International Journal of Synergy in Engineering and Technology Vol.4 No. 2 (2023) 105-118

International Journal of Synergy in Engineering and Technology

Journal homepage: https://tatiuc.edu.my/ijset/index.php/ijset/ e-ISSN: 2735-0622

Design of Adaptive RFID on IoT Platform with Passive Tag Based on Laboratory Management System (LMS)

Umar Ismat Mohd Nasri[1*], Kharudin Ali[1], Damhuji Rifai[1], Ahmed N. Abdalla[2] and Mooner A. Faraj[3]

[1] Faculty of Engineering Technology (Electrical and Automation) University College TATI, Jalan Panchor, Telok Kalong, 24000 Kemaman, MALAYSIA
[2] Faculty of Electronic Information Engineering, Huaiyin Institute of Technology, Huai'an, Jiangsu, China
[3] Electrical and Electronics Engineering Department, Omar Al-Mukhtar University, Al-Baida, Libya

*Corresponding author email: 20B03G003@siswa.tatiuc.edu.my, kharudin@uctati.edu.my

KEYWORDS

RFID
Tag and Reader
IoT platforms
UHF

ABSTRACT

Radio Frequency Identification (RFID) refers to a wireless system comprising two components: tags and readers. The reader is a device that has one or more antennas that emit radio waves and receive signals back from the RFID tag. RFID is available on most systems applications especially involving security systems, including house/office access systems, toll systems, and laboratory systems. Range detection for RFID will affect accessibility data, information, and conditioning of object in monitoring system. This information can be some static data that are preloaded in the tag's memory for reflecting the tagged product's attributes (e.g., expiry date) or some dynamic sensing data (e.g., temperature) in a sensor-augmented RFID system for item-level monitoring. Through this research, the development of adaptive RFID on IoT platforms with different types of passive tag laboratory systems highly emphasized monitoring the status equipment besides maximum range detection and quantity of RFID tags should be analysed. This research also considering on double layer of securities for equipment before crossing the laboratory gate. The frequency RFID are 860-900 MHz with the Ultra High Frequency (UHF) band due to its affordability and ease of implementation. According to the result shows for maximum RFID tag sticker can be detected on the same times are 7 units with the range 1m. Lastly the angle 80 to 100 degrees will giving the maximum range of detection within 5.5m.

Received 20 September 2023; Revised 18 October 2023; Accepted 22 October 2023; Published 30 October 2023.

1.0 INTRODUCTION

Radio Frequency Identification (RFID) stands as a wireless, contactless technology employed for the identification of individuals or objects through the utilization of radio waves. This technology heralded as the next generation in emerging wireless communication, finds application across diverse domains, including transportation systems, manufacturing management, and tracking and tracing, among others. In recent times, RFID has garnered mounting interest from industry and academic institutions alike (1)(2)(3)(4).

Particularly in institutional settings, manual inventory processes have traditionally prevailed, presenting inherent challenges such as time consumption. The difficulties escalate when dealing with substantial inventory volumes (5)(6). For instance, within a laboratory environment, where a multitude of items necessitates scrutiny, reliance on manual procedures mandates the employment of numerous personnel, consequently inflating labour costs for the institution. In light of these issues, the adoption of RFID technology becomes imperative to mitigate inventory shortages(7)(8)(9)(10)(11).

A RFID system primarily comprises two integral components: the transponder, which are tags affixed to objects, and the Interrogator, also known as the RFID reader. Communication between the RFID reader and tags transpires wirelessly, typically without the need for direct line-of-sight between the devices. Various identification methods exist, with the most prevalent involving the storage of a serial number that uniquely identifies individuals or objects, along with potential supplementary data, on a microchip attached to an antenna. This amalgamation of chip and antenna is referred to as an RFID transponder or tag (5)(12)(13)(14)(15). The antenna facilitates the transmission of identification information from the chip to a reader. Subsequently, the reader decodes the radio waves reflected by the RFID tag into digital data, which can then be relayed to computers for further utilization.

The advent of RFID technology has considerably streamlined and systematized inventory management systems. The integration of RFID technology has greatly simplified and organized inventory management systems. In this paper, we propose a laboratory management system that harnesses the potential of RFID technology as its core framework. The design of the system is thoroughly discussed, utilizing RFID readers and an inventory database to automatically record and store the complete circulation history and real-time status of the tracked laboratory equipment.

