Monitoring of the Medication Distribution and the Refrigeration Temperature in a Pharmacy based on Internet of Things (IoT) Technology

Elie N. Mambou, S. M. Nlom, Theo G. Swart, K. Ouahada, A. R. Ndjiongue and H. C. Ferreira
Dept. of Electrical and Electronic Engineering Science
University of Johannesburg
P. O. Box 524, Auckland Park, 2006, South Africa
Email: {emambou, smartin, tgswart, kouahada, arrichard, hcferreira}@uj.ac.za

***Abstract*—For the past 15 years since its appearance, Internet of Things (IoT) technology has been leading the planet towards a smart world where all devices and physical objects, referred to as "things", will be connected via electronic sensors through the Internet. The distribution of medication to patients at a pharmacy in certain regions is still very traditional and outdated. Patients wait for a long time in queues to receive their medications, this is mostly due to the absence of an efficient distribution system. Also, the refrigeration temperature within several pharmacies is a huge problem, as medications must be kept at a constant temperature for an optimal results.**

In this paper we propose a simple and reliable approach to monitor a pharmacy store, the method is based on electronic sensors connected to an Intel Galileo board, to perform a medication search and also to control the refrigeration temperature within pharmacy shelves. The implementation cost of such systems is considerably cheaper than a software based system; this makes such systems appropriate for underprivileged areas. This system was designed and built for a pharmacy but it can be generalized for other purposes.

Keywords—Intel Galileo board, Xively, Zapier, potentiometer, touch sensor, temperature sensor, relay.

I. Introduction

It has always been a fundamental priority in the world to improve hospital infrastructures in terms of electronic devices and equipments, as it provides more efficient health care to patients. The Internet of Things (IoT) technology brought a new vision in the world of technologies which is applicable in various fields. A very detailed work on descriptive models for IoT is presented in [1] and a process definition language for IoT in [2]. In the medical world, more precisely in a pharmacy environment, IoT can be applied for instance to the auditing and the tracking of medications. Also, IoT can significantly reduce the paper work needed when checking medications in or out from the pharmacy, which is partially the cause of long queues for patients at tellers.

A study was performed in the pharmacy of the *Helen Joseph Hospital* located in Johannesburg, South Africa, in order to investigate possible improvements on the current system. Some problems in the pharmacy functioning were observed, like long queues of patients at tellers, paperwork-based system, pharmaceutical refrigeration monitoring issues and medications placed in disorder on shelves.

A system was designed and developed to partially solve the problems that were mentioned above. The brain of this system is an Intel Galileo board which is a micro controller provided with open-source software and hardware Integrated Development Environment (IDE) for project developments. The Galileo board was chosen for the several features that it has, like shield compatibility, Wifi/Ethernet library compatibility, familiar Arduino IDE, real time clock, micro SD card support, USB host port, serial connectivity, Linux on Board, works with peripheral (PCI), two-wire serial interface (TWI)/inter-integrated circuit (I2C) and serial peripheral interface (SPI) support [3]. A detailed study on the performance of the Intel Galileo board can be found in [4], where a comparison between two development boards for embedded system functionalities, the Intel Galileo and the Intel Atom board SYS9400, is presented.

Much work have been done on the application of IoT in the field of medicine and health care. As an example, a broad study was done in [5], where applications of IoT were highlighted in medical micro fields such as telemedecine, mobile medical care, medical information management, medical equipment and medication control. However, this work like many others is purely theoretical in the sense that there was no case study considered and therefore few efficient results on the applicability of IoT in the medical and health care domain.

In this paper, an efficient and simple system is proposed to monitor the distribution of medication in a pharmacy, and also to control the pharmaceutical refrigeration temperature of medications. This approach defines a system made of hardware and software components. It is a user friendly system featuring a simple Graphical User Interface (GUI).

