

The DHT11 Temperature and Humidity System contains a sophisticated temperature and humidity system with digital signal quality modified. It guarantees strong reliability and outstanding long-term reliability by using the limited electronic-signal-obtaining device and temperature and humidity detection technologies. This detector integrates a resistive moisture calculation system and an NTC heat prediction device, and a heavy-performance 8-piece microcontroller design that offers outstanding efficiency, rapid reaction, anti-user flexibility and price-effectiveness. Its small size, lower power consumption and a signal distribution of up to 20 meters renders it the best choice for separate applications [71].

Figure 4. 6: DHT11 Sensor

iii. MG811 - Carbon Dioxide Gas CO2 Sensor Module Detector sensor

This detector module for MG811 is just a little bit special because it needs 6V DC to function properly. There's an on-board signal stabilization circuit to boost feedback signals and a thermal circuit on-board to power the sensor. The MG-811 is extremely CO2-touchy and less drug- and CO responsive. It could be used in air quality management, fermentation process, device n-door air tracking. The device's output voltage decreases as CO2 integration rises [72].

Figure 4. 7: MG811 Sensor

Sensor Connection & Transmission of Data:

This smart inhaler system is focused on IoT are sensors that function as a clip on established inhaler. These sensors are attached to a device that the patient is expected to update on their mobile. On the mobile or a plug-in device, sensors can easily converse this information to the app through **Bluetooth**. This are also seen as part of the asthma treatment system, under the supervision of a practitioner. Main point of the connectivity will be Bluetooth. Using the **Raspberry Pi 0 W**, it is easy to get the Bluetooth feature for transmitting those data from sensor to the application server.

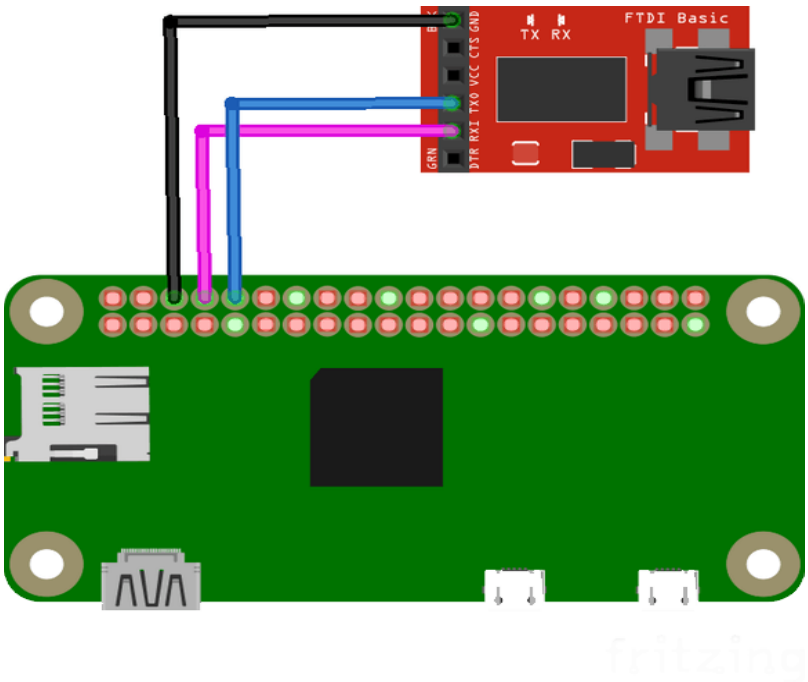

Figure 4.6: Connecting Sensor with Raspberry Pi 0 W

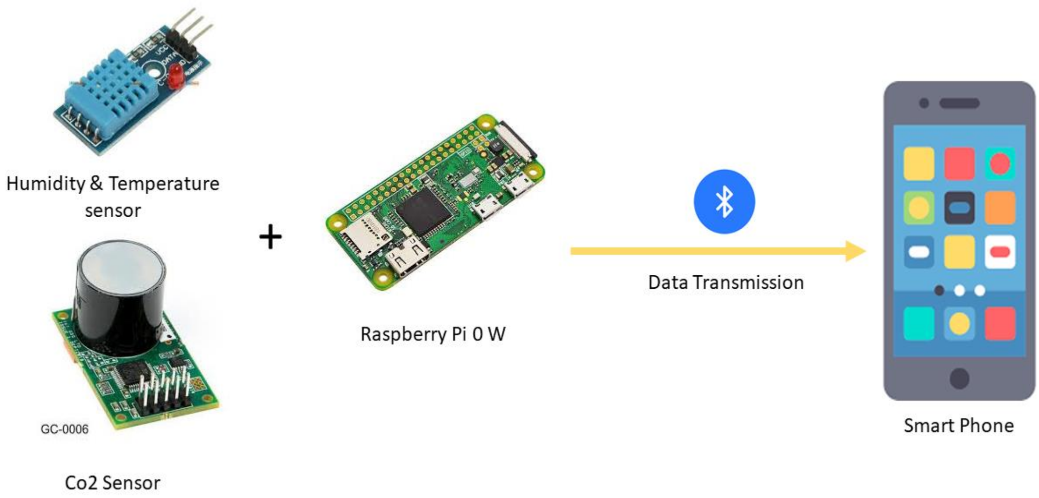

Figure 4. 7: Sensors & Data Transfer

In a picture, the whole process is descripted. Sensors are connected with the Raspberry Pi 0 W, and all the data of sensor are going through here by using the Bluetooth feature to the smartphone & application server for further decision making.

Monitor Readings and Interact with Sensors:

a) At first needed to open the directory which indicates that has the shown codes ***cd ~/Raspberry-Pi-sample-code***

b) Then by running the I2C script also known as ***sudo python i2c.py***

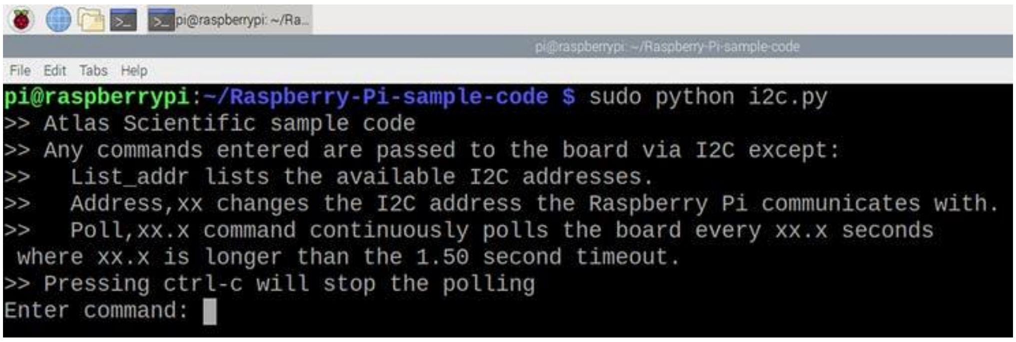

Figure 4. 8: Sample Code for humidity Sensor**.**

Every when the script is run, the menu displayed above is shown to the user. Example: List the attached sensor names, and ask the system details for each.

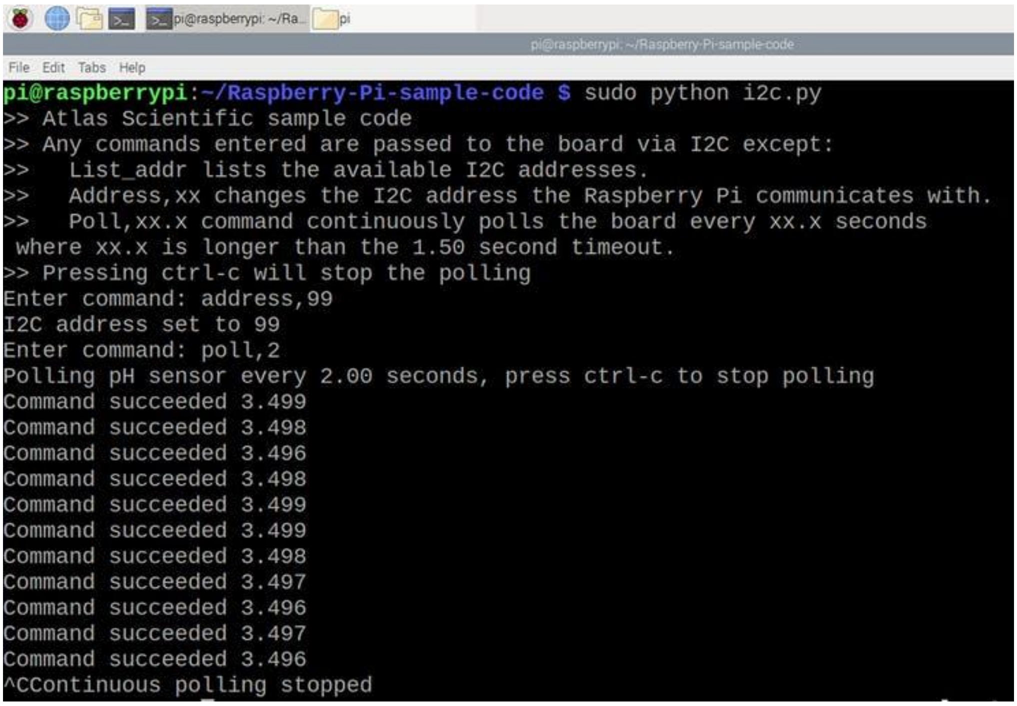

Figure 4. 9 : Checking that sensor is calibrated

Data Flow:

The system system will use Node-Red to record and archive the MQTT data in the database using node-red-Node-MySQL. Python can be used to collect MQTT data using the Paho framework-Steves MQTT guide has two ways to log in-one to a log file and one to MySQL.