2.0 METHODOLOGY

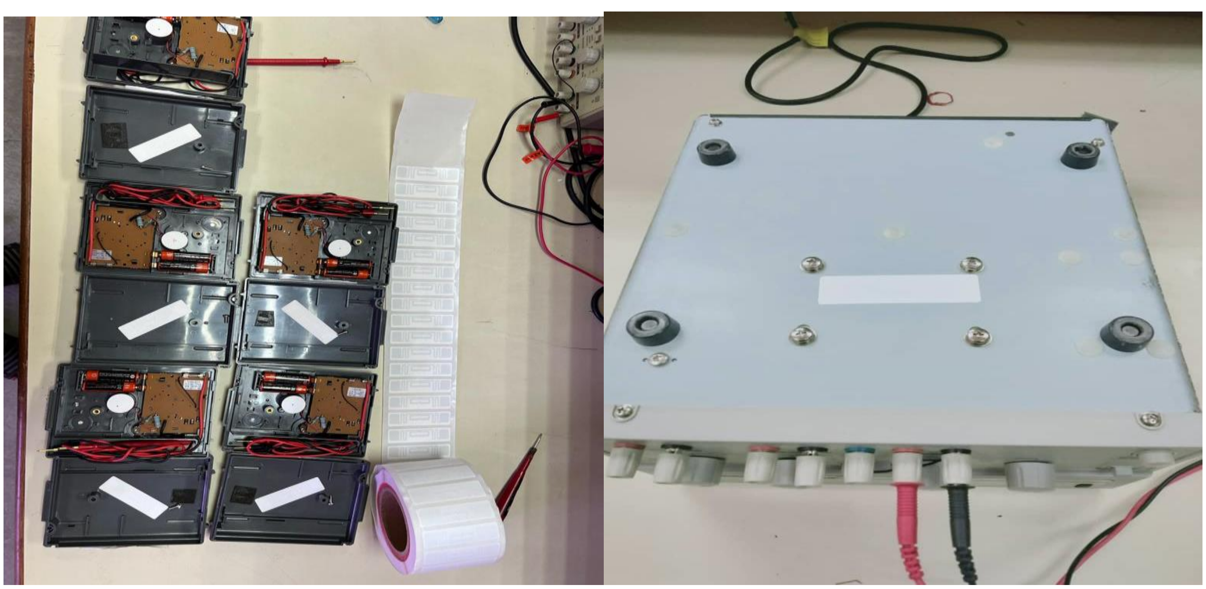
2.1 Project Methodology

Laboratory management includes areas such as borrowing and returning of equipment, classification of materials, cataloguing and barcoding. Many of these areas, including the aforementioned, have direct effects on customer satisfaction. As an example, even in small libraries, where the collection size is small, items can often be misplaced which can cause discontent in patrons. RFID technology had its first commercial applications introduced in the late 1980's. Since then technologies in different fields have advanced causing the cost of RFID tags and readers to go down, thus making it available to a broader market. For example, libraries have slowly started to adopt this technology as RFID tags have become cheaper. Data will be collected by tracking and monitoring laboratory assets, and performance metrics such as read range, tag response time, data throughput, and error rates will be measured and analyzed. User feedback and observations will be qualitatively assessed to evaluate the system's usability. Validation and comparison with traditional LMS solutions will demonstrate the system's superiority. Ethical considerations regarding data privacy and informed consent will be addressed throughout the study. This methodology will guide the systematic investigation and evaluation of the proposed adaptive RFID on IoT platform with passive tags, leading to the achievement of research objectives in enhancing laboratory management efficiency.

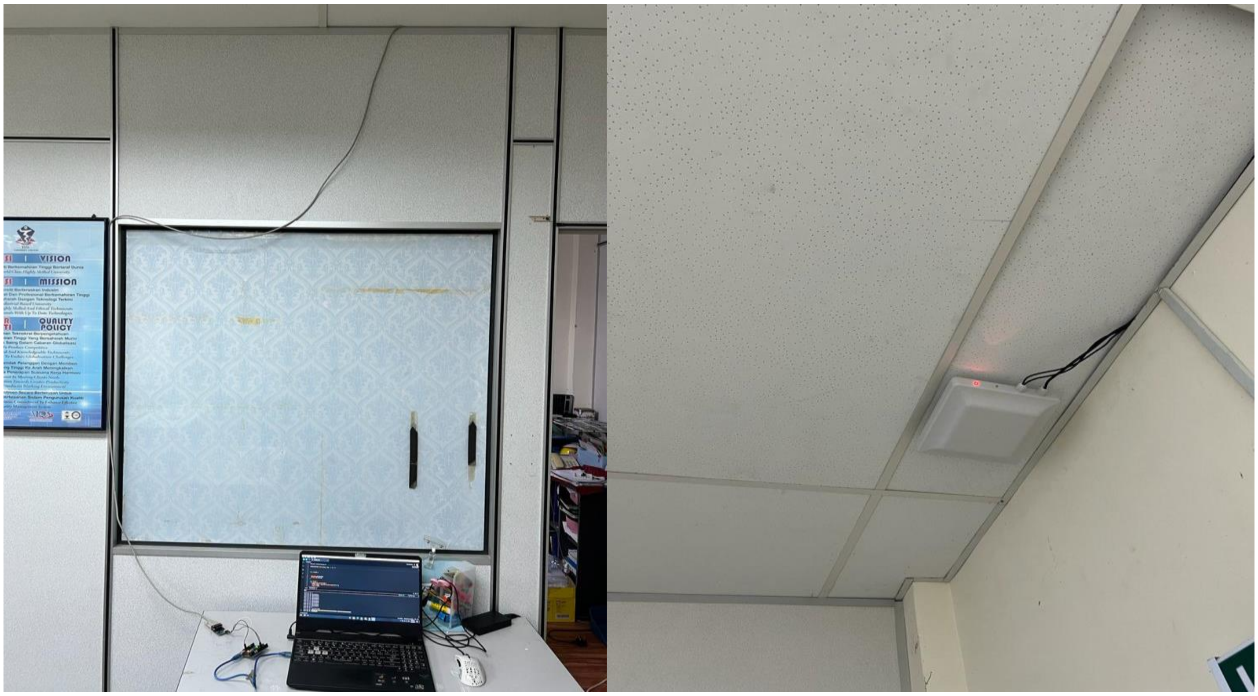
2.2 Project Setup and Design

RFID technology is involved in various modules in laboratories. Such as tagging station to tag the RFID label to each laboratory material/ equipment and anti-theft security gates ensure the items are checked-out before leaving the laboratory by detecting if the RFID tags that are attached in the item is activated; and finally, as to the self-management, for example patrons can track the searching items that were miss-shelved by the use of RFID handheld reader. Figure 2.1 show the overall system setup on this project.