The rest of this paper is structured as follows: Section II presents the conception and the design of the proposed pharmacy monitoring system. The implementation is highlighted in Section III. Then in Section IV the results obtained are presented. A discussion and some analysis of the system are shown in Section V. Finally the conclusion of this work is provided in Section VI.

II. Conception and Design of the System

The proposed approach for a pharmacy monitoring system (PMS) was divided into two subsystems, namely the *med-*

ication distribution monitoring subsystem (MDMS) and the *temperature control subsystem* (TCS).

A. Design of the Medication Distribution Monitoring Subsystem (MDMS)

The MDMS manages the medication distribution using a database for all the medications in the pharmacy and they are classified in shelves according to their usage. To check medication in or out, a teller chooses the appropriate shelf via a touch sensor and browses through all categories of medication in that shelf via a potentiometer. Additionally, the teller is required to specify the number of units needed. However, all transactions are recorded on the cloud. This system also keeps track of the quantity of each category of medication in the store. There is a real-time update of the quantity of medication from the cloud at any time when a transaction is done. Also when the store is running out of a product, the manager is notified via a cellphone message and/or by email.

B. Design of the Temperature Control Subsystem (TCS)

A 5 V input micro controller board is used to drive a 230 V input fan motor via a relay module. A temperature sensor is connected to the same micro controller. This performs complete monitoring of the room temperature via the GUI. The temperature of the room is sensed and the relay is triggered for the fan motor to be on and its speed is controlled to obtain a preset temperature. The temperature report of the room is also accessible from the cloud.

Fig. 1 presents the overall design of the pharmacy monitoring system.

Basically the PMS was designed to facilitate the distribution of medications to the patients and also to make the work of the tellers easier. From a paper-based work system where all medication transactions were done manually, this system proposes an efficient approach where the teller interacts with the electronic sensors to choose the appropriate medications and sign them out to the patients. The major benefits of this approach is that all the transactions are recorded on the cloud, it is based on electronic sensors therefore the chances of making a mistake when checking medication in or out, or a system failure, is much less compared to full computer based systems. Also, computer illiterate people can still use it, especially old persons as the system GUI is purely for reading purposes.

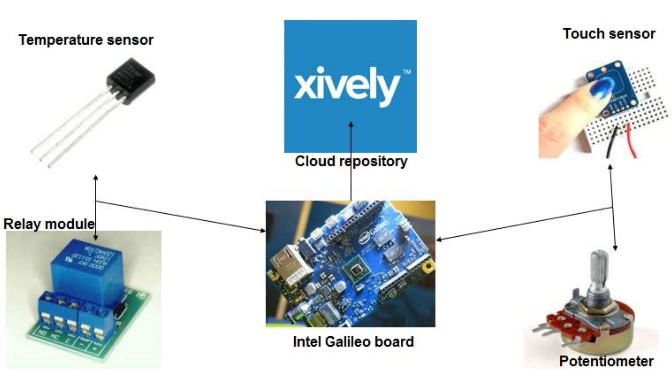

Fig. 1. Design of the system

III. Implementation of the System

The above described system was designed and implemented successfully. For the purposes of the implementation, a pharmacy of four shelves (Shelf 1, Shelf 2, Shelf 3 and Shelf 4) was considered, with each shelf containing five types of medication (Meds1, Meds2, Meds3, Meds4 and Meds5).

The Intel Galileo board used, was running Arduino IDE 1.5.3 on a Windows 7 computer. It was powered from a 5 V input USB cable. More information about the installation of Galileo IDE, drivers and connections can be found in [6]. A stereo jack to DB9 RS-232 cable was connected to the board to allow watching and interaction with Linux OS through the Serial Interface. The serial terminal emulator program, "putty" was used where the serial port COM was set to "COM4" and the baud rate to 115200 bps. More details on configuring the Linux environment on the Intel Galileo board can be found in [6]. Finally the board was connected to the cloud via its Ethernet port.