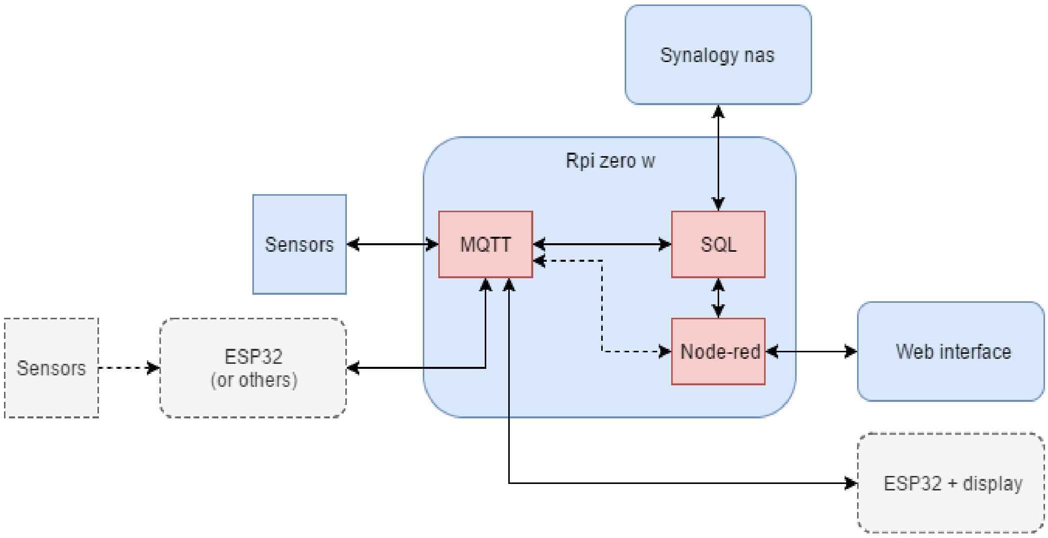

Figure 4. 10: Managing Database.

ESP32 is a series of low-cost, low-power device with embedded Bluetooth Wi-Fi and dual mode on a chip microcontroller.

Synalogy NAS (Network Connected Storage) is a smart storage system, that our proposed system can access files and utilize different resources that the NAS offers over the Internet.

Node-RED is a design method for cabling in different and exciting forms hardware computers, APIs and web resources together. This offers a browser-based editor that allows this simple to connect flows together utilizing the large variety of nodes in the palette and can be implemented in a single click to run time.

Using MQTT to publish sensor data from each system, then host any control s/w to subscribe and record those data as well as trigger some actions / responses to some particular data state (i.e. blocked high pressure / pump-> switch off pump). Regardless of how we treat MQTT subscriptions, it is as easy as copying and pasting the first handler to extend and include further sources, madding just to suit the latest data source and destination. Node Red is a very effective tool when used with MQTT, but we may also create our own python MQTT subscription / treatment script or scripts, or some other MQTT-enabled toolkit like some of the hassio home automation suite choices etc.

4.6 Machine Learning Algorithm for Decision making:

Artificial Intelligence (AI) is concerned with the analysis and design of systems capable of carrying out complex acts, such as translating a document, driving a vehicle, blocking unwanted emails or recommending a book. A significant type of action that intelligent software routinely performs is that of classification: assigning an object to one of several possible categories. It involves, for example, the role of making individual decisions as a special case about blocking or endorsing a web page, or diagnosing a patient. Although decisions can be made based on various factors, modern methods of AI are mostly generated by introducing a learning algorithm to a large number of examples of training, a technique known as 'machine learning'. In AI language, the properties used to define the object to be graded are often referred to as "features" and the classes assigned to each item are called "labels." So, our proposed system might describe an email by the terms it includes, a patient through the result of a series of clinical tests, a customer through a set of criteria defining their payments track record. For example, the labels applied to an email may be 'spam' or 'ham,' those applied to a patient may be 'diabetic' or 'healthy,' those being 'free' or 'risky' for the loan client. A learning algorithm's aim is to create a feature (a "classifier") that assigns a class label (e.g. 'spam' or 'ham') to any entity that has not yet been classified (e.g., emails). For making the decision in our project work our proposed system will be using here is Naive Bayes classifier algorithm. Naive Bayes is a predictive method commonly used to issue identification .

Naive Bayes Classifier Algorithm:

In the identification methodology, Naïve Bayes algorithm is a basic predictive method that derives its likelihood value from the relevant collection based on the calculation of occurrence and quality combos [74]. This algorithm assumes it is independent of all attributes [73]. Naïve Bayes' classification method requires multiple hints or instructions to assess the data class to be analyzed. Consequently, Equation 1 applies [75]. (1) Factor C is a category in Equation 1, and factor F1 ... Fn reflects the features needed to do a category. Thus, the likelihood of comparing data of a certain feature in C class (posterior) is that C class possibility arose compounded by the possibility of sample behaviors in C class (probability), and then distributed collectively by the likelihood of test types (evidences) [72].

$$P\ (C|F_1 \ldots F_n) = \frac{P(C).P(F_1 \ldots F_n|C)}{P(F_1 \ldots F_n)} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Meanwhile, constant data identification uses the Gauss concentration function, as seen in equation 2 [14].

$$P\ (X_i = x_i|\ Y = y_j) = \frac{1}{\sqrt{2\pi}\sigma_{ij}} e^{-\frac{(x_{i-}\mu_{ij})^2}{2\sigma^2{}_{ij}}} \qquad \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

If P is a chance, X_i is a predictive variable, xi is the meaning of the prediction variable, Y is the category to be checked for, y_i is a post-class of Y, π is a constant valued at 3.14, μ implies that perhaps the average of all prediction variable in the same class is specified, π is a standard deviation implying variations of all prediction variable in a particular class, and e is a constant valued at 2.7183. The pseudocode [75] Naïve Bayes method with persistent data is seen as in the figure 4.15.

```
Input:
        Training dataset T,
                F= (f1, f2, f3,.., fn) // value of the
                predictor variable in testing dataset.
Output:
        A class of testing dataset.
Step:
        1. Read the training dataset T;
        2. Calculate the mean and standard deviation of
        the predictor variables in each class;
        3. Repeat

                Calculate the probability of fi using the
                gauss density equation in each class;
          Until the probability of all predictor variables
          (f1, f2, f3,.., fn) has      been calculated.

        4. Calculate the likelihood for each class;
        5. Get the greatest likelihood;
```

Figure 4.15: Pseudocode of naïve bayes algorithm.

Here Naive Bayes classifier is implemented for both Physiological and contextual modules to make the decision about the current Physiological and contextual conditions of the user which trigger asthma. As this classifier working with 3 feature data for each module, and these type of datasets are not available in other resources. So for training and testing purpose estimated some data and by leveled them, demo datasets are being used for training and testing purpose. After get the test data (data coming from sensors) as classified data (leveled data) by the naïve bayes classifier, this data is taken as decision for user's current Physiological and contextual conditions, which is better for asthma medication. Then application server sends these decisions to the app and web server as decisions for the user - in form of messages. In the smartphone app these data will be presented nicely as notifications by the help of android application developing technologies.

For this research work, the age of smart inhaler user is 30 years are considered. And the data also considered for training and testing in Naive Bayes classifier model - which are appropriate for a 30 years aged person.

Feature data for Physiological module:

The training and testing set includes 3 features regarding physiological conditions,

Table 4. 1: Feature data for Physiological module

FEATURE	DESCRIPTION
1. Oxygen level	Oxygen level (%) in user blood
2. Heart beat Rate	Heart beat rate (BPM) on user body
3. Body Temperature	Body temperature (°F) of user

In this case, this model uses 2 labels reflecting the classification of user:

1) Risk = risk condition for user.

2) Normal= normal condition for user.

Oxygen level in blood in Human Body:

Here are some measurements of Oxygen level and their classification for human Physiological Condition [76].

Table 4. 2: Oxygen level in human body classification

Oxygen level in blood (%)	Physiological Condition
95 – 100	Normal
Less than 95	Below normal

Heart Rate in Human Body:

Here are some measurements of Heart Rate in human body and their classification for human Physiological Condition [77].