(a)



(b)



(c)

Figure 2.1: (a) The process of measuring angle and range of RFID (b) the installation of RFID sticker to equipment at laboratory and (c) the implementation of UHF RFID at the ceiling of laboratory

2.3 Principle of Operation

A basic RFID system consists of three modules: Tags, Readers and Antennas. An RFID Tag is made up of a coupling element and a chip; each tag has a unique electronic code, attached to the object used to identify the target. RFID readers are devices that are used to retrieve and write the information on RFID tags. There are two types of RFID tags mostly used in the market, that are active and passive. Active RFID tags have a transmitter and their own power source (typically a battery). The power source is used to run the microchip's circuitry and to broadcast a signal to a reader (the way a cell phone transmits signals to a base station). Passive tags have no battery. This project is using is the passive type. There are handheld readers and fixed readers. Handheld readers designed that act like handheld bar code scanners and fixed readers are mounted to read tags automatically as items pass nearby them. The antenna emits radio signals to activate the tag and to read and write data to it. As it can be seen from Figure 2.2, a reader transfers energy to the transponder by emitting electromagnetic waves through air. A transponder uses energy to charge up and as well as receives data signal and responds accordingly. The reader receives transponder response and sends to a host computer or external devices through its control lines. The application of this project is on the in and out access gate. From here the RFID receiver module will be apply. Besides the alarm lamp and buzzer will be apply together. This system is integrated in each other for complete system functioning.

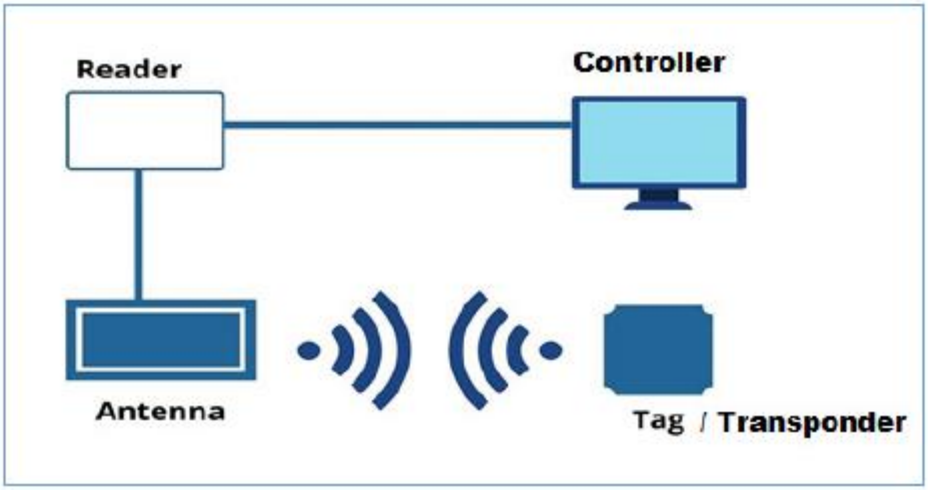


Figure 2.2: System Schematic

Flowcharts are used in designing and documenting simple processes or programs. Like other types of diagrams, they help visualize what is going on and thereby help understand a process of works or project. As shown in Figure 2.3, the flowchart shows the workflow of the lab's equipment issuing or borrowing process. Equipment must be recorded at the Lab's Instructor desk counter for borrowed condition. Here the RFID reader/writer will detect the tag that has been attached to the laboratory equipment. Then the lab's instructor will push the "PEMINJAMAN" pushbutton to write the tag's memory which is for going out condition. When the equipment is taken to cross the security gate, the RFID reader at the gate will detect whether the equipment has been recorded for the borrowing status. The alarm and buzzer at the security gate will activate once the RFID reader triggered the unwanted condition.

