A Health-IoT Platform Based on the Integration of Intelligent Packaging, Unobtrusive Bio-Sensor and Intelligent Medicine Box

D.Ilakiya, K.Niroopa, A.Priscilla, B.Vigneswari, Mrs.sneha.k
UG Students1,2,3,4, Assistant professor
EEE Department, Velammal college of engineering and technology, Madurai, Tamilnadu.

Abstract

A desirable system should be capable of taking care of the patients from all aspects, covering personalized medication, vital signs monitoring, on-site diagnosis and interaction with remote physicians. The project gives an experimental idea of patients health condition. the platform involves 1) an open-platform-based intelligent medicine box (iMedBox) with enhanced connectivity and interchange ability for the integration of devices and services, 2) intelligent pharmaceutical packaging (iMedPack) with communication capability enabled actuation capability enabled by functional materials, and 3) flexible and wearable bio-medical sensor device (Bio-Patch) enabled by the state-of-the-art inkjet printing technology and system-on-chip. The proposed platform seamlessly fuses IoT devices.

Index Terms - *Internet of Medical Things; Compliance; Host Management System; Assisting Device; Cloud Storage*

I. INTRODUCTION

IoT is making strong inroads in the medical industry with the introduction of relevant sensors and devices. IoMT is a collection of medical devices connected to healthcare IT systems for different applications. The growth of IoMT has particularly impacted healthcare for the aged and disabled people, but not just limited to them. In the fast-paced world, even ordinary persons need support with their daily activities. One such important activity is to help them to take their medications on a daily basis without missing any dose. The presently available devices for medication adherence have some drawbacks and are restricted to basic functionality like serving only a single purpose of a reminder system. The complexity and cost associated with more elaborate systems led to the development of a new portable device in this paper named as "MEDIBOX" – an intelligent medication dispensing device. It is designed to help the elderly people who often forget to take their medications or take the wrong pills or dosage. It also helps people who used to travel frequently and are supposed to take regular medication. Hence, we proposed a multi-purpose, portable IoT-enabled MEDIBOX which is used purposely to address those pertinent issues.

Only about 50 percent of patients adhere to their medication regimen well enough to receive the full benefits of their prescriptions [1]. There are many reasons for not strictly following the regimen i.e., forgetfulness, complexity, lack of proper awareness about the medications, a lack of involvement from family and friends and so on. Many people cannot remember whether they took their medicine on time, especially those who take multiple drugs. Those who delay their dosage timings run the risk of an overdose when medicating at the next scheduled time. Under and over-dosage of medicine, the absence of medication administration and monitoring mechanisms can lead to many complexities in health. Although errors can occur in any stages of medication process, it often happens during the administration stage. MEDIBOX is designed to alert the patient at the right times along with the right dosage in prescription. Along with reminding a patient about medication it should be ensured that drugs are consumed without degrading their potency. Storage is an important aspect of the total drug control system, so in the design of MEDIBOX an appropriate environment is created to maintain the drug efficacy. The history of medications a person consumed is very important, so the consumption details are uploaded to the cloud for further medical reference. MEDIBOX is also capable enough to alert its user about their next appointment with the doctor.

Ambient Assisted Living (AAL) encompasses technical systems to support elderly individuals in their daily activities to allow an independent and safe lifestyle as long as possible [6]. MEDIBOX is focused on assisting the elderly and patients in adhering to the medications regularly without fail, thus helping them to avoid any future difficulties. The details of the consumed medicines with specific time interval are saved on a secure cloud that can be used for further analysis. Hence in this paper, we have designed a healthcare system that, through the use of IoT-enabled sensors and relevant hardware, assists individuals in

taking their prescribed medicines on time avoiding future consequences.

The paper is organized as follows. Section II introduces several closely relevant research projects. Section III presents the overview of the proposed design. Section IV introduces the MEDIBOX working methodology which includes real time data generation and actuation steps and cloud based analysis for IoMT requirements. Section V depicts the results and people in assisted living. Finally, relevant conclusion and future works are provided in Section VII analysis and in Section VI, it explains how it benefits to aged people.