Table 4. 3: Heart Rate in human body classification

Heart Rate (BPM)	Physiological Condition
60 -100	Normal
100 <	Raising
190	Maximum

Body temperature in Human Body:

The average body temperature is generally accepted as 98.6 °F (37 °C). Here are some measurements of Body temperature in human body and their classification for human Physiological Condition [78].

Table 4. 4: Body temperature in human body classification

Body temperature (°F)	Physiological Condition
97.7 – 99.5 °F	Normal
99.5 or 100.9 °F <	Fever
95.0 °F >	Hypothermia

Training data for the Naive Bayes algorithm in Physiological module:

Table 4. 5: Training data for Naive Bayes classifier (Physiological module)

	Oxy_level	H_Rate	B_Temp	Level
1	98	65	98.5	Normal
2	92	60	97.7	Risk
3	98	150	99	Risk
4	95	100	98	Normal
5	95	98	99.5	Normal
6	97	66	98.4	Normal
7	89	52	94.2	Risk

8	96	85	97.6	Normal
9	95	62	98.1	Normal
10	99.1	70	97.9	Normal
11	100	60	99.7	Normal
12	90	65	95.2	Risk
. . .				
1015	97.1	68	97.9	Normal
1016	95	190	103.6	Risk

The data continuously coming for physiological condition measurement sensors will be use for physiological condition measurement reading of user body. Now these data will be send to Naive Bayes classifier to test them. The data would be unleveled data. The classifier will level these data. The non-classify data would be like these:

Table 4. 6: Test data for Naive Bayes classifier (Physiological module)

	Oxy_level	H_Rate	B_Temp	Level
1	95	64	99.2	?
2	91	85	96.7	
3	98	150	99	
4	95	106	98	

Feature data for contextual module:

The training and testing set includes 3 features regarding contextual conditions,

Table 4. 7: Feature data for contextual module

FEATURE	DESCRIPTION
1. Temperature (°F)	Temperature in the user context
2. Humidity (%)	Humidity in the user context

3. Air quality (mg/m^3)[13]	Quality of gas mixing in the air of user's context

In this case, this model uses 2 labels reflecting the classification of user:

1) Risk = risk condition for user.

2) Normal= normal condition for user.

Temperature in the context:

Researchers found that a room temperature of about 71 ° F (21.6 ° C) did not cause symptoms of asthma, but at 120 ° F (48.8 ° C) breathing in super-hot air did. And also try to remain indoors when the temperature drops very low, particularly if it is below 10 ° F (-12.2 ° C) to avoid asthma attacks [79].

Table 4. 8: Temperature in the context classification

Temperature (°F)	Physiological Condition
10 – 100	Normal
greater than 100	Risk
Less than 10	Risk

Humidity in the context:

People usually find the most comfortable relative humidity between 30 and 60 percent, with guidelines for maintaining relative humidity indoors between 30 and 50 percent where possible. Higher humidity levels in the home provide an atmosphere for two excessive asthma and allergy causes [79].

Table 4. 9: Humidity in the context classification

Humidity (%)	Physiological Condition
31 -50	Normal

greater than 50	Risk
Less than 31	Risk

Air Quality in context:

Breathe comfortably with the Multi-Pixel Gas Sensor SGP30 which is a fully integrated MOX gas sensor. To offer more accurate air quality signals, the SGP integrates several metal-oxide sensing elements on one chip. It returns a reading of Total Volatile Organic Compound (TVOC), and a reading of carbon dioxide (eCO2) equivalent [80].

Table 4. 10: Humidity in the context classification

TVOC (mg/m^3)[13]	**Air quality**
Less than 0.3	Very good
1.0 – 3.0	Good
Greater then 3.0	Poor

Training data for the Naive Bayes algorithm in contextual module:

Table 4. 11 : Training data for Naive Bayes classifier (contextual module)

	Temp	**Humi**	**Air_q**	**Level**
1	10	35	0.8	Normal
2	25	43	1.2	Normal
3	103	55	3.5	Risk
4	36	40	1.9	Normal
5	36	42	3.5	Risk
6	9	29	0.9	Risk
7	5	27	0.8	Risk
8	57	43	2.7	Normal
9	99	50	3.0	Normal
10	87	49	2.4	Normal
11	44	35	1.9	Normal
12	25	46	0.3	Risk
. . .				
1015	40	41	2.8	Normal
1016	68	37	1.2	Normal

The data continuously coming for contextual condition measurement sensors will be use for contextual condition measurement reading of user context. Now these data will be send to Naive Bayes classifier to test them. The data would be unleveled data. The classifier will level these data. The non-classified data would be like these:

Table 4. 12: Test data for Naive Bayes classifier (contextual module)

	Temp	**Humi**	**Air_q**	**Level**
1	25	32	3.0	?
2	101	50	1.9	
3	76	39	2.5	
4	54	42	0.9	

4.7 Use of Socket:

To manage the link, essentially two forms of sockets - client and server, are needed. AsyncTask would be used to render link as a background function, Callback Interface to control incoming communications, Handler to refresh the Application and TCPClient class representing the client.

AsyncTask:

AsyncTask will be used to prevent catastrophic network access errors on StrictMode. The StrictMode strategy clearly forbids anyone from getting an impact on UI Link. An entity TCPClient will be build in this AsyncTask. In the TCPClient constructor, entity Handler will be pass to modify the UI, Order. Command will be submutted after obtaining the correct response, or if the incorrect request are received, the "false" order will be given and the device will be interrupted. Afterwards the system will be moved to 'onPostExecute'. So basically what is going on:

i. AsyncTask generates TCPClient object in TCPClient constructor our proposed system will be transfering Handler, Address, IP Number and Callback object,

ii. When TCPClient begins communicating, it sends a message to the server when our proposed system will be receiving server reply, the callback transfers it to 'onProgressUpdate',

If the received reply (server response) is equivalent to the message, our system will submit Address to send to server.

In the meantime, the handler receives empty messages with MainActivity specified 'msg. what' integers which are responsible for updating the Interface.

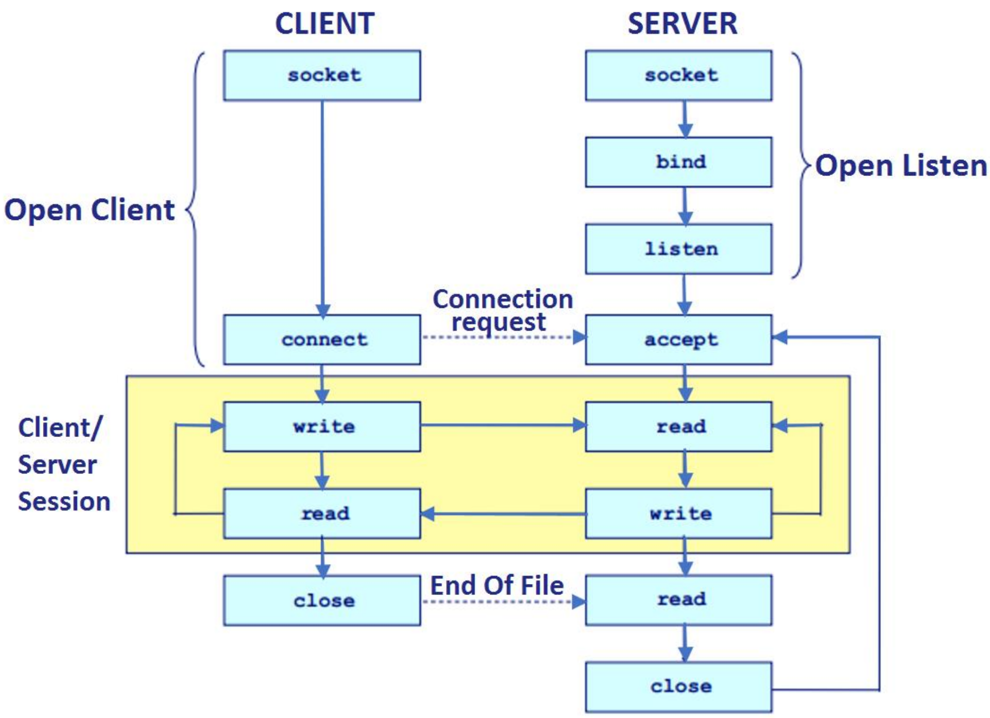

Figure 4. 11: Socket API

TCPClient:

This class is responsible for holding the link going. Here the magic will happen - in process 'run ().' It is where 'try-catch' resources will be used to manage exceptions (server not allowed, network not proper, etc.). We'll have endless while loop for the incoming messages to respond to. with the method 'stopClient ()' it would be easily interrupted and finalized (used with the process 'onProgressUpdate').