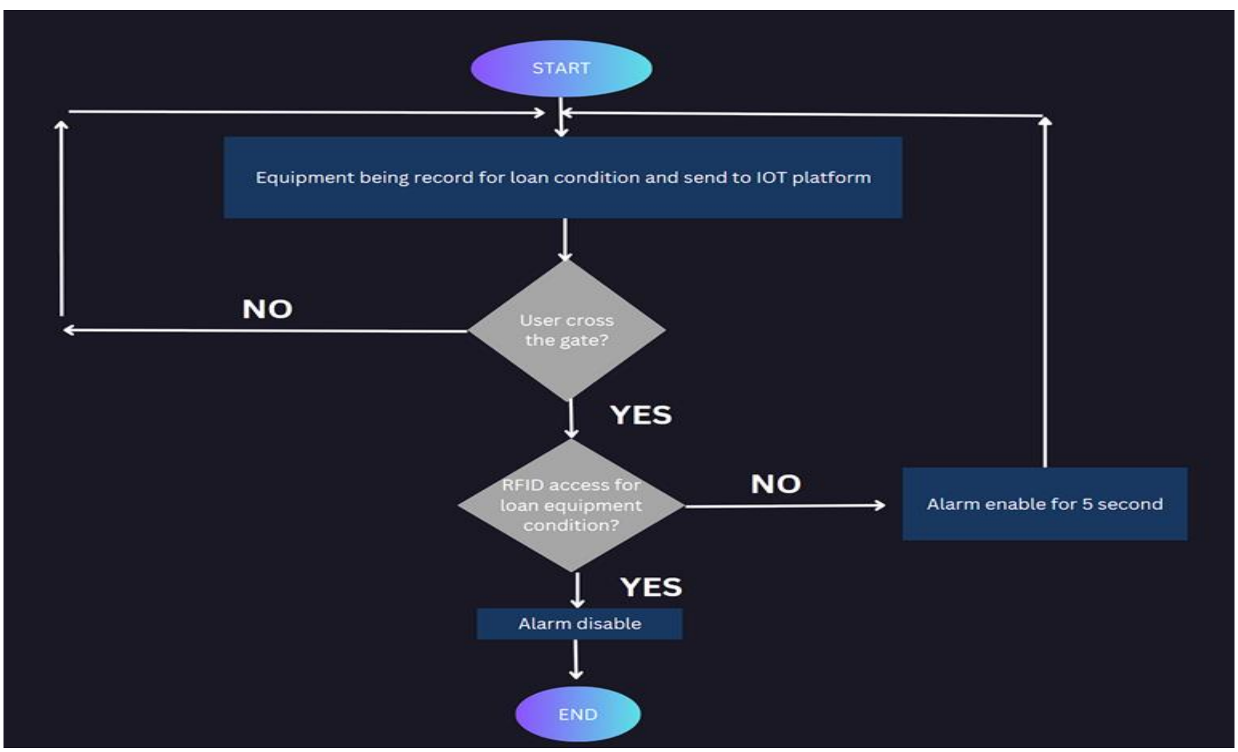


Figure 2.3: Flowchart of the of operation

Each of the equipment in laboratory will be equipped with RFID labels or unique tag ID. A reader transfers energy to the transponder by emitting electromagnetic waves through the air. A transponder uses RF energy to charge up and receive data signals and respond accordingly. The application of this project is on the in and out access gate. The data and equipment id will transfer and record by wireless to the IoT platform (THINGER.IO). Authorized persons can only access the IoT platform. According to data in the IoT platform, the user's name, matric id, date and phone number will be recorded for authorized person reference. The IoT Platform was show on Figure 2.4.

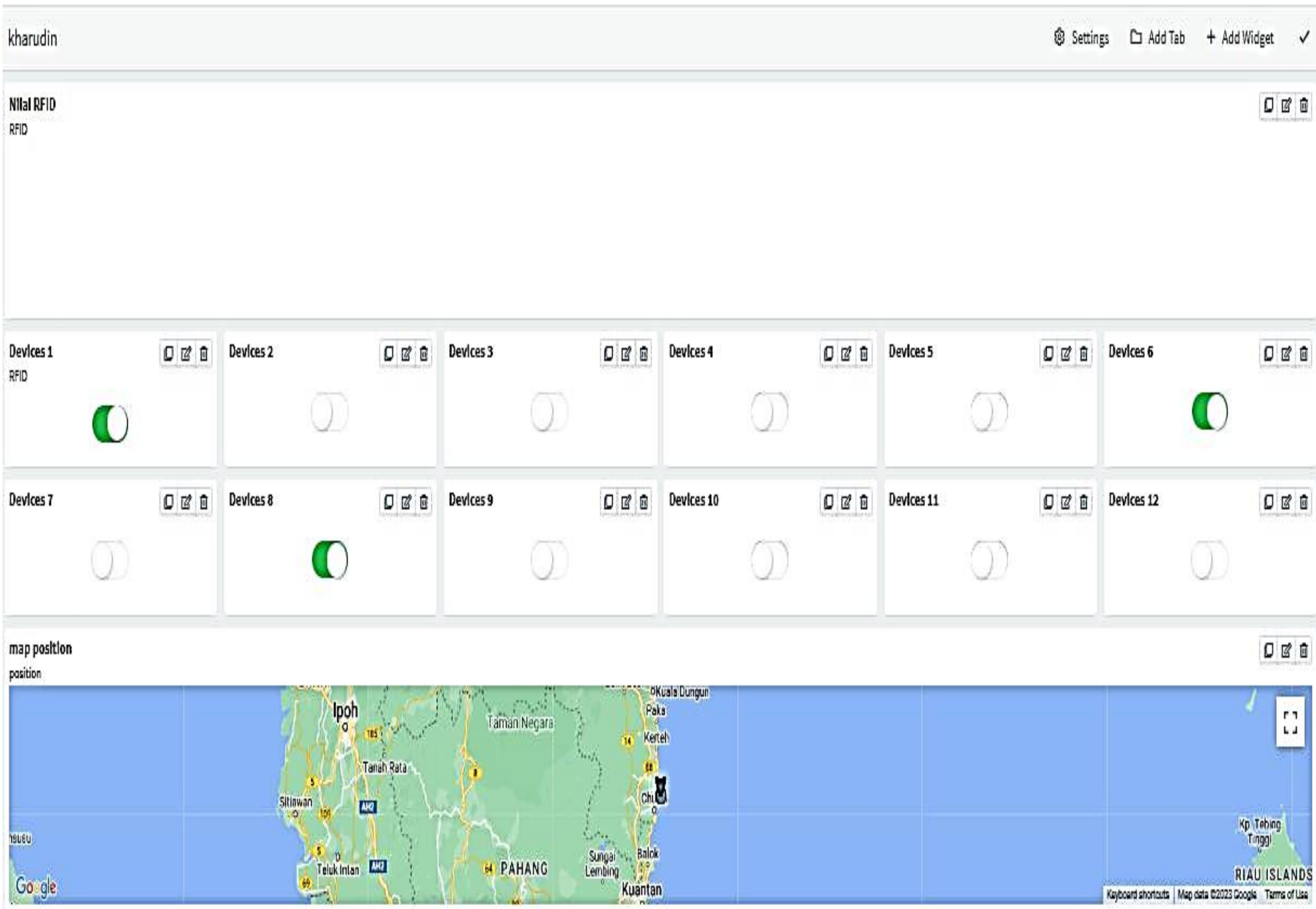
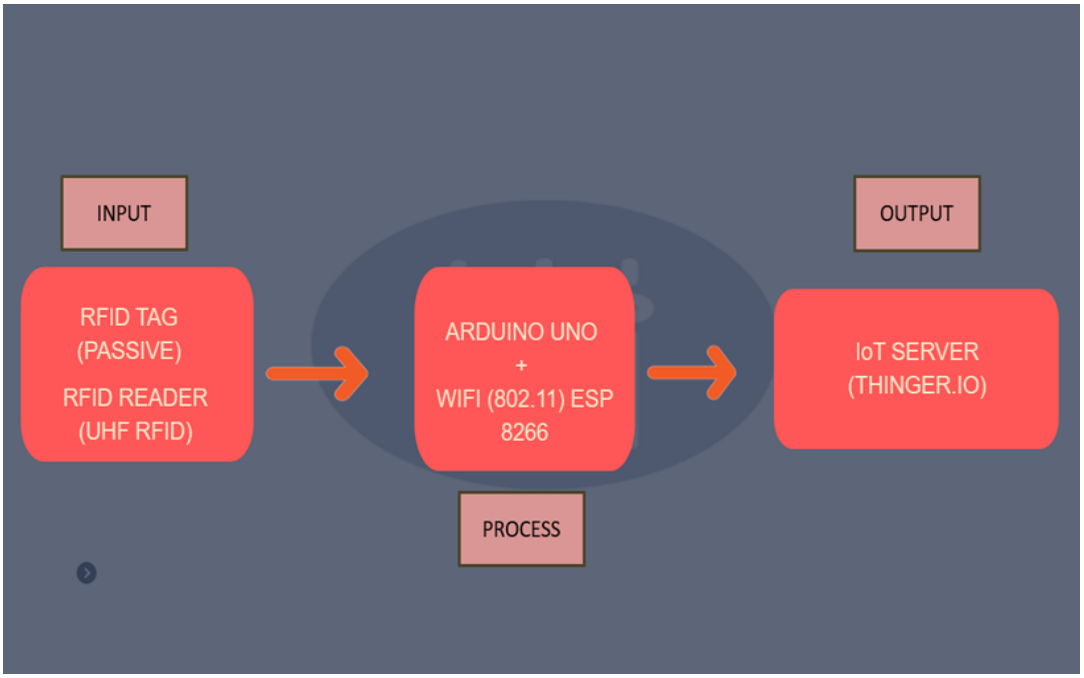