II. RELATED WORK

The Internet of Things (IoT) is widely being recognized by researchers as one of the most sophisticated technologies with the prospective to dramatically change health, safety and security and addresses major impacts within the society. Medical device companies are transmuting themselves from devices/consumable providers to disease/care management firms. The IoMT provides an environment in which the patient's vital parameter details get transmitted through a gateway onto a cloud based platform where it is stored, aggregated and analyzed. It helps store data for millions of patients details and performs analysis in real time, ultimately ensuring an evidence-based medicine system. Ambient Assisted Living (AAL) [8] is a new approach which promises to address the needs of elderly people. Ambient Intelligence technologies are widely developed in this domain aiming to construct safe environments around assisted people and help them maintain independent living. However, there are still many fundamental issues in AAL that remain open. Most of the current work still does not fully express the power of human beings, and the importance of social connections and social activities is less noticed.

Various electronic pillboxes have been developed in both industry and academia during the past three decades. Most of the current methods for assessing adherence to medication regimens only remind the patient to consume the medicine. A medication event monitoring system (MEMS) consists of a conventional medicine container with a special lid that keeps track of the time and date each time the container is opened and closed [2]. Medication Adherence by using a hybrid automatic reminder machine reminds the patient based on a specific schedule which is defined by user input. The design consists of home use medication reminder machine and a Bluetooth bracelet. The bracelet sounds and flashes to remind the user to take pills or medicine from a bag [3]. Smart Phone based medicine in-take scheduler, reminder and monitor application named as Wedjat that helps patients to avoid mistakes in taking medication. Wedjat can remind patients to take the correct medicines on time and keep an in-take record for later review by healthcare professionals [4]. Medication reminder and healthcare is an android application where patients need not remember their medicine dosage timings as they can set an alarm for their dosage timings. The alarm can be set for taking multiple medicines and contains information pertaining to date, time and medicine description. A notification will be sent to them through email or message as chosen by the patients [5]. A Medication Adherence Monitoring System for people with dementia provides a system for medication adherence monitoring of people with memory-degrading conditions (dementia). It mainly vocally guides the patient through the steps of medication intake, controlling correctness and completeness of his actions and alerting the caretaker if problems occur [6]. Med-alert, an IoT device provides notification about the right medication to be consumed at the prescribed time through audio and visual alerts along with SMS sent to the patient's smartphone [7]. Medication Reminder and feedback system for elders proposes a design specifically for a wider population of aged and elderly users. It contains the combination of an automated process technique, Voice over IP, SMS and web services to devise an effective reminder and feedback solution which connects both the elders and supervising healthcare professionals [9]. The existing systems fail to keep the efficacy of maintaining the medicine and only concentrate on reminding the patients about the right time of the dosage. There are other systems that fail to remind about the dosage but rather remind only about the timing.

In this paper, our proposed solution not only reminds the patient about the in-take of medicine including time and dosage, and it also creates a suitable environment to maintain the efficiency of the medicine. The history of medication details is also stored on the cloud so that it helps for further reference about all the medicines consumed by the patient. Host Management System proposed in our system can assists the users of the MEDIBOX with installation, handling and configuration. It also helps the manufacturer to monitor and correct the design issues in future productions.

III. MEDIBOX OVERVIEW

The main objective of our proposed system is to create a user- friendly design that the patients can use as a reminder alert to take their daily medication on time. The device incorporates three main parts; circuitry, cooling system, and power supply. The various components used in the MEDIBOX are as shown in Fig 1.

Fig 1. MEDIBOX Overview

The circuitry incorporates multiple sensors incorporated with the required hardware modules. The cooling system consists of a cooling module and other related heat dissipation units. It includes a Peltier device, exhaust fans and heat sink. The power supply is intended to supply the essential power needed for each and every component used in the design. It uses a battery along with a buck converter to supply power to all components. Now we will describe the components used in MEDIBOX with its salient features.