4.8 Smartphone Application:

Smartphone app offers the user the right to get any of those choices in their pockets. They can quickly access certain tools, and release themselves from numerous tensions. As we said earlier, in the smart inhaler system, there will be monitoring, notifying, context awareness features. All these features and the connection between these features and the smart inhaler - a android mobile app is here to put all of these possibilities to existence. Considering all the features described before the prototype of this app are:

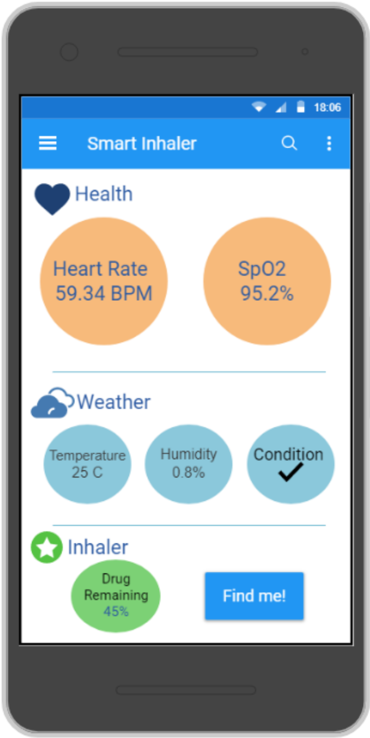

Figure 4. 12: Smartphone App view

This is the main menu view of the App, there is the interface for all most all the features that discribed previouslly. For every feature there will be different interface and some of them are given below:

Finding:

The importance of this part has already described, and for here there is a clicking option called find. By pressing this button, a buzzer will come out of the inhaler and user will find their inhaler. The app will give order of a signal to the inhaler & the buzzer will be triggered in the inhaler So if someone accidently miss places their inhaler, this option will help them to find their inhaler and rescue them from an emergency inhalation situation.

Figure 4. 13: Finding Option UI.

Notification:

This option will notify a user, in case they forget to keep inhaler with themselves, when going outside. raspberry Pi 0 W as our main broad and the connect between the broad & user's smartphone devices will be Bluetooth. So considering the range, after given limited distance, when the smart phone will be disconnected from the inhaler, this kind of warning will pop up on the smart phone app screen.

Figure 4. 14: Notification Option UI.

Environmental Conditions:

The information related with the environmental situation will also be shown by the App. Like temperature, humidity etc. Change in this kind of situation will bring harm to asthma patients. As there will be sensor like temperature sensor, humidity sensors, all the data coming from those sensors will come to the smart phone app. By connecting the smart inhaler with the raspberry pi 0 W broad with Bluetooth, all this data will come to our application and shown in UI.

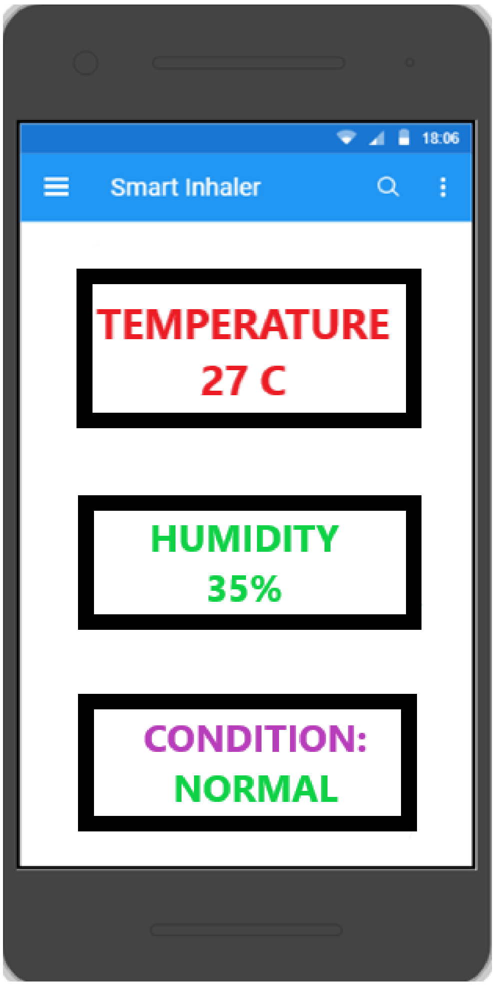

Figure 4. 15: Environmental Situation UI.

Physiological Conditions:

For asthma patients, there physical condition very important. Like Oxygen level in their blood, heartbeat rate etc. So a smart watch is planned to put in user's wrist and through that watch there will be data transmitting to the system. Those data will be shown in the smartphone application, so that the user can also track their physical conditions.

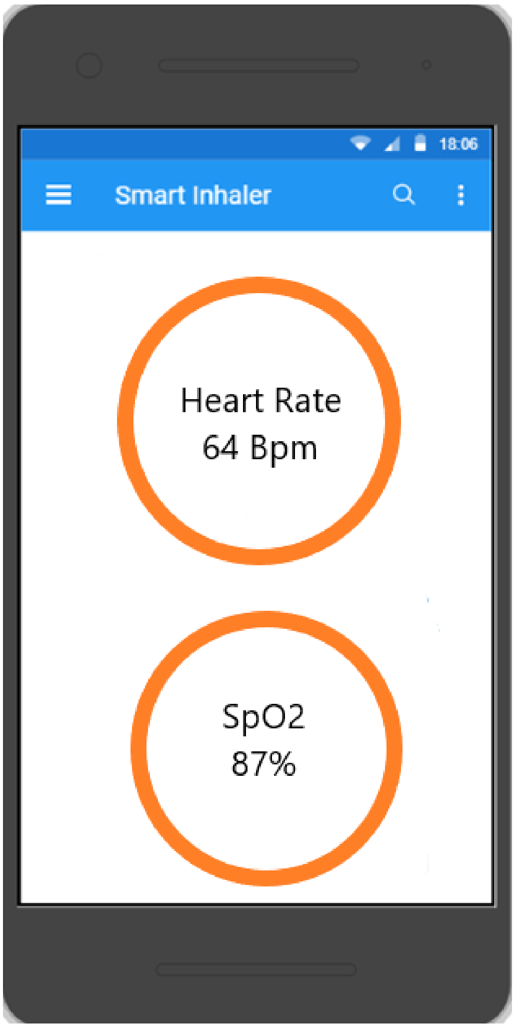

Figure 4. 16: Physiological Situation UI**.**

Creating the Smart Phone App:

For developing the app Android Studio IDE is used and the language is JAVA for activity and XML for the layout of thre app. This app is developed under in android API level 19 (Kitkat), which means most of android device will support this app. Here are some description about application developing:

Started by choosing the different types. As choosed to move between Code and Interface, or live in Split view, depending on the screen size and job style. In case the Module Tree vanishes, covered the Palette and reveal it.

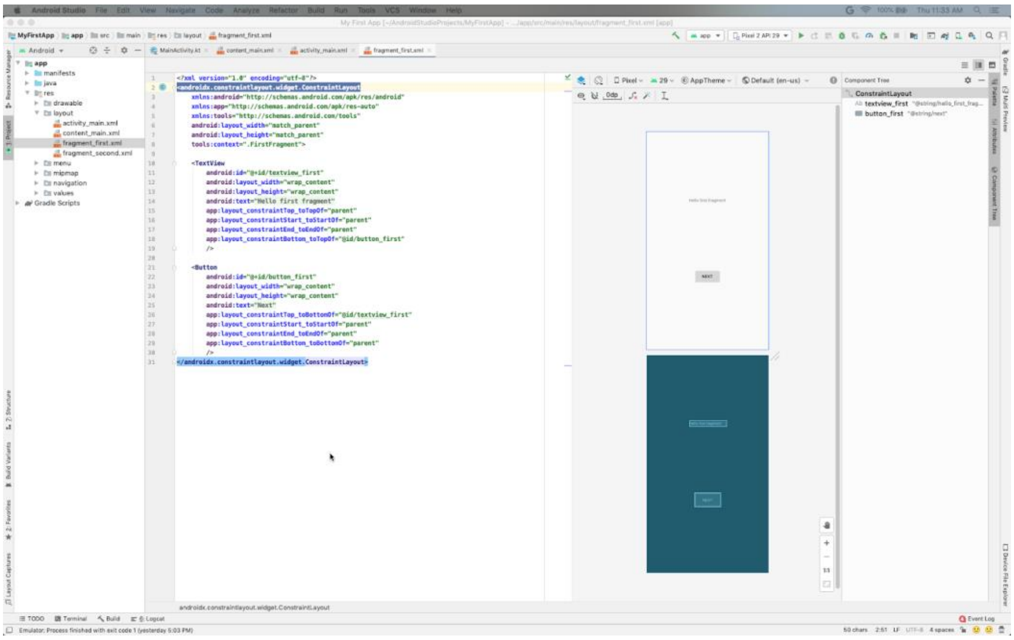

Figure 4. 17: Choosing between Interfaces in Android studio IDE.

For example, The properties were examined inside the TextView feature in the code editor. Also tried to look right at the Attributes row, and open the Defined Attributes section if appropriate.