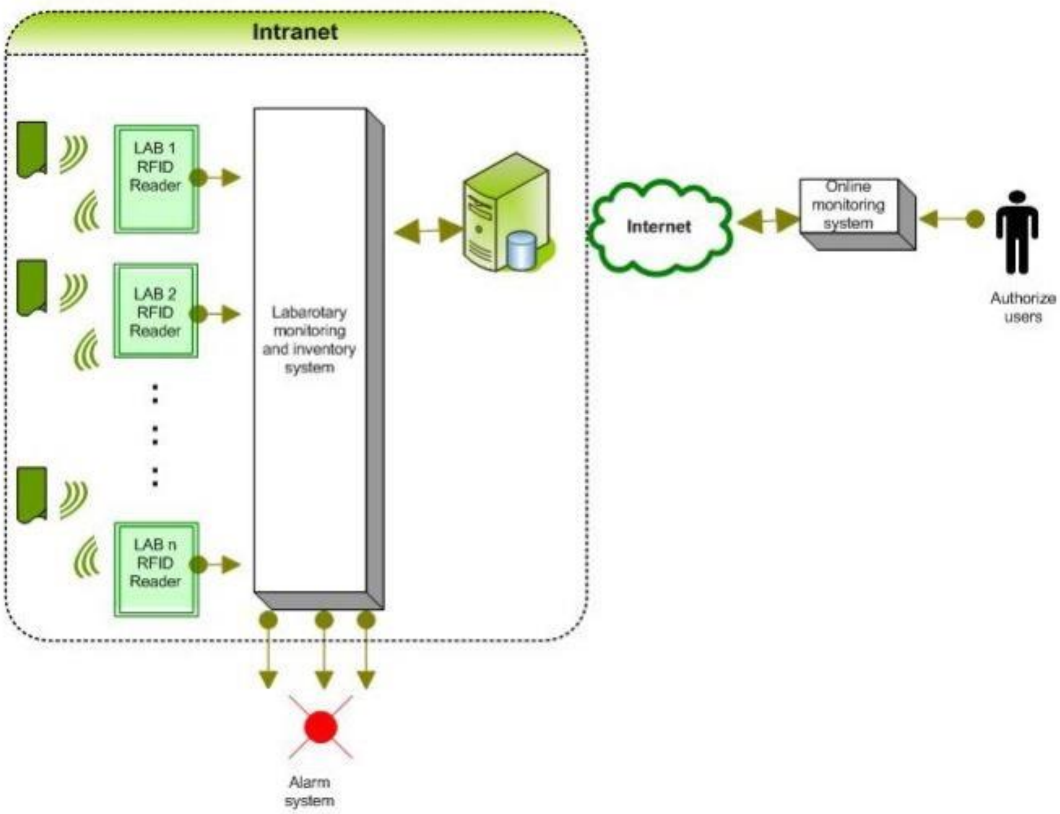
Figure 2.4: IoT platform (THINGER.IO)

2.4 Block Diagram

The block diagram and data flow are as Figure 2.5 below: RFID tags are interrogated by the UHF RFID reader, and their unique identification information is relayed to the Arduino Uno microcontroller. The Arduino Uno, in turn, processes this data and transmits it to the ESP8266 Wi-Fi module. Subsequently, the ESP8266 establishes a connection to Thinger.io, delivering the RFID tag data to the cloud-based IoT server, where it can be accessed, analyzed, and utilized as required.