A. Implementation of the Medication Distribution Monitoring Subsystem (MDMS)

Fig. 2 presents the setup of the MDMS. There are four touch sensors that represents the four shelves in the store. When a shelf is selected its corresponding LED turns on to notify the user of the exact shelf selection. There are two potentiometers in this system as presented in Fig. 2, "Pot 1" is to browse through all medication in every shelf and "Pot 2" is to monitor the quantity of tablets. Therefore after selecting the appropriate shelf, the user specify the medication name as well as the quantity. On the same figure, in the middle of the breadboard, there is the "OK button", this is a switch button. A long press on that button is to validate the checking in or out of a specific medication with the quantity. To avoid mistakes after making a selection of the shelf, the medication name and the quantity, the user can double check details before pressing the button for confirmation.

The use of the potentiometer requires the function "map" which maps the complete cycle of the potentiometer to a specific range. Therefore for browsing through the five products in

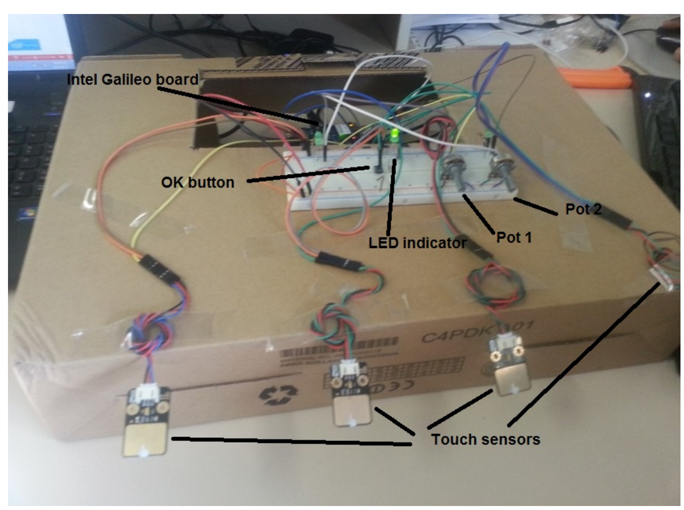

Fig. 2. Medication distribution monitoring subsystem

each shelf, the pseudo code for "MedNameSelect()" function is as follow:

```
sensorValue=analogRead(MEDNAME);
int sensorOut=map(sensorValue,0,1023,1,5);
select medication;
return Medname;
```

For specifying the quantity of any product, considering that the maximum was set to 50 units for every prescription, QtySelect() function is as follow:

```
sensorValue = analogRead(QTY);
int sensorQty=map(sensorValue,0,1023,1,50);
return sensorQty;
```

Therefore the algorithm for the MDMS is:

```
valuex = digitalRead(TOUCHx);
select valueX;
ledStateX == HIGH;
MedNameSelect();
QtySelect();
print out ``Shelf x, Meds y, Qty z'';
```

B. Implementation of the Temperature Control Subsystem (TCS)

Fig. 3 presents the implementation of the TCS, where a relay module is connected between the board and a 230 V input fan motor. The temperature sensor, TMP36 was connected to the board as well. The board was programmed to trigger the relay module when the temperature of the room exceeds 25°C. The green LED on the picture shows that the relay module has been triggered for the fan motor to be active to regulate the temperature of the room.

The algorithm for the TCS is as follows:

```
int value=readDigital(TemperatureSensor);
if(value >= 25)
    Trip off the relay to turn on the fan.
    Turn on the green LED.
```

