Long-range Monitoring System with PDMS Material

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ABSTRACT

This paper describes the development of a long range monitoring system that integrates Cottonwood: UHF Long Distance RFID reader module with Raspberry Pi 3. When a UHF RFID tag is within the UHF RFID reader antenna's range, the unique ID of the tag will be transferred to the Raspberry Pi 3 to be processed. Then, the data will be sent over to the database wirelessly to be managed, stored, and displayed. The paper also describes the measurement done to determine the most suitable thickness of PDMS material so that it could be incorporated as a wearable transponder. After the result is calculated and tabulated, it can be concluded that the most suitable thickness of PDMS material for the transponder is 8 mm.

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1. INTRODUCTION

In this day and age, the use of Radio Frequency Identification (RFID) systems can be seen everywhere. With recent technology developments, the Internet of Things (IoT), and the RAIN RFID partnership, RFID is going conventional with a number of major retailers and manufacturers installing RFID systems for handling inventories and supply chains activities. Two of the largest retailers such as TESCO and Marks and Spencer (M&S) have incorporated RFID in their product tracking system throughout the whole ranges of merchandises which leads these retailers to having maximum benefit. The system is able to play a key part in ensuring staffs are being stationed in customer facing roles instead of the standard administrative works such as stock counting [1]. Furthermore, payments now can be made using credit cards and debit cards that use Near Field Communication (NFC) which is a subset of the RFID family. Moreover, in personnel identifications, RIFD are being integrated with access control system which grants user access to restricted areas or buildings with their identifications in the system.

On that note, localization systems tend to use Global Positioning System (GPS) to track and locate user before displaying the result on a device [2]. This system has a lot of limitations where one of them is the inability to send signals from inside of a building. This is due to weak signals emitted by the GPS and their disability to go through most building materials thus, making GPS inefficient in tracking indoor subjects. Plus, GPS also need a clear line-of-sight from the earth to the sky. This will render the device useless during stormy days, rainy days, and even in cloudy days. Meanwhile, systems designed based on Radio Frequency (RF) will undoubtedly be the main localization technique as it could operate when the rain pours as it applies the usage of electromagnetic waves which is capable to go through opaque objects such as walls and even human bodies [3].

On the other hand, RFID system consists of three components, an RFID transponder or tag, RFID reader, and an antenna. The tag contains an integrated circuit (IC) which will be powered up by the electromagnetic waves transmitted by the reader. When the tag is powered up, the IC is used to transmit data to the RFID reader and then transferred through a communication interface to a computer system where it can be stored, displayed, or analysed at a later time [4], [5]. On the other hand, there are generally two types of RFID devices which are active RFID and passive RFID. The main difference between the two is the transponders for active RFID have its own transmitter and power source while the passive RFID transponder does not. Plus, active RFID usually operates in Ultra High Frequency (UHF) band meanwhile passive RFID can operate in three different bands which are Low Frequency (LF) band, High Frequency (HF) band, and also in UHF radio band. Next, passive tags are cheaper, smaller, and easier to manufacture compared to the active tags because they do not require their own transmitter or power source, but only a tag chip and an antenna. On the other hand, the read range of passive tags are typically less than 10m compared to 100m read range of active tags as they are limited by the power of the tag's backscatter, or the radio signal reflected from the tag back to the reader. Reference papers [2], [6 - 9], elaborates on the usage of RFID in different fields including indoor location sensing in hospitals, inventories checking for big retailers, car tracking, and even human monitoring in correctional facilities.

2. RESEARCH METHOD

In this section, the method for UHF RFID system development and transponder testing is explained and summarized in two different parts.

2.1. UHF RFID System Development

Figure 1 shows the concept of data transfer of the monitoring system that consist of the integration of Raspberry Pi 3 and Cottonwood: UHF Long Distance RFID reader module.