(a)



(b)

Figure 2.5: (a) Block Diagram of the Operation, and (b) The Architecture of the operation

3.0 RESULTS AND DISCUSSION

3.1 Time Response

The obtained results exhibit a consistent pattern, affirming the UHF RFID system's remarkable efficacy in detecting RFID tags across a range of time intervals, spanning from 0.5 seconds to 5 seconds, across multiple experimental trials. Table 3.1 shows the results of time response for UHF RFID reader. This unwavering performance underscores the system's capacity for swift and dependable detection, thereby rendering it well-suited for a diverse array of real-world applications. It is discovered that the UHF RFID system has exceptional time response characteristics, consistently detecting RFID tags within the set temporal boundaries. The findings of this study shed light on the untapped potential of UHF RFID technology for usage in scenarios requiring rapid and consistent object tracking and identification.

Table 3.1: Result of Time Response of UHF RFID

TIME RESPONSE					
Time(second)	**Detection**				
0.5	1	1	1	1	1
1	1	1	1	1	1
1.5	1	1	1	1	1
2	1	1	1	1	1
2.5	1	1	1	1	1
3	1	1	1	1	1
3	1	1	1	1	1
4	1	1	1	1	1
4.5	1	1	1	1	1
5	1	1	1	1	1

3.2 Detection Rate Based on RFID Quantity

The results of our inquiry into the detection rate of a UHF (Ultra-High Frequency) RFID reader when several RFID tags are present within its read range. The key objective of this study was to evaluate the reader's ability to reliably identify UHF RFID tags in scenarios with varied tag counts. According on the Table 3.2 show the maximum numbers of RFID sticker can be detector are seven ID in the same times. This detection was tested on range 3-meter fix, when 1 to 7 UHF RFID tags simultaneously entered the reader's read range, the system consistently achieved a 100% detection rate. These findings underscore the reader's robust performance in environments characterized by moderate tag density.

Table 3.2: Result of Detection Rate Based on RFID quantity

Detection Rate Based On RFID Quantity	
Quantity RFID	**Number Of Detection**
1	1
2	2
3	3
4	4
5	5
6	6
7	7
8	7
9	7
10	7

Significantly, when 8 or more UHF RFID tags endeavoured to traverse the reader's read range simultaneously, the system consistently detected a maximum of 7 tags. Beyond this threshold, no additional tags were identified.

The measured detection rate trend indicates that the UHF RFID reader system can identify up to 7 UHF RFID tags at the same time. This performance meets industry standards, especially in applications where high-density tag circumstances are uncommon. However, it is imperative to acknowledge the reader's inherent limitation in detecting more than 7 UHF RFID tags concurrently. This constraint may be attributed to factors such as potential signal interference and the reader's processing capacity.

3.3 Distance Detection

This section presents the results of our study aimed at assessing the distance detection capability of UHF (Ultra-High Frequency) RFID tags within a controlled laboratory environment. The capacity of UHF RFID systems to detect RFID tags across varying distances has been a subject of paramount interest, with profound implications for applications demanding long-range identification and tracking. In particular, the ability of UHF RFID tags to communicate with a reader at extended distances holds significant promise for optimizing processes in environments characterized by large-scale asset management and tracking.

The purpose of this research is to thoroughly evaluate UHF RFID tags' ability to detect objects at a distance in a controlled lab setting. The main goal is to offer insightful information about how well the system performs when detecting RFID tags at various ranges from the reader. This study adds to the basic information required for the successful implementation of UHF RFID technology in practical applications by diving into the specifics of the system's reading range.

Table 3.3: Result of distance detection

Distance Detection					
Distance (cm)	**Detection**				
20	1	1	1	1	1
40	1	1	1	1	1
60	1	1	1	1	1
80	1	1	1	1	1
100	1	1	1	1	1
120	1	1	1	1	1
140	1	1	1	1	1
160	1	1	1	1	1
180	1	1	1	1	1
200	1	1	1	1	1
220	1	1	1	1	1
240	1	1	1	1	1
260	1	1	1	1	1
280	1	1	1	1	1
300	1	1	1	1	1
320	1	1	1	1	1
340	1	1	1	1	1
360	1	1	1	1	1
380	1	1	1	1	1
400	1	1	1	1	1
420	1	1	1	1	1
440	1	1	1	1	1
460	1	1	1	1	1
480	1	1	1	1	1
500	1	1	1	1	1
550	1	1	1	1	1
600	0	0	0	0	0

Table 3.3 shows that at 0.2 meters, the UHF RFID system demonstrated the remarkable capability to reliably detect RFID tags at an extended reading range of up to 5.5 meters. This exemplifies the system's capacity to detect tags well beyond the initial proximity point.

As the distance from the reader increased, we observed a gradual decrease in the system's detection capability. Beyond a distance of 6 meters, the UHF RFID system ceased to detect RFID tags effectively. The results of our research on distance detection highlight the UHF RFID system's excellent performance in controlled laboratory conditions. The system's effectiveness in expanding the reading range beyond expectations is demonstrated by the capability to identify RFID tags at 5.5 metres from the reader at an initial proximity of 0.2 metres.