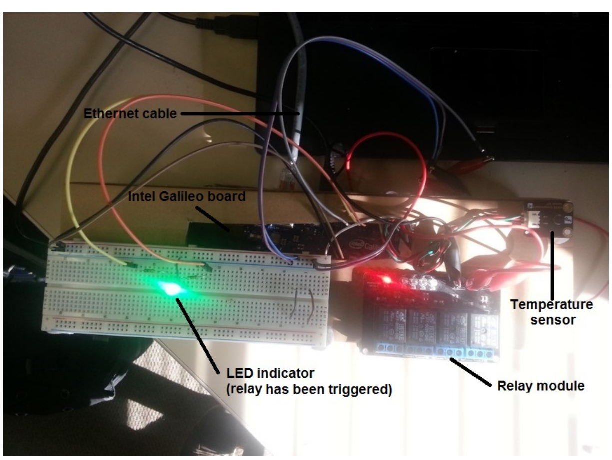

Fig. 3. Temperature control subsystem

C. Cloud Communications

For uploading the data to the cloud, the Xively technology was used. Xively, previously known as Cosm and Pachube, offers an IoT platform as a service [7]. In order to make use of the Xively services, one should create an account at "xively.com", and then register the Galileo board that is in use. More details on the procedures of connecting the Galileo board to the cloud via Xively can be found in [7]. Each device on a network must have a unique MAC address. The Galileo board will then connect to the created account and upload sensor data every 10 seconds. For controlling the Galileo board via the cloud, the full duplex data transfer is needed. This consists of sending a HTTP PUT message to the cloud and then a HTTP GET message to get control data from the cloud.

Finally the Zapier technology, which sends notifications to the user via cellphone message or email, is linked to the Xively account. Like Xively, Zapier also requires the user to create an account on "zapier.com", and then register every sensor that the user would require a notification from. More details on Zapier and how to link the sensor data to the cloud can be retrieved at [8].

IV. Results

All categories of medications from the five shelves were successfully registered on Xively. Each medication can be tracked from the cloud in the sense that the quantity and the distribution time of a specific medication can be accessed successfully.

Fig. 4 presents the monitoring graph for the Meds1 medication from Shelf 1, it can be observed that there are 75 units of this medication category remaining in Shelf 1. The graph can be zoomed in or out to clearly appreciate the checking out time and other details.

Fig. 5 shows the monitoring of the Meds5 medication from Shelf 1. Once again, one can observe the remaining stock which is 111 units. The initial quantity of every product is preset in the system when the medication is loaded on the shelf. Modifications can be made on the graph only by the user who has access to the Xively online account.

Fig. 6 presents the temperature monitoring graph. From this graph, one can track the temperature of the room at any point in time. The current temperature is 21°C, the figure shows a range of temperature mostly between 20 and 21°C.

Fig. 7 presents the Zapier online account GUI which shows the list of medications and sensors that the user will be notified about when a certain threshold is reached. On the picture, one can observe that the Meds1, Meds2 and Meds3 alerts are turned on, as well as the temperature control alert. For the medications, the limit was set to 50. Therefore whenever the quantity of a product will be less or equal to 50, the user will get an appropriate notification via email and/or cellphone message. For the temperature control, the threshold was set to 25°C, therefore the relay module will be triggered to regulate the room temperature if the sensor reads a value above that threshold.

Finally, Fig. 8 presents the GUI of the system from the serial monitor. It consists of the list of all transactions that