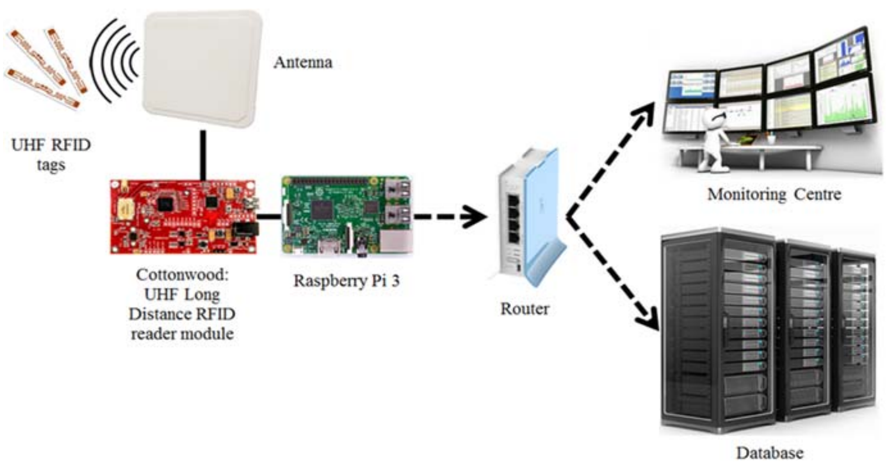

Figure 1. The concept of data transfer of UHF RFID monitoring system

When an RFID tag is within the reader antenna's range, the unique ID of the tag will be collected and transferred to the Raspberry Pi 3 to be processed. Next, the Raspberry Pi 3 will translate, add details of detection to the data obtained, and send it to the database created using XAMPP software. After that, the data can be monitored through the monitoring center that displays the details such as the location of detected tag, time, date, and also the list of previous tag detections. The goal for this set up is that whenever the tag is within the UHF RFID reader antenna's range, the reader will collect the tag ID, send it over to Raspberry Pi 3 to be translated and processed before sending the complete information to the database.

To link the Raspberry Pi 3 to the UHF RFID reader, an algorithm is designed so that when a transponder or tag is detected, the unique ID of the tag is displayed on the command prompt. Figure 2 shows the process flowchart for the UHF RFID-Raspberry Pi 3 sensor.

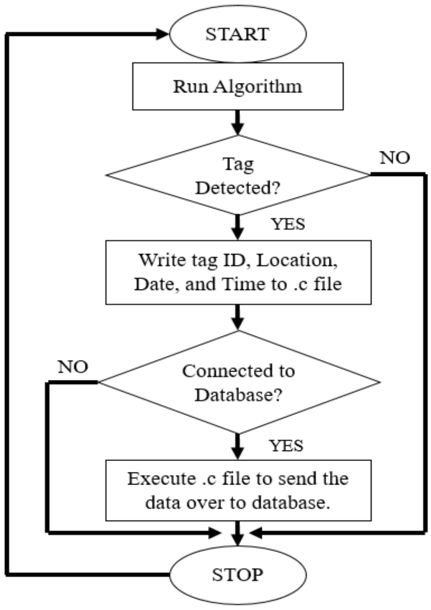

Figure 2. Process flowchart for UHF RFID-Raspberry Pi 3 sensor

2.2. Transponder with PDMS Material Detection Measurement

PDMS material or polydimethylsiloxane, is a silicone elastomer that is mainly used to embed electronic components such as chips, thorugh casting which helps lengthen the lifespan of the chip. PDMS is widely used as it acts as a dielectric isolator and protects the electrical components from external environmental influences and mechanical shock [10]. To incorporate wearable tag using PDMS material for the system, a series of tests and measurements is needed to determine the most suitable PDMS thickness for the tag. On that note, PDMS material used in this measurement has no colour and was divided into 5 parts with different thickness as shown in Figure 3. The transponder used is the UPM RAFLATAC DogBone, which has a sticky base so that it holds on to the PDMS material better. The thickness of PDMS material used for this measurement is 2mm, 3.5mm, 8mm, 10mm, and 20mm.

Figure 3. Different thickness of PDMS material used for this measurement

The setup of the measurement is illustrated as shown in Figure 4. The measurement is done in a line-of-sight condition and the result is taken when the details of detection is shown in the monitor.

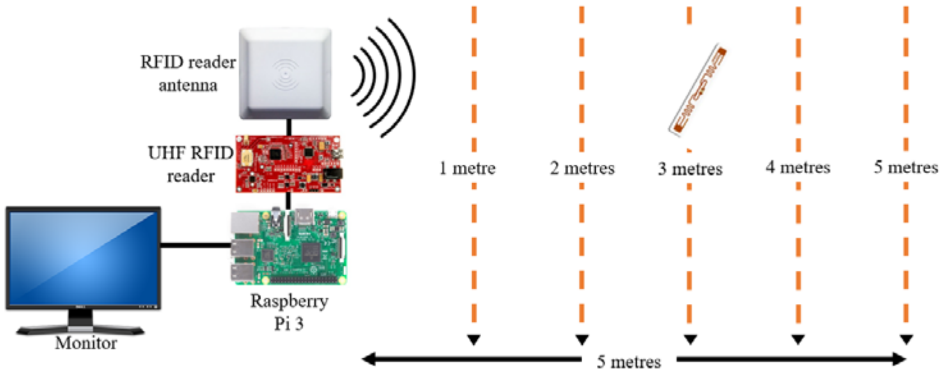

Figure 4. The illustration of setup of measurement

3. RESULTS AND ANALYSIS

The results for UHF RFID system development and transponder with PDMS material detection measurement is presented in two parts.