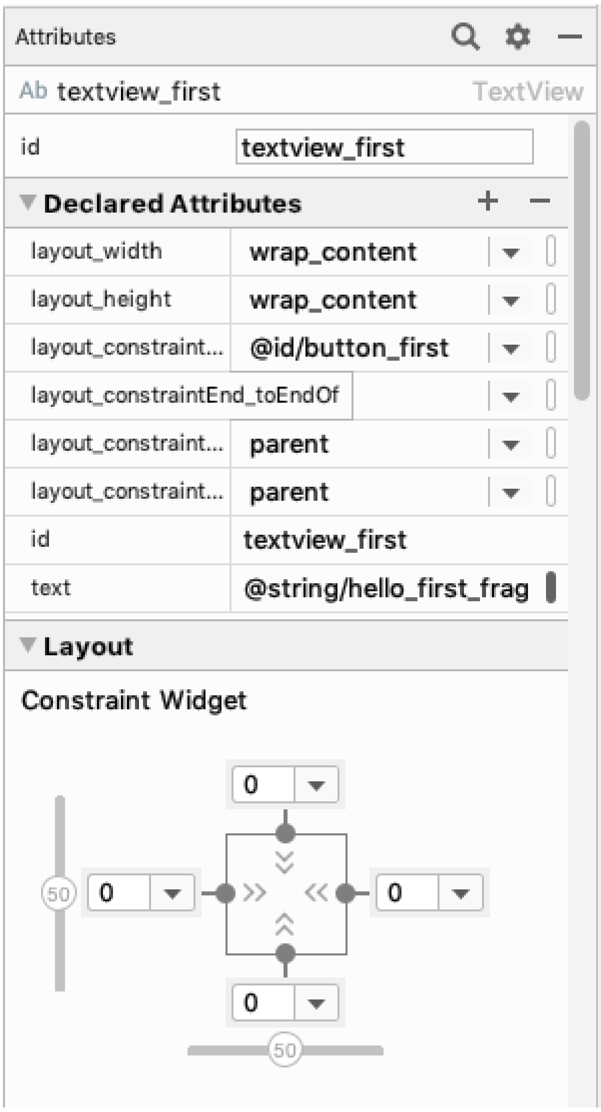

Figure 4. 18: Textview Option in Android studio IDE.

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Auto-imports have allowed to make the development simpler, such that Android Studio can automatically import any classes needed by the Java code. Opened the configuration editor in Android Lab, by heading to Tab > Other Configuration > New Project Preferences and Made sure that Attaching Unambiguous Imports to the fly is tested in the Java line.

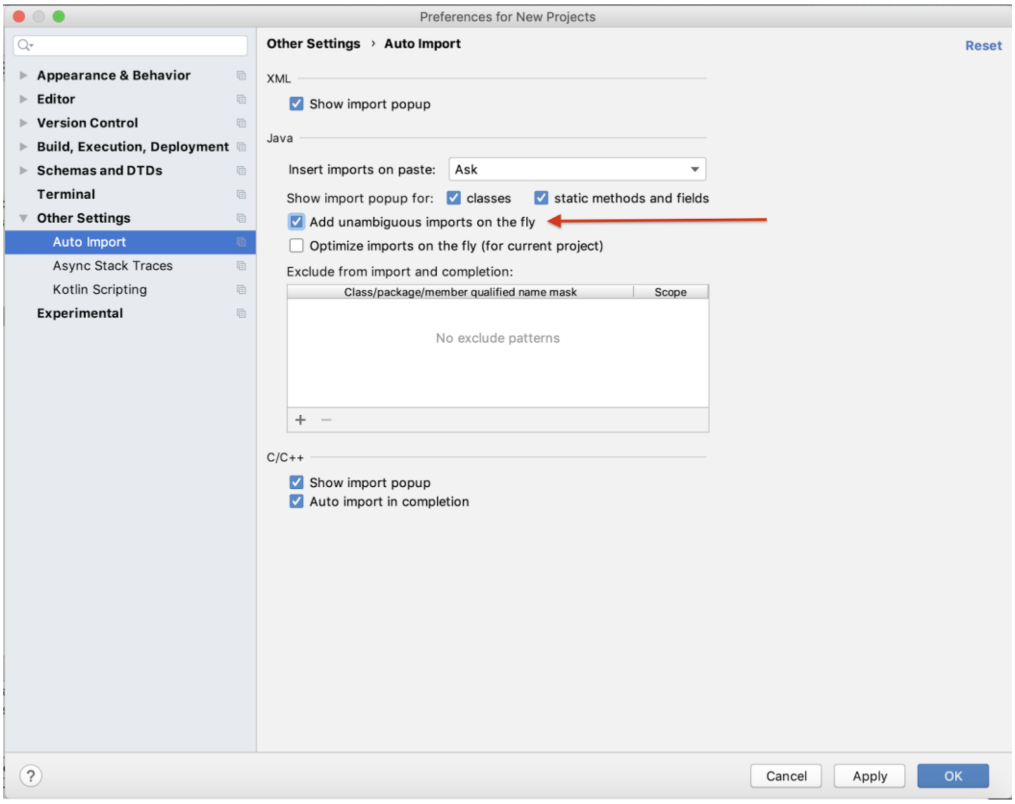

Figure 4. 19: Add Import Option in Android studio IDE.

Limited the top edge of the latest TextView to the bottom of the first TextView, the left edge to the left of the panel, and the right edge to the right of the computer, and the bottom to the top of the previous row. Placed wrap content both in width and height. Set textColor to @android: white or other colors, set textSize to 72sp or others, and textStyle to bold if necessary.

Figure 4. 20: Text Style in Android studio IDE.

4.9 Implementation for Notification to the Smartphone Application:

An android Application has been developed which give notification when the user smartphone (which is connected to the inhaler through bluetooh module) is connnected to inhaler and also gives notification when the smartphone is out of range of Bluetooth (Typically less than 10 m (33 ft)) which means app is disconnected from the inhaler.

In this project work, the application is connected to the inhaler means, serial data is passing from the BLE (Bluetooth low energy) module to the smartphone app. When these serial data passing will stop that means the app is disconnected from the buletooth module or out of range of bluetooth, then the app give disconnected notificaton to the user to not to forget to take inhaler. For the time being, this project work is done without BLE (Bluetooth low energy) module which would be attached to the inhaler, but the experiment is done with laptop and the app by data passing between them which is same as data passing between BLE device and app.

Considering Laptop as a Smart Inhaler: The app gives notification when bluetooth is connected & disconnected based on data transfer between a Laptop and a Smsrtphone. The notification shows connected at the time when any data such as an image or music is shared, and the app shows disconnected right after the data transfer is finished. Considering Laptop, when the app is out of range of bluetooth connection with the Laptop, the Laptop does not notify disconnection notification to the user Smartphone, this is because, once the Smartphone is paired with the Laptop it is paired permanently and remains paired until the history is removed. But the app works with BLE module properly.

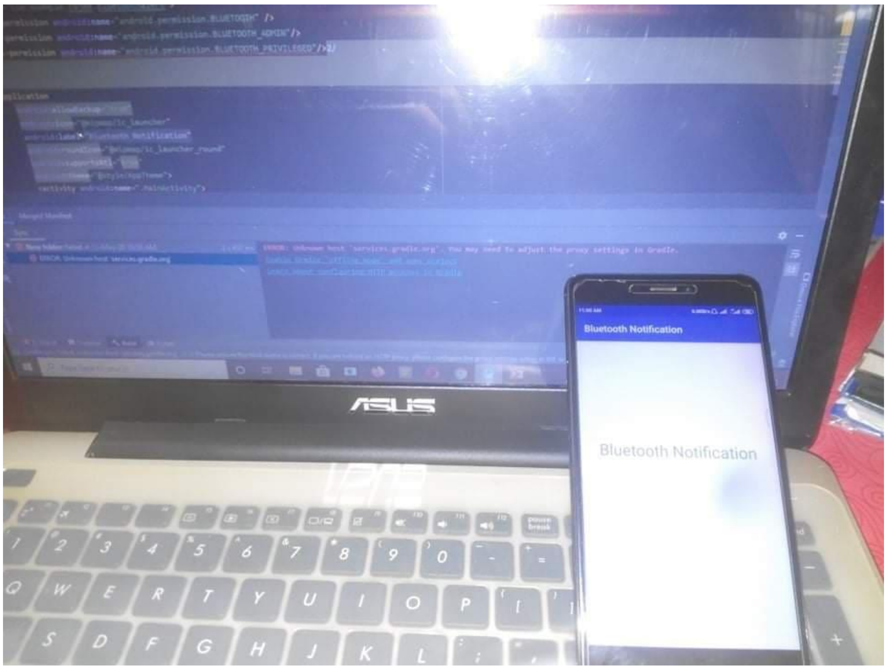

Figure 4.21: Application connected with laptop via Bluetooth

Considering BLE with Arduino: When the app is connected with the "HC-05 Bluetooth Module of Arduino", a serial data transfer is established between Arduino Bluetooth Module and the app. The Arduino Serial Monitor function displays Serial Data sent from Arduino.The Serial Monitor is a separate pop-up window that acts as a separate terminal that communicates by receiving and sending Serial Data. The Arduino IDE provides a Serial Monitor to display serial data received by Arduino. The Serial monitor is shown in Figure 4.22.