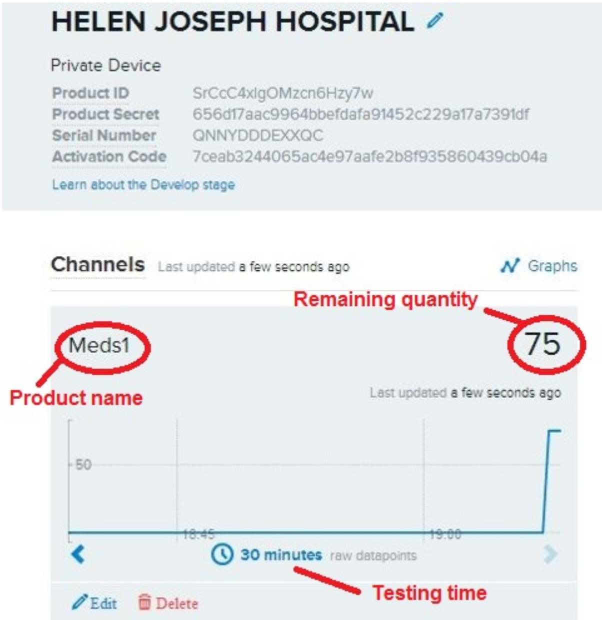

Fig. 4. Monitoring of the Meds1 medication from Shelf 1

Fig. 5. Monitoring of the Meds5 medication from Shelf 1

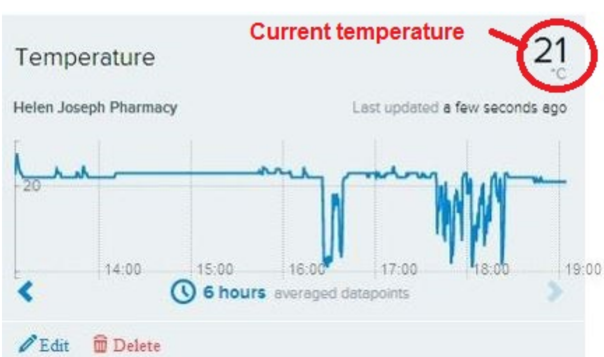

Fig. 6. Temperature monitoring

have been operating from the sensors. A permanent Internet connection is required to check a product in or out as this will update the online server.

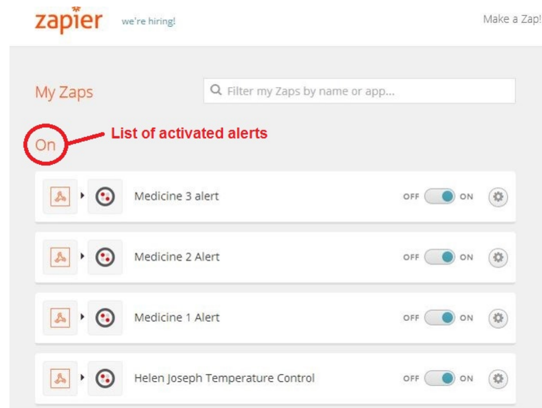

Fig. 7. Notification details

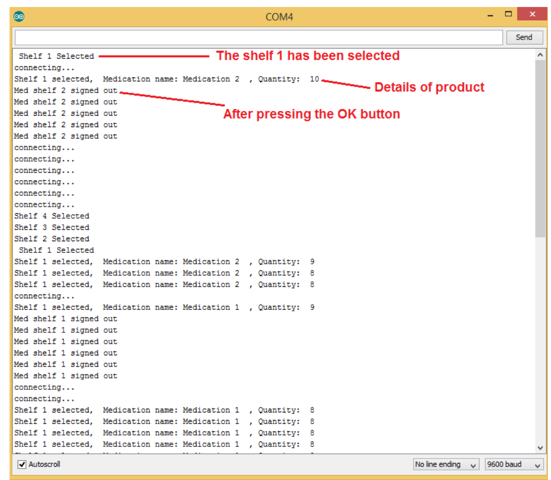

Fig. 8. Serial monitor GUI

V. System Analysis

From the results presented in the previous section, the monitoring and distribution of medication and the temperature control in a pharmacy can be performed with a simple and reliable system based on IoT. The implementation costs of such systems are relatively cheaper than software-based systems as these systems require frequent updates and maintenance. But with a system based on electronic sensors, the user interacts manually with the system which makes the usage easier, reduces the chances of making mistakes and requires less maintenance work. This kind of system is very appropriate for underprivileged pharmacies. Also it reduces the paper based work because all transactions are saved on the cloud which facilitates the monitoring and auditing of the firm for accountability purposes. However, it is important to underline the fact that IoT suffers from Internet hacking and other types of bugs. A study performed on the impact of the IoT attacks is provided in [9]. The proposed system makes use of the Xively and Zapier technology on the cloud side, these services are essential, as a user is required to open an account with a strong password to access the cloud. On the other hand, the use of big data in IoT is the current challenge that might also be problematic in the proposed system, a study on the impacts of IoT through the use of big data analytics are well explained in [10]. Therefore more work has to be conducted in order to make the IoT technology more reliable, safe and applicable in every domain. A detail research on the vision and the future of IoT is presented in [11].