NodeMCU [8]: NodeMCU has a firmware that runs on ESP8266 Wi-Fi SoC and includes a hardware based on ESP-12 module. The development board integrates GPIO, PWM, I2C, 1-Wire and ADC all in the same board. NodeMCU is preferred as the controller here due to more number of serial communication pins, compact size inbuilt Wi-Fi and low cost. Some modules in the circuitry need a 3.3V and others 5V supply. As NodeMCU incorporates both 3.3V and 5V pin there was no need for external regulating circuitry for these modules. We have used NodeMCU V1.0 which is a ESP8266 breakout board.fig8.1 shows

BME280 [9]: is an environmental sensor that has integrated pressure, temperature and humidity sensors. BME280 is a sensor developed mainly for mobile applications. It has both I2C and SPI communication pins. Two parameters are important for the drug maintenance: temperature and relative humidity. This sensor is a low-cost solution as well as compact in usage and it very much suits to our requirements in MEDIBOX.

LCD [12]: Grove LCD is used for display notification. It also has an I2C communication method shrinking the number of pins required from 10 to 2. Grove LCD also has the feature of supporting user defined characters. It is used for displaying the notification to the patient at the exact timings and other notifications regarding the battery.

The sequence of operations performed in MEDIBOX to represent the events of the various components. The system contains a BME280 sensor to monitor the temperature, humidity and pressure that is interfaced with the controller using I2C protocol. The sensor provides the data obtained in the controller, following which the controller actuates the cooling system (Peltier module) to function according to the required temperature and pressure to maintain the medicine's efficacy. The additional functionalities of the system include an alert mechanism, data logging and displaying notifications. The LCD and buzzer are responsible for providing alert notification as they are configured with the medication time, when the patient misses at any one time, a suitable alert will be generated by the buzzer and the corresponding message will be displayed on the LCD. SD card logger has the log of the patient details which can be later uploaded to the cloud when Wi-Fi is available. It can be used to view the patient's medication history by the doctor so the patient need not carry the prescription with him when he/she meets the doctor. All these components are interfaced with the controller using serial communication protocol such as I2C and SPI. Further, there is a web application to configure the box based on specific user requirements.

Fig8.1

IV. MEDIBOX FRAMEWORK AND WORKING METHODOLOGY

The MEDIBOX is designed as a compact and portable device that also facilitates connectivity to a secure cloud storage for further analyses. The device when connected to the Wi-Fi sends all the data to cloud storage. The data saved in the SD card logger is sent to the mobile app/web app which acts as a gateway for sending it via the internet. The device utilizes MQTT data protocol and Wi-Fi transport protocol for its communication. The MQTT protocol enables a publish/subscribe messaging model in a lightweight manner. It is important for connections with remote locations where a small code footprint is required and/or network bandwidth is at a premium. WTP (Wireless transaction protocol) provides functions closer to TCP (Transaction control protocol), except that WTP has lesser quantity of information needed for each transaction (e.g. does not include a provision for rearranging out-of-order packets).

A. Features of MEDIBOX

MEDIBOX incorporates different features like medication storage, medication reminder, cloud storage and HMS.

1) **Medication Storage**: High temperature and relative humidity (RH) are the most important factors that lead to drug degradation. All medicinal products must be stored in accordance with the manufacturer's directions. Medicines, especially vaccines which are sensitive biological materials are susceptible to heat, light etc. They will lose their potency with time but this becomes more rapid if they are not continuously stored at the appropriate temperature. MEDIBOX design uses an environmental sensor BME280 for continuously keeping track of the temperature and humidity which are

considered as the key parameters of medicine degradation. The temperature and humidity are maintained using a cooling system consisting of a heat sink and an exhaust fan.

2) **Medication Reminder**: A majority of patients find it difficult to take their medications at appropriate times for an extended duration of the medication course. They need to be notified about the medications prescribed by the doctor at the correct timings. MEDIBOX gives an alert using a voice as well as a visual reminder using the display on the box. Notifications are also delivered to the user's smartphone. The MEDIBOX uses RTC for keeping track of the current time and date without error. By syncing with Google calendar, the patient will be also reminded about his next appointment with the doctor.