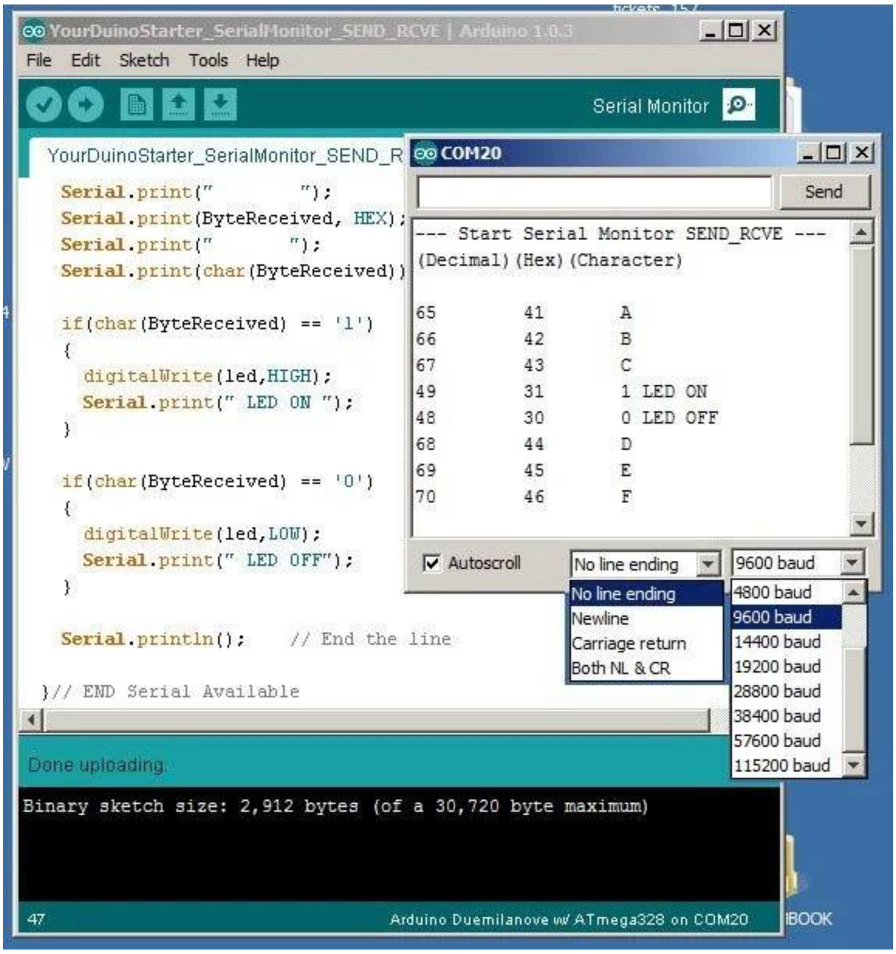

Figure 4.22: Serial monitor of Arduino

So, in case the smartphone is out of range from the Arduino Bluetooth Module, the transfer of serial data will be stoped and then "Disconnected" will be notified.

Notifications to the smartphone application

The smartphone application and main purpose of the application is to provide notification in case the user forgets the smart inhaler to carry with. There will be notification given in the notification bar. The app has been developed using BluetoothAdapter API of Android development and tested for this project work, when the application is connected with the Bluetooth of the laptop, considering the passing of serial data option, the app will show notification as “Connected” when there is data transfer is happening between them and will show “Disconnected” when there is no data transfer is happening between them.

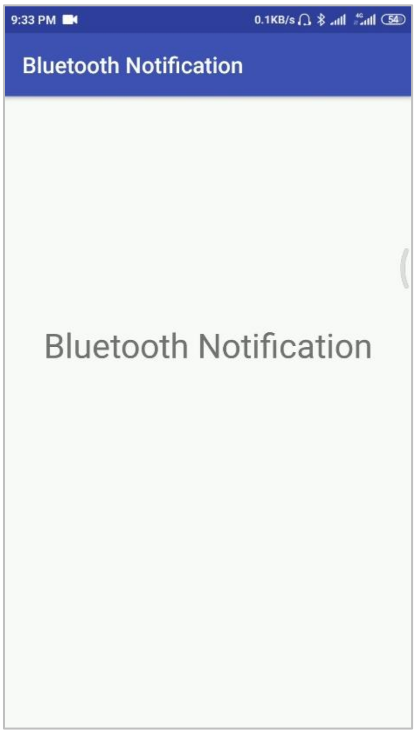

Figure 4.23: Smartphone Application

When the app is connected with the Bluetooth of the laptop the app notifies connected as the data transfer is being started. As long as the data transfer is taken place, the app will show connected that represents connection between Laptop as Smart Inhaler and smartphone app. The figure 4.24 shows the connected status of the smartphone app.

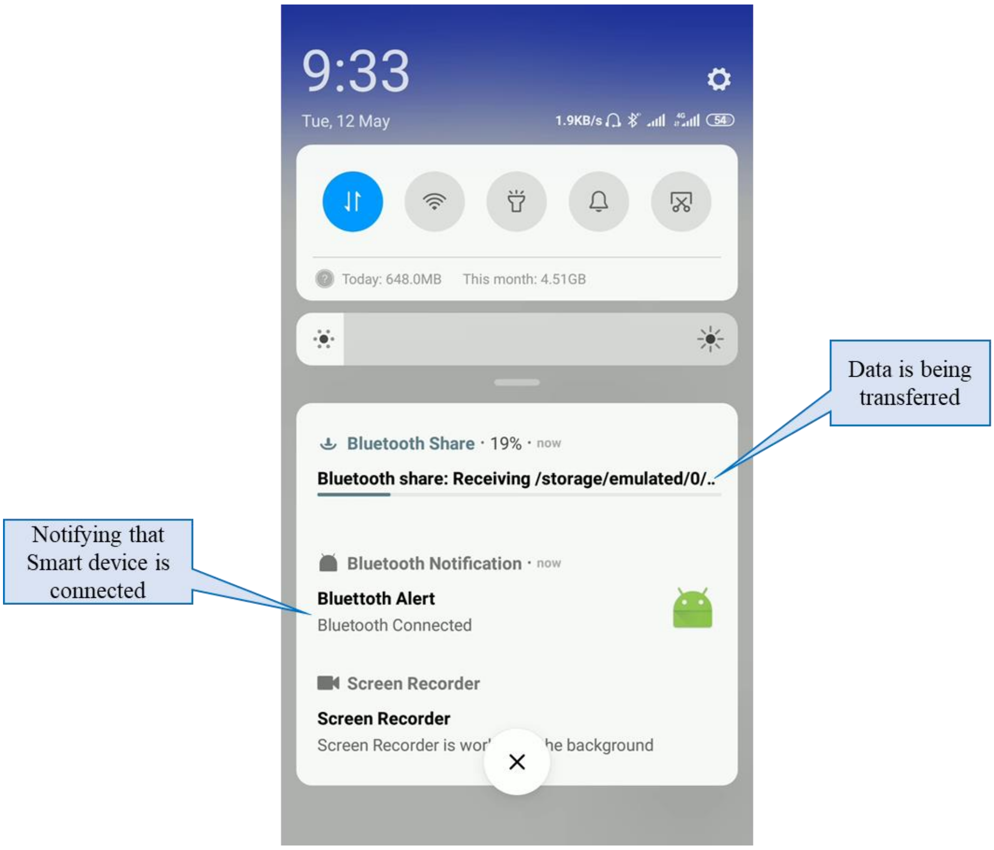

Figure 4.24: Connected State of Notification

At the time, data transfer is completed from the Laptop to the smartphone, the smartphone app will automatically notify “Disconnected”. This state implies that if smart Inhaler lost netwrok connection from the smartphone, the smartphone app will automatically notify the user. Figure 4.25 shows that after successfully completion of data transfer from the laptop to the smartphone, the smartphone app shows “Disconnected”.