VI. Conclusion

An approach to monitor the medication distribution as well as controlling the temperature of a pharmacy store was presented. This system was designed and implemented successfully to partially solve the current system in some pharmacies which is purely paperwork based. The proposed system made use of electronic sensors, namely the touch and temperature sensors. This kind of interacting system is very advantageous as the risk of making mistake is reduced and also computer illiterate persons can use it. The biggest advantage is that all the transactions are recorded on the cloud, this allows the manager to access and monitor data remotely.

This system demonstrates once again that IoT technology is an efficient and reliable way of connecting all electronic devices together to bring the whole wide world in front of a screen in real time. The IoT have its applications in all fields of science, technology and engineering. Having a "smart world" where all devices will be connected is still a dream in the sense that a lot effort is still necessary to reach that state.

VII. Acknowledgment

The authors would like to thank Intel Pty. Ltd. for organizing an Engineering Innovation Week at the University of Johannesburg, South Africa, to advance technology and social innovation in Sub Saharan Africa.

References

[1] Y. Huang and G. Li, "Descriptive models for Internet of Things", in *Proc. Int. Conf. Intell. Control Inf. Process.*, Dalian, China, Aug. 13–15, 2010, pp. 483–486.

[2] F. Chen, C. Ren, Q. Wang and B. Shao, "A process definition language for Internet of Things", in *Proc. IEEE Int. Conf. Service Operations and Logistics, and Informat.*, Suzhou, China, Jul. 8–10, 2012, pp. 107–110.

[3] M. Richardson, "10 Great Intel Galileo Features," http://makezine.com/2013/10/03/10-great-intel-galileo-features/, [Online; accessed 31 July 2014].

[4] A. Siri, R. Kishan, G. R. Meghana and R. Hegde, "Comparison of two development boards for embedded system functionalities – Intel Galileo and Intel Atom board SYS9400," in *Proc. Int. Conf. Circuits Commun. Control Comput.*, Bangalore, India, Nov. 21-22, 2014, pp. 153–155.

[5] F. Hu, D. Xie and S. Shen, "On the application of the Internet of Things in the field of medical and health care", in *Proc. IEEE Int. Conf. Internet of Things and IEEE Int. Conf. Cyber, Physical and Social Comput.*, Beijing, China, Aug. 20–23, 2013, pp. 2053–2058.

[6] Intel, "Intel Galileo Support Community," https://communities.intel.com/community/tech/galileo/overview/, [Online; accessed 20 July 2014].

[7] Xively, "Xively Homepage," https://xively.com/, [Online; accessed 25 July 2014].

[8] "Trigger anything with Zapier," https://xively.com/dev/tutorials/zapier/, [Online; accessed 27 July 2014].

[9] A. M. Gamundani, "An impact review on Internet of Things attacks", in *Proc. Int. Conf. Emerging Trends Netw. Comput. Commun.*, Windhoek, Namibia, May 17–20, 2015, pp. 114–118.

[10] F. J. Riggins and S. F. Wamba, "Research directions on the adoption, usage, and impact of the Internet of Things through the use of big data analytics", in *Proc. Hawaii Int. Conf. Syst. Sci.*, Kauai, USA, Jan. 5–8, 2015, pp. 1531–1540.

[11] M. H. Asghar, N. Mohammadzadeh and A. Negi, "Principle application and vision in Internet of Things (IoT)", in *Proc. Int. Conf. Comput. Commun. Automat.*, Noida, India, May 15–16, 2015, pp. 427–431.