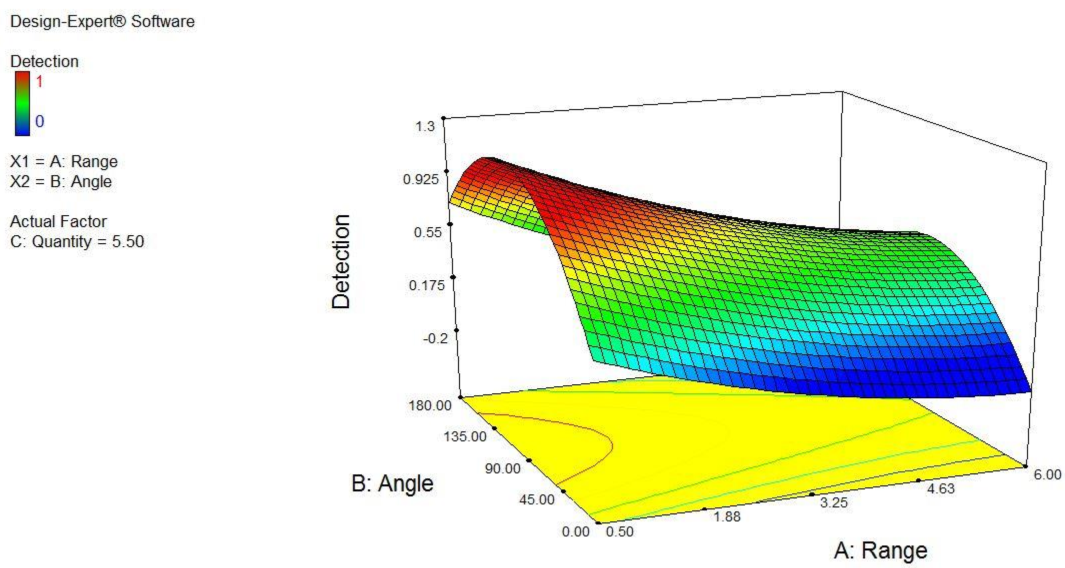
However, as distances increased beyond 6 meters, we observed a diminishing detection capability. Factors contributing to this decrease may include signal attenuation, interference, and limitations in the RFID reader's transmission power within the laboratory environment.

3.4 Angle Detection Distance

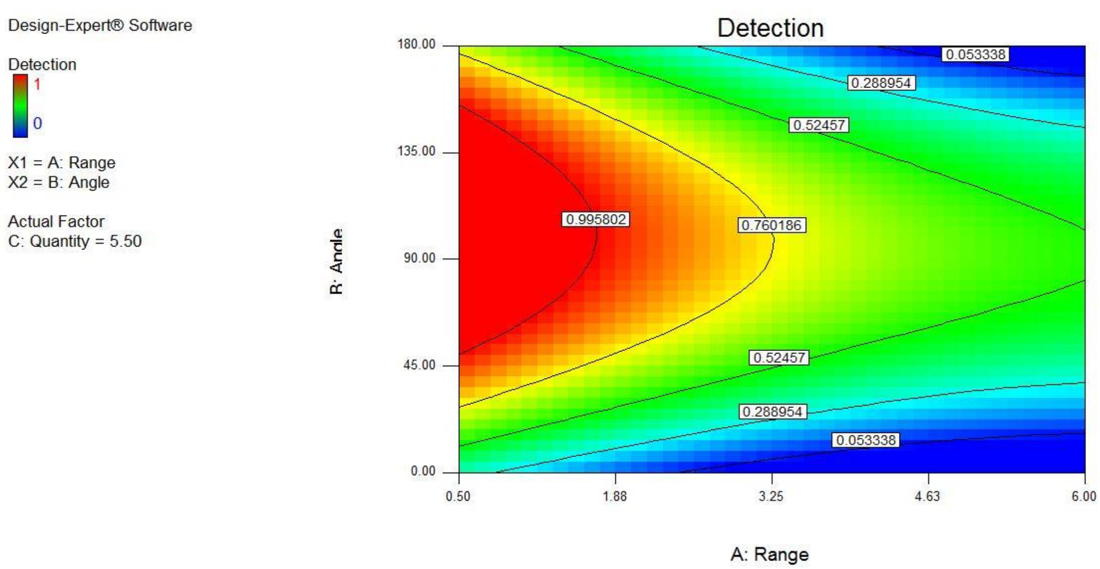
The importance of angle-dependent RFID tag detection cannot be overstated. In practical scenarios, such as inventory management, asset tracking, and access control, the ability to precisely determine the angle at which a tag is detected, in conjunction with the distance from the reader, can significantly impact system performance. This understanding is especially crucial in applications where specific tag orientation is essential for successful identification and tracking. The research, which was carried out in a highly controlled laboratory setting, focuses on the complicated relationship between angle and distance in the context of UHF RFID tag recognition. This study tries to identify UHF RFID devices and provide helpful information about their angle-dependent detection distances. It also aims to discover any limits and optimization opportunities within this dynamic interplay. Table 3.4 show the result for angle detection distance. From here the maximum distance can be detected by RFID reader is 100 degrees within in 5.5meter. The lower detection distance is 0 degree and 180 degrees within 0.5 meter and 1 meter. Figure 3.1(a) show the 3D graph for angle detection based on range and angle detection. The higher signal detection is shown on Figure 3.1(b).

Table 3.4: Result of Angle detection Distance

Angle Detection Distance										
Distance (meter)	**Angle(°)**									
	0	20	40	60	80	100	120	140	160	180
0.5	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1
1.5	0	1	1	1	1	1	1	1	1	0
2	0	0	1	1	1	1	1	1	0	0
2.5	0	0	1	1	1	1	1	1	0	0
3	0	0	0	1	1	1	1	0	0	0
3.5	0	0	0	1	1	1	1	0	0	0
4	0	0	0	1	1	1	1	0	0	0
4.5	0	0	0	0	1	1	0	0	0	0
5	0	0	0	0	1	1	0	0	0	0
5.5	0	0	0	0	1	1	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0



(a)



(b)

Figure 3.1: (a)3D plot effect of result of Angle Detection Distance and (b)3D plot effect of result of Angle Detection Distance

Based on Figure 3.1, the results are briefly summarized below:

- **0 Degree:** At a 0-degree angle, the UHF RFID system consistently detected tags within a distance range from 0.5 meters to 1 meter. However, beyond 1 meter, the system could no longer detect tags effectively.
- **20 Degrees:** For an angle of 20 degrees, the RFID system extended its detection range from 0.5 meters to 1.5 meters. Yet, similar to the 0-degree scenario, the system's detection capability ceased beyond 1.5 meters.
- **40 Degrees:** At a 40-degree angle, the system exhibited an extended detection range from 0.5 meters to 2.5 meters. Beyond 2.5 meters, detection ceased.