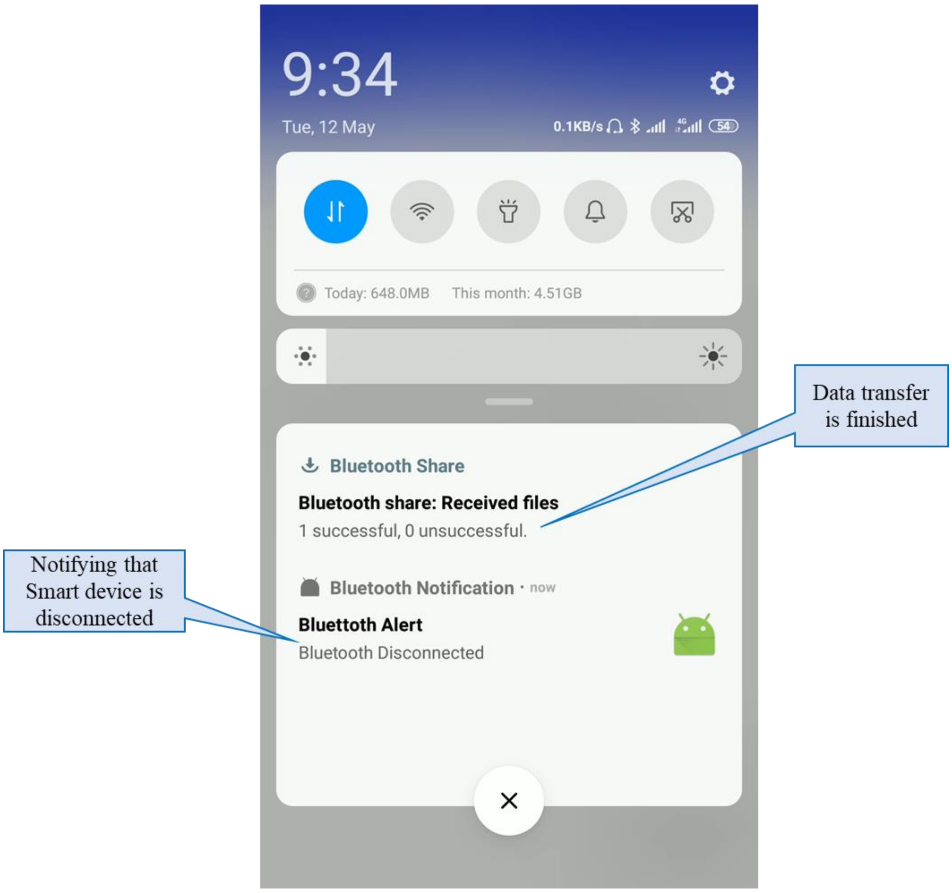

Figure 4.25: Disconnected State of Notification

CHAPTER 5

CONCLUSION

On the main side, the function of health care is to include patients in vital details and to encourage patients to accept responsibility for their condition and cure the disease. So our target for Smart Inhaler is not different, the key goal is for the individual to continue to survive as symptom-free as possible while getting as much influence as possible over asthma. Those users who will use this smart inhaler will lead a much efficient and better life. Furthermore, it is vital for the individual to learn to identify early indicators of improvement and allow appropriate risk evaluations and to recognize when to adjust the drug items, if exacerbation happens. As those people will come to know more about their asthma attack symptoms, they will be much careful and alert when our smartphone app will notify them about the changing condition of their body as well as the environment around them. For the time being four features have been chosen to be added in this smart inhaler system: Tracking, Notification, Physiological & Environmental awareness and Prediction. Rest of the features will be our future work.

In other terms, the power will remain in the possession of the asthmatic, but it is necessary to recognize their own boundaries when seeking for power and accountability, and not feel bad about the circumstances. Till now, the asthma cannot be cured completely, but the smart inhaler system will give them the ability to recognize those changes in their asthma behavior and act smartly prevent the next attack. We always seek to accomplish this sort of tool in our situation, which would offer asthma patients the ability to have more smart control over their everyday inhaler & self-care and we have a solution with this smart inhaler system.

We also expanded our expertise of user-centered architecture and aim for better user experience, so that the user of the smart inhalers system can have great comfort when using this device. Besides the comfort, the cost of medical admission will be saved, as there will be less medical admission. They will be able to give more time to their family. Go to different places, having the ability to know the change that will come with it. Their fare of forgetting the inhaler will be gone. In a word, making those asthma patients more comfortable in their daily life is our main goal from this project. They can't cure their asthma completely, but they will be leading a much efficient life by using our Smart Inhaler.

Unless it had to be modified, it will be best having further time to check the new design towards the conclusion of the analysis process. Complementing such findings with own thoughts about, for example, how (or if) reporting actually enhances asthma treatment and helps identify causes for asthma, will be useful. The main focus of the project work wasn't only the user of this device, but also doctors, who will see the statistics of the usages, changes in the medication of the user, ups & downs in their health. All of this indicator will give much better medication option for the user. As the doctor will analyze the statistics, they will give better suggestions to the users.

We hopes that all of our effort would result in less emergency room admissions, Parents having less time off to take their children to clinics, and stronger and quicker commitment than the conventional approach by allowing the patient more power of their everyday inhaler and knowledge of their asthma. We believe that, coupled with the opportunity to gather useful scientific results to enhance long-term asthma studies, would be of tremendous value to a community with an increasing population of asthma. Most of all giving a life, where they can worry less and enjoy more of their life. Because they will be in control most of the time, by overlooking their physical, environment & medication change in their daily life.

Due to the current situation it was difficult to collect the Hardware devices. We did our research work using Online references, journals, conference papers. In the future work, we wish that we will collect the necessary devices and we will practically implement our system.

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Appendix

Snippet of Code for Android Application development:

AndroidManifest.xml

```xml
<?xml version="1.0" encoding="utf-8"?>
<manifest xmlns:android="http://schemas.android.com/apk/res/android"
    package="com.example.rajme.bluetoothalert">
    <uses-permission android:name="android.permission.BLUETOOTH" />
    <uses-permission
android:name="android.permission.BLUETOOTH_ADMIN"/>
    <uses-permission
android:name="android.permission.BLUETOOTH_PRIVILEGED"/>


    <application
        android:allowBackup="true"
        android:icon="@mipmap/ic_launcher"
        android:label="@string/app_name"
        android:roundIcon="@mipmap/ic_launcher_round"
        android:supportsRtl="true"
        android:theme="@style/AppTheme">
        <activity android:name=".MainActivity">
            <intent-filter>
                <action android:name="android.intent.action.MAIN" />

                <category
android:name="android.intent.category.LAUNCHER" />
            </intent-filter>
        </activity>
    </application>

</manifest>
```

MainActivity.java

```java
import android.app.NotificationManager;
import android.app.PendingIntent;
import android.bluetooth.BluetoothAdapter;
import android.bluetooth.BluetoothDevice;
import android.bluetooth.BluetoothGatt;
import android.bluetooth.BluetoothGattCallback;
import android.content.BroadcastReceiver;
import android.content.Context;
import android.content.Intent;
import android.content.IntentFilter;
import android.graphics.BitmapFactory;
import android.os.Build;
import android.support.v4.app.NotificationCompat;
import android.support.v7.app.AppCompatActivity;
import android.os.Bundle;
import android.text.TextUtils;
import android.widget.Toast;

import java.lang.reflect.Method;

import static android.telecom.Call.STATE_DISCONNECTED;
```

```java
public class MainActivity extends AppCompatActivity {

    BluetoothAdapter bluetoothAdapter;

    @Override
    protected void onCreate(Bundle savedInstanceState) {
        super.onCreate(savedInstanceState);
        setContentView(R.layout.activity_main);



        IntentFilter filter1 = new
IntentFilter(BluetoothDevice.ACTION_ACL_CONNECTED);
        IntentFilter filter2 = new
IntentFilter(BluetoothDevice.ACTION_ACL_DISCONNECT_REQUESTED);
        IntentFilter filter3 = new
IntentFilter(BluetoothDevice.ACTION_ACL_DISCONNECTED);


        this.registerReceiver(mReceiver, filter1);
        this.registerReceiver(mReceiver, filter2);
        this.registerReceiver(mReceiver, filter3);



    }

    private final BroadcastReceiver mReceiver = new
BroadcastReceiver() {
        @Override
        public void onReceive(Context context, Intent intent) {
            String action = intent.getAction();
            BluetoothDevice device =
intent.getParcelableExtra(BluetoothDevice.EXTRA_DEVICE);
            if (BluetoothDevice.ACTION_ACL_CONNECTED.equals(action)){
                pushNotification(context, "Bluetooth Connected");
//                  Toast.makeText(getApplicationContext(), "BT
Connected", Toast.LENGTH_SHORT).show();
            }
            else if
(BluetoothDevice.ACTION_ACL_DISCONNECTED.equals(action)){
                pushNotification(context, "Bluetooth Disconnected");
//                  Toast.makeText(getApplicationContext(), "BT
Disconnected", Toast.LENGTH_SHORT).show();
            }
        }

    };

    public void pushNotification(Context context, String msg) {

        NotificationCompat.Builder builder = new
NotificationCompat.Builder(context);
        builder.setSmallIcon(R.mipmap.ic_launcher);

        builder.setAutoCancel(true);


builder.setLargeIcon(BitmapFactory.decodeResource(context.getResources
(), R.mipmap.ic_launcher));

        builder.setContentTitle("Bluettoth Alert");
        builder.setContentText(msg);

        NotificationManager notificationManager =
(NotificationManager)
context.getSystemService(context.NOTIFICATION_SERVICE);
```

```
            notificationManager.notify(1, builder.build());
        }
}
```

activity_main.xml

```
<?xml version="1.0" encoding="utf-8"?>
<RelativeLayout
xmlns:android="http://schemas.android.com/apk/res/android"
    xmlns:app="http://schemas.android.com/apk/res-auto"
    xmlns:tools="http://schemas.android.com/tools"
    android:layout_width="match_parent"
    android:layout_height="match_parent"
    tools:context="com.example.rajme.bluetoothalert.MainActivity">


    <TextView
        android:id="@+id/label"
        android:layout_width="fill_parent"
        android:layout_height="wrap_content"
        android:gravity="center"
        android:textSize="30dp"
        android:layout_marginTop="200dp"
        android:text="Bluetooth Notification" />



</RelativeLayout>
```