3) **Cloud Storage**: Medical records are the records of the hospital and do not belong to the patient, clinical department or the doctor. The patient also has no proprietary right on his own clinical record today. The patient only carries with him the discharge summary of his clinical investigation reports and usually radiology films or images. Important clinical data is also not available for research and reference to aide in clinical decision support. Storing the clinical data on a secured cloud storage makes it convenient for the future reference.

4) **Host Monitoring System (HMS)**: The MEDIBOX system incorporates an HMS for automating the installation and changes in the settings. HMS is a powerful framework which can handle the installation for multiple boxes, perform component testing and User Acceptance Testing, monitor in remote and local mode, generate reports on demand, send alerts to the respective person, run test cases and intelligently handle errors in parallel. HMS can run phase-wise testing when the installation is in progress; a report of the test cases run can be provided to the customer on demand. The host monitoring system is important for enhancing MEDIBOX's usage which helps in completely supporting the customer with the product.

NodeMCU is an open source IoT platform and acts as a micro-controller in our system. NodeMCU is preferred because of its small size and number of serial communication pins. BME280 used in our system act as an integrated environmental sensor to measure both pressure and temperature and is suitable for mobile applications. RTC (real time clock) is an integrated circuit that keeps track of the time. RTC is preferred because of its low power consumption; it frees the system for time-critical tasks and is more accurate. The SD Card Shield is a simple solution for transferring data to and from a standard SD card. SD card logger is used to configure the box and store the log so that it can later be uploaded to the cloud whenever a Wi-Fi connection is available. For notifications in the box we use an LCD display and a buzzer. All these modules have I^2C communication except for the SD card logger which uses SPI communication. This also shrinks the circuit and makes the circuit compact.

B. Essential Features of Cooling Module

The cooling system contains a power supply that uses battery power whose rating is 11.1 V and 3000 mAh. In order to limit the maximum current and voltage drawn from the power supply, a buck converter is used which provides an output of 3.3V. This power is used to power the Peltier module which has a manually adjustable potentiometer. The system also has two exhaust fans, one in-take fan which draws air externally and transfers it to the heat sink and then passed onto the Peltier. The air thus cools and is allowed to circulate inside the system with the help of another exhaust fan.

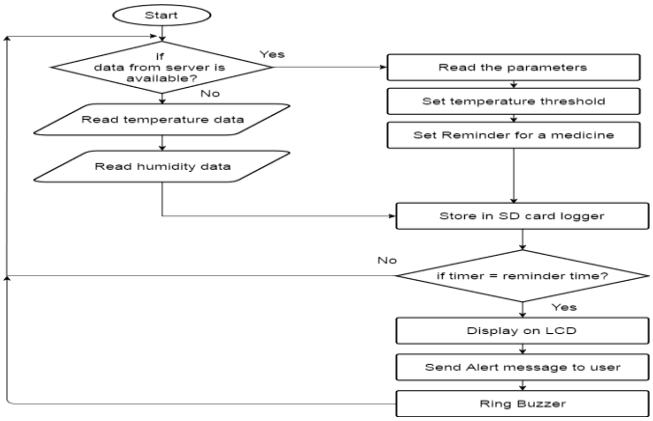

Fig 3. Flow of events show the generation of alerts in the system

C. Cloud-Based Analytics for IoMT

The service is hosted on a cloud for the benefit of the customers and the vendor to monitor the installation and working stages of MEDIBOX. Since the service is designed using the HTML5 technology, the web page is platform independent. The web page can be accessed using a smartphone or a laptop. The data processed by the service is stored on a database located in the cloud; each installation corresponds to a set of data and the final report is generated based on the data in the cloud storage. The various tests that are run by the user at the UAT stage are also known to the vendor, so that the vendor can get a detailed report of what happened during the installation. The alert system sends emails to the customer and the vendor about the issues that occurred during the time of its usage, so that the vendor and the customer can work on fixing the issue together.