3.1. UHF RFID System Development

When the tag is within the UHF RFID reader antenna's range, the unique ID of the tag will be collected and sent over to the Raspberry Pi 3. Raspberry Pi 3 will then add other detection details such as the date, time, and the location of the sensor and then display them on the command prompt as shown in Figure 5. Next, the data will be stored in database designed using XAMPP software that is also used to develop an interface module that could display the ID and the details of detection such as time, date, and the location of the sensor. The user interface will then display the information stored in the database as shown in Figure 6 for monitoring purposes.

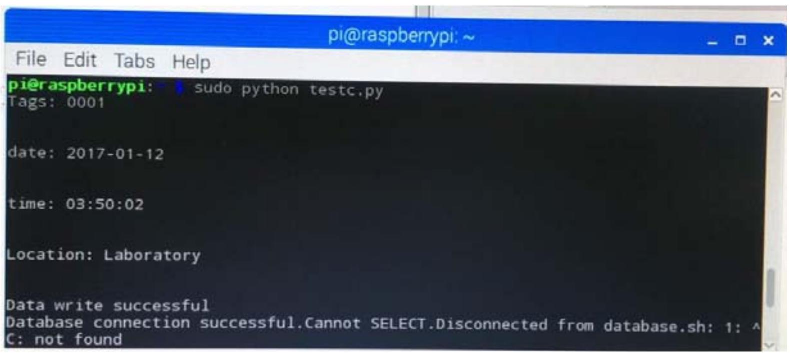

Figure 5. Details of detected tag on Raspberry Pi 3 command prompt

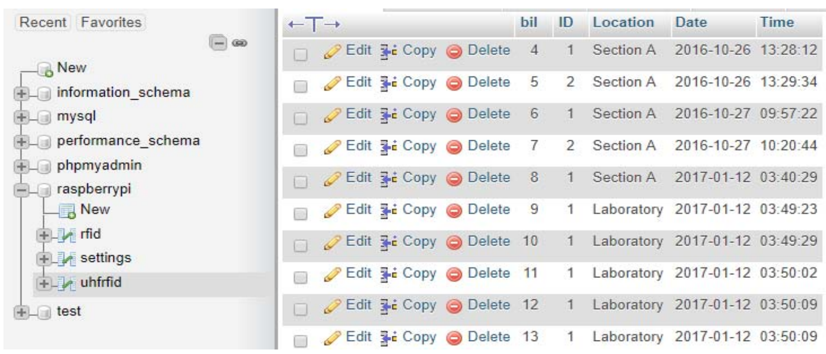

Figure 6. List of detected tag history on database

3.2. Transponder with PDMS Material Detection Measurement

The measurement took place inside the laboratory with the line-of-sight condition. Every metre away from the UHF RFID antenna is marked with a line before the measurement start. Table 1 shows the how many times the reader is able to detect the transponder in 10 seconds without being placed on the arms.

Table 1. Distance vs. number of data collected in 10 seconds

Distance (m)	UPM DogBone
1	108
2	102
3	98
4	91
5	91

Next, the subject placed the transponder with PDMS material on her arm and starts the algorithm. The result is as shown in Table 2 below. The data denotes whether the sensor is able to detect the transponder or not.

Table 2. Thickness of PDMS material vs. Distance from UHF RFID antenna

Distance (m) Thickness (mm)	< 0.5	1	1.5	2
2	✓	X	X	X
3.5	✓	✓	X	X
8	✓	✓	✓	X
10	✓	✓	✓	X
20	✓	✓	✓	X

For distance less than 0.5 metres away from the UHF RFID reader antenna, tag with all of the different thickness of PDMS material was successfully detected. Next, when the subject is set to be 1 metre away from the UHF RFID reader antenna, the transponder with the thinnest PDMS material attached can no longer be detected. After that, the subject moved 1.5 metres away from the UHF RFID reader antenna, the transponder with 3.5 mm PDMS material could not be detected. Finally, when the subject is placed 2 metres away from the UHF RFID reader antenna, none of the transponder is detected.

4. CONCLUSION

The development of monitoring system with long detection using UHF RFID has been discussed. The details of detected tag are successfully displayed on the Rapberry Pi 3 command prompt and sent over to the database. Next, different thickness of PDMS material is tested against this sytem to determine the most suitable thickness to be incorporated as a wearable transponder. By comparing the result between the different thicknesses of the PDMS material, tranponder with PDMS material of 8 mm is better in terms of balance between detection and thickness. On the other hand, the decline in transponder performance noted from Table 1 to Table 2 is due to the fact that the properties of the human skin causes frequency shift on the transponder antenna. The thickness of the PDMS material helps to combat this problem.

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Norsaidah Muhamad Nadzir received her B. Eng. degree in Electrical Engineering (Computer Engineering) from Universiti Teknologi Malaysia in 2016. She is currently pursuing her M. Eng. degree in Electrical Engineering in Universiti Teknologi Malaysia. Her research interest includes RFID antennas for readers and tags, computer aided design for antennas, small antennas, computer systems, and wireless sensor networks.

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