- **60 Degrees:** The RFID system's performance at a 60-degree angle allowed for detection distances ranging from 0.5 meters to an impressive 4 meters. However, beyond this distance, the system's detection capability diminished.
- **80 Degrees and Beyond:** As the angle increased to 80 degrees and beyond, the detection range gradually extended. For instance, at an 80-degree angle, the system reliably detected tags within a distance range from 0.5 meters to 5.5 meters, but beyond 5.5 meters, detection ceased. A similar pattern persisted for angles up to 180 degrees.

4.0 CONCLUSIONS

Design of Adaptive RFID on IoT Platform with Passive Tag Based on Laboratory Management System is proposed to effectively monitor the in-out equipment from the laboratory. Via this system, every activity involving laboratory equipment can be monitored and updated through the Thinger.IO IoT Platform environment. For security purposes, only authorized personnel have the permit to monitor the transaction activities of laboratory equipment in real-time. The efficiency of this system is very high until 100% when the angle of detection is 90 degree and distance detection is less than 1 meter. The adaptation of RFID-based Equipment Monitoring System also would promote diversity on laboratory management which previously were handled manually.

Author Contribution

Umar Ismat: Conceptualization, methodology, investigation, visualisation, writing and editing. Kharudin Ali: investigation, supervision, writing, IoT and editing. Damhuji Rifai: Data analysis and optimization. Ahmed N. Abdalla : Proofread and AI. Mooner A. Faraj: Methodology, writing and editing.

Conflict of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

We would like to express our gratitude to UC TATI for the Short Term Grant (STG) 9001-2106 SP, facilities, and equipment provided for this research. The authors also hope that more collaborative research between UC TATI and the library can be carried out in the future to promote academic development while contributing to the development of technology in the country.

5.0 REFERENCES

1. Bukova B, Tengler J, Brumercikova E, Brumercik F, Kissova O. Environmental Burden Case Study of RFID Technology in Logistics Centre. Sensors. 2023;23(3).
2. Singh NK, Mahajan P. APPLICATION OF RFID TECHNOLOGY IN LIBRARIES International Journal of Library and Information Studies. Int J Libr Inf Stud [Internet]. 2014;4(2):1–9. Available from: http://www.ijlis.org/img/2014_Vol_4_Issue_2/1-9.pdf
3. Pandey P, Mahajan KD. Application of RFID Technology in Libraries and Role of Librarian. 12th MANLIBNET Conv 2010 [Internet]. 2010;(December):109–18. Available from: http://eprints.rclis.org/15253/3/RFID.pdf

4. Azimi FH, Yusof M, Hamdan MF, Aw SR. Design and Implementation of IoT Integrated Electrical Solar Fence for Crop and Farm Protection Using Blynk Application. 2023;4(1):90–101.
5. Koppikar U, Hiremath S, Shiralkar A, Rajoor A, Baligar VP. IoT based Smart Attendance Monitoring System using RFID. 1st IEEE Int Conf Adv Inf Technol ICAIT 2019 - Proc. 2019;10(4):193–7.
6. Vidyamandira RM, Math B, Bengal W. RFID and Library Services : Use & Concern. 2017. 8 p.
7. Radhakrishna K, Rani KNA, Wahab AA, Rosli SJ, Rahim HA, Seng LY, et al. Design of A 20-Bit Chipless RFID Tag Utilizing Multiple Resonators in UWB Frequency Range. J Adv Res Appl Sci Eng Technol. 2023;29(2):25–37.
8. Yusof MK, Saman MY. The adoption and implementation of RFID: A literature survey. Libres. 2016;26(1):31–52.
9. Chhetri M, Thakur RS. Implementation of RFID technology in libraries: A case study in UPES library. Libr Philos Pract. 2019;2019(May).
10. Zhang X, Tentzeris M. Applications of fast-moving RFID tags in high-speed railway systems. Int J Eng Bus Manag. 2011;3(1):27–31.
11. Study C, Library TC. Implementation of RFID, Case Study : Turku City Library. 2011;
12. Abcouwer K, van Loon E. Library inventory using a RFID wand: contribution of tag and book specific factors on the read rate. Libr Hi Tech. 2020;39(2):368–79.
13. Casella G, Bigliardi B, Bottani E. The evolution of RFID technology in the logistics field: A review. Procedia Comput Sci [Internet]. 2022;200(2019):1582–92. Available from: https://doi.org/10.1016/j.procs.2022.01.359
14. Suhaimi MF, Huda N, Tahir M, Mohamad SN, Ridzuan S, Aquarium A. IoT Based Automatic Aquarium Monitoring System for Freshwater. Int J Synerg Eng Technol Vol. 2021;2(1):125–33.
15. Suda K, Rani N. Radio Frequency Identification for Efficient Library Management. IjbssnetCom [Internet]. 2013;4(15):125–31. Available from: http://ijbssnet.com/journals/Vol_4_No_15_Special_Issue_November_2013/18.pdf