IV. RESULTS AND DISCUSSIONS

The MEDIBOX as explained earlier consist of a circuitry with various components. Each of these components are tested and verified individually. All the modules are interfaced with the microcontroller using I2C or SPI communication. NodeMCU is used as a controller here due to its compactness, inbuilt Wi-Fi feature and number of serial communication pins. The serial communication pins are required to interface with the other modules in the design that use serial communication. Many of the boards support a higher number of GPIO pins than serial communication pins. BME280 sensor integrates temperature, humidity and pressure in one module. So rather than using different sensors for different parameters a single module helps in simplifying the design and in the measurement of all the parameters

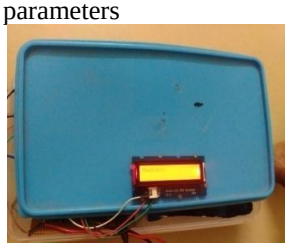

Fig 6. Initial LCD display MEDIBOX

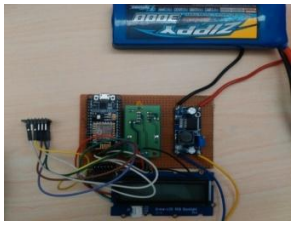

Fig 7. PCB design of

Fig 7 shows the entire circuitry of the MEDIBOX design. NodeMCU micro-controller and other modules like, BME280, RTC, , LCD, battery, buck converter which are soldered on to a PCB. A 12V battery is used as a power supply and is stepped down using a buck converter for powering different modules. Fig 8 shows the cooling system with Peltier module, heat sink and exhaust fans. The exhaust fans are provided with a voltage of 12V using battery whereas Peltier is powered from the output side of the buck converter. Fig 9 shows App configuration part. A medicine - for example "Allercet" is set to time 11:52 PM. This saves the data on the SD card and patient will be reminded at time 11:52 PM.
10 shows the LCD display showing the alert to take the medicine on time. The display will also show the medicine name and dosage. All the medication details are then saved in the cloud for further reference.

Now consider the scenario of a patient who has a very busy work schedule and suppose to travel around as a part of his job. In his busy schedule, he has to carry all these medicines in a proper environment and has to consume it at appropriate timings without failure. MEDIBOX helps him maintain the medicines in the proper environment and reminds him at proper timings to consume the medicines. The weight of the box is estimated below 5000 grains. The dimension of the designed system approximately is 25cm*15cm*5cm. The weight in this design is more due to the battery used in this design. This battery is used for the high current requirement of Peltier module. The weight of the box can be further reduced by the usage of another battery with a high current rating and low weight.

We have rigorously carried out a different set of experiments on the MEDIBOX by testing sensors placed inside the storage part and measuring the temperature and how efficiently it reminds different timings set using the App. Here the medicine was maintained at the proper temperature and alert was given at exact timings. Finally, we have seen that the designed MEDIBOX function as a proper assisting device for the patients with different needs.

V. ADVANTAGES AND BENEFITS TO AGED PEOPLE IN ASSISTED LIVING

MEDIBOX helps the patient keep track of the medicines and provides a reminder so that the patient takes the medicines at the appropriate time and hence prevents the consequences of missing dosages. The system is very useful for patients with dementia and Alzheimer's, who are facing memory related issues. Missing a dosage, over dose, under dose etc. can result in fatal effects on the patient. The MEDIBOX design thus helps the elderly and other patients in their daily life. The potency of a medicine is very important and MEDIBOX maintains an appropriate environment for the medicine thus retaining the efficacy of the medicine. Since it's a portable system, the patient can easily carry it with them during the travel and take the medicines at prescribed timings. It will also notify the patient well in time to refill the medicines and remind them about the next appointment with the doctor. The patient's medication details will be stored in cloud storage from where the doctor can fetch the medication information related to a specific patient. These details can be used for the doctor reference because many of the patients may not have a proper record of their medication history. The HMS helps the customers of the product with the configuration of the box and it alerts the change in settings due to some other reasons. The system is thus focused on making a compact design with less complexity and user friendliness.