Snippet of Code for Heart-Rate Monitor Sensor (MAX30100):

```
Import
smbus


        INT_STATUS    = 0x00  # Which interrupts are tripped
        INT_ENABLE    = 0x01  # Which interrupts are active
        FIFO_WR_PTR   = 0x02  # Where data is being written
        OVRFLOW_CTR   = 0x03  # Number of lost samples
        FIFO_RD_PTR   = 0x04  # Where to read from
        FIFO_DATA     = 0x05  # Ouput data buffer
        MODE_CONFIG   = 0x06  # Control register
        SPO2_CONFIG   = 0x07  # Oximetry settings
        LED_CONFIG    = 0x09  # Pulse width and power of LEDs
        TEMP_INTG     = 0x16  # Temperature value, whole number
        TEMP_FRAC     = 0x17  # Temperature value, fraction
        REV_ID        = 0xFE  # Part revision
        PART_ID       = 0xFF  # Part ID, normally 0x11
```

```
}

I2C_ADDRESS  = 0x57  # I2C address of the MAX30100 device


PULSE_WIDTH = {
    200: 0,
    400: 1,
    800: 2,
   1600: 3,
}


SAMPLE_RATE = {
    50: 0,
   100: 1,
   167: 2,
   200: 3,
   400: 4,
   600: 5,
   800: 6,
  1000: 7,
}


LED_CURRENT = {
       0: 0,
     4.4: 1,
     7.6: 2,
    11.0: 3,
    14.2: 4,
    17.4: 5,
    20.8: 6,
    24.0: 7,
    27.1: 8,
    30.6: 9,
    33.8: 10,
    37.0: 11,
    40.2: 12,
    43.6: 13,
    46.8: 14,
    50.0: 15
}
```

```
def _get_valid(d, value):
    try:
        return d[value]
    except KeyError:
        raise KeyError("Value %s not valid, use one of: %s" %
(value, ', '.join([str(s) for s in d.keys()])))


def _twos_complement(val, bits):
    """compute the 2's complement of int value val"""
    if (val & (1 << (bits - 1))) != 0: # if sign bit is set
e.g., 8bit: 128-255
        val = val - (1 << bits)
    return val


INTERRUPT_SPO2 = 0
INTERRUPT_HR = 1
INTERRUPT_TEMP = 2
INTERRUPT_FIFO = 3


MODE_HR = 0x02
MODE_SPO2 = 0x03




class MAX30100(object):


    def __init__(self,
                 i2c=None,
                 mode=MODE_HR,
                 sample_rate=100,
                 led_current_red=11.0,
                 led_current_ir=11.0,
                 pulse_width=1600,
                 max_buffer_len=10000
                 ):


        # Default to the standard I2C bus on Pi.
        self.i2c = i2c if i2c else smbus.SMBus(1)
```

```
        self.set_mode(MODE_HR)  # Trigger an initial temperature
read.
        self.set_led_current(led_current_red, led_current_ir)
        self.set_spo_config(sample_rate, pulse_width)


        # Reflectance data (latest update)
        self.buffer_red = []
        self.buffer_ir = []


        self.max_buffer_len = max_buffer_len
        self._interrupt = None


    @property
    def red(self):
        return self.buffer_red[-1] if self.buffer_red else None


    @property
    def ir(self):
        return self.buffer_ir[-1] if self.buffer_ir else None


    def set_led_current(self, led_current_red=11.0,
led_current_ir=11.0):
        # Validate the settings, convert to bit values.
        led_current_red = _get_valid(LED_CURRENT,
led_current_red)
        led_current_ir = _get_valid(LED_CURRENT, led_current_ir)
        self.i2c.write_byte_data(I2C_ADDRESS, LED_CONFIG,
(led_current_red << 4) | led_current_ir)


    def set_mode(self, mode):
        reg = self.i2c.read_byte_data(I2C_ADDRESS, MODE_CONFIG)
        self.i2c.write_byte_data(I2C_ADDRESS, MODE_CONFIG, reg &
0x74) # mask the SHDN bit
        self.i2c.write_byte_data(I2C_ADDRESS, MODE_CONFIG, reg |
mode)


    def set_spo_config(self, sample_rate=100, pulse_width=1600):
        reg = self.i2c.read_byte_data(I2C_ADDRESS, SPO2_CONFIG)
        reg = reg & 0xFC  # Set LED pulsewidth to 00
```

```
        self.i2c.write_byte_data(I2C_ADDRESS, SPO2_CONFIG, reg |
pulse_width)


    def enable_spo2(self):
        self.set_mode(MODE_SPO2)


    def disable_spo2(self):
        self.set_mode(MODE_HR)


    def enable_interrupt(self, interrupt_type):
        self.i2c.write_byte_data(I2C_ADDRESS, INT_ENABLE,
(interrupt_type + 1)<<4)
        self.i2c.read_byte_data(I2C_ADDRESS, INT_STATUS)


    def get_number_of_samples(self):
        write_ptr = self.i2c.read_byte_data(I2C_ADDRESS,
FIFO_WR_PTR)
        read_ptr = self.i2c.read_byte_data(I2C_ADDRESS,
FIFO_RD_PTR)
        return abs(16+write_ptr - read_ptr) % 16


    def read_sensor(self):
        bytes = self.i2c.read_i2c_block_data(I2C_ADDRESS,
FIFO_DATA, 4)
        # Add latest values.
        self.buffer_ir.append(bytes[0]<<8 | bytes[1])
        self.buffer_red.append(bytes[2]<<8 | bytes[3])
        # Crop our local FIFO buffer to length.
        self.buffer_red = self.buffer_red[-self.max_buffer_len:]
        self.buffer_ir = self.buffer_ir[-self.max_buffer_len:]


    def shutdown(self):
        reg = self.i2c.read_byte_data(I2C_ADDRESS, MODE_CONFIG)
        self.i2c.write_byte_data(I2C_ADDRESS, MODE_CONFIG, reg |
0x80)


    def reset(self):
        reg = self.i2c.read_byte_data(I2C_ADDRESS, MODE_CONFIG)
```

```
        self.i2c.write_byte_data(I2C_ADDRESS, MODE_CONFIG, reg |
0x40)


    def refresh_temperature(self):
        reg = self.i2c.read_byte_data(I2C_ADDRESS, MODE_CONFIG)
        self.i2c.write_byte_data(I2C_ADDRESS, MODE_CONFIG, reg |
(1 << 3))


    def get_temperature(self):
        intg =
_twos_complement(self.i2c.read_byte_data(I2C_ADDRESS,
TEMP_INTG))
        frac = self.i2c.read_byte_data(I2C_ADDRESS, TEMP_FRAC)
        return intg + (frac * 0.0625)


    def get_rev_id(self):
        return self.i2c.read_byte_data(I2C_ADDRESS, REV_ID)


    def get_part_id(self):
        return self.i2c.read_byte_data(I2C_ADDRESS, PART_ID)


    def get_registers(self):
        return {
            "INT_STATUS": self.i2c.read_byte_data(I2C_ADDRESS,
INT_STATUS),
            "INT_ENABLE": self.i2c.read_byte_data(I2C_ADDRESS,
INT_ENABLE),
            "FIFO_WR_PTR": self.i2c.read_byte_data(I2C_ADDRESS,
FIFO_WR_PTR),
            "OVRFLOW_CTR": self.i2c.read_byte_data(I2C_ADDRESS,
OVRFLOW_CTR),
            "FIFO_RD_PTR": self.i2c.read_byte_data(I2C_ADDRESS,
FIFO_RD_PTR),
            "FIFO_DATA": self.i2c.read_byte_data(I2C_ADDRESS,
FIFO_DATA),
            "MODE_CONFIG": self.i2c.read_byte_data(I2C_ADDRESS,
MODE_CONFIG),
            "SPO2_CONFIG": self.i2c.read_byte_data(I2C_ADDRESS,
SPO2_CONFIG),
            "LED_CONFIG": self.i2c.read_byte_data(I2C_ADDRESS,
LED_CONFIG),
```

```
            "TEMP_INTG": self.i2c.read_byte_data(I2C_ADDRESS,
TEMP_INTG),
            "TEMP_FRAC": self.i2c.read_byte_data(I2C_ADDRESS,
TEMP_FRAC),
            "REV_ID": self.i2c.read_byte_data(I2C_ADDRESS,
REV_ID),
            "PART_ID": self.i2c.read_byte_data(I2C_ADDRESS,
PART_ID),
        }
```

End