CONCLUSION AND FUTURE WORK

In today's scenario, people are busy with their daily schedules and cannot remember their medication timings, which puts them in a difficult condition. In this paper, we have designed a new device MEDIBOX which aims at assisting a patient completely with a compact and user-friendly manner. It reminds the patient to consume the medications and provides a suitable

storage condition for the drugs. Storage of medications intake details can assist the doctor for future references i.e. the effectiveness of drugs on the patient can be found through the history of medication intake helping him to prescribe accordingly to the patient. The medication details are also stored in a secure cloud along with its storage details. One challenge faced with the design of the box was the cooling module. The Peltier module draws more current, so we need a battery with a high current rating which in effect increased the size of the MEDIBOX.

As a future enhancement to the MEDIBOX, health monitoring sensors can also be added to the system. Prediction of storage conditions included in the system makes the box more intelligent and also to consider the placement of multiple compartments inside the box to satisfy the requirement of different users in a home environment. Privacy and reliability measures should also be taken care. A suitable cooling system with less battery rating can make the system more compact and cost effective.

REFERENCES

[1] Marie T. Brown, MD and Jennifer K. Bussell, MD, "Medication Adherence: WHO Cares?", Mayo Clin Proc. 2011 Apr; 86(4): 304314doi: 10.4065/mcp.2010.0575

[2] Cramer JA, Mattson RH, Prevey ML, Scheyer RD, Ouellette VL, "How often is medication taken as prescribed? A novel assessment technique", Erratum in JAMA 1989 Sep 15; 262(11): 1472.

[3] Machine Ying-Wen Bai and Ting-Hsuan Kuo, "Medication Adherence by Using a Hybrid Automatic Reminder" IEEE International Conference on Consumer Electronics (ICCE), Las Vegas, USA, 2016.

[4] John K. Zao ; Mei-Ying Wang ; Peihsuan Tsai ; Jane W.S. Liu, "Smart phone based medicine in-take scheduler, reminder and monitor" 12th IEEE International Conference on E-Health Networking Applications and Services (Healthcom), 2010

[5] Deepti Ameta, Kalpana Mudaliar , Palak Patel , "Medication Reminder And Healthcare – An Android Application", International Journal of Managing Public Sector Information and Communication Technologies (IJMPICT) Vol. 6, No. 2, June 2015 DOI : 10.5121/ijmpict.2015.6204 39

[6] Vasily Moshnyaga, Masaki Koyanagi, Fumiyuki Hirayama, Akihisa Takahama, " Medication Adherence Monitoring System for People with Dementia", IEEE International Conference on Systems, Man, and Cybernetics, Budapest, Hungary, 2016

[7] S. Jayanth; M B Poorvi; M P Sunil, "MED-Alert: An IoT device", 2016 International Conference on Inventive Computation Technologies (ICICT), Coimbatore, India, 2016

[8] A Dohr ,R.Modre-Opsrian, M.Drobics ;D. Hayn ; G.Schreier, "The Internet of Things for Ambient Assisted Living,", 2010 Seventh International Conference on Information Technology: New Generations (ITNG), Las Vegas, USA, 2010

[9] Suthat Ronglong, Chaiyawut Sookplang, Chonlameth Arpnikanondt, Vajirasak Vanijja, "Design of a Medication Reminder and Feedback System for Thai Elders,", International Conference on Computer & Information Science (ICCIS), Kuala lumpur, Malaysia, 2012

[10] Kemal Serdaroglu , Gamze Uslu ; Sebnem Baydere, "Medication intake adherence with real time activity recognition on IoT", IEEE 11th International Conference 2015 on Wireless and Mobile Computing, Networking and Communications (WiMob), Abu Dhabi, UAE, 2015.

[11] https://nodemcu.readthedocs.io/en/master/

[12] https://cdn-shop.adafruit.com/datasheets/BST-BME280_DS001-10.pdf

[13] https://datasheets.maximintegrated.com/en/ds/DS1307.pdf

[14] https://cdn-learn.adafruit.com/downloads/pdf/adafruit-micro-sd-breakout-board-card-tutorial.pdf