Linen Monitoring using RFID for UTAR Hospital

By

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ABSTRACT

This project explores the application of Radio Frequency Identification (RFID) technology to enhance linen management in a hospital. It introduces a semi-automated system to enhance the efficiency and accuracy of linen handling and tracking. The system integrates RFID readers and a backend server to track and identify linen items in real time. It has a simple interface that makes the linen handling process easy to use, even for users with different educational levels.

Throughout the development process, the project progressed from literature review and research to prototype implementation and testing. Despite the difficulties in the form of hardware limitations and the limited resources available, an RFID-based linen monitoring fully functional prototype was established. The system is able to read RFID tag data, process it through the server, and depict key information to enable improved monitoring and decision-making.

Testing confirmed that the system accurately detects, tracks, and manages linen items in a controlled environment, thereby confirming its feasibility for real-world deployment. This achievement demonstrates a practical and scalable solution for improving hospital linen operations. The project is expected to be completed within eight months to support timely deployment in a healthcare setting.

Area of Study: Internet of Things, Python-based application development

Keywords: UTAR Hospital, RFID, Application, QR codes, Python, linen monitoring, Frappe

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LIST OF ABBREVIATIONS

UTAR	University Tunku Abdul Rahman
RFID	Radio-frequency Identification
MBBS	Bachelor of Medicine and Bachelor of Surgery
TCM	Traditional Chinese Medicine
MDTi	MDT Innovations
IoT	Internet of Things
UHF	Ultra high frequency
CCD	Charge Coupled Device
IDE	Integrated Development Environment
EPC	Electronic Product Code

CHAPTER 1

Introduction

The introduction, research Objectives, project Scope and direction, contributions, and report organization of this project will be presented in this chapter.

UTAR Hospital as a not-for-profit and self-sustaining hospital provides advanced sub-specialised services and secondary and tertiary referral services including TCM services [1]. For example, key-hole and robotic surgeries, radiotherapy services for cancers and others. The proposed setting up of UTAR hospital will not provide affordable and high-quality basic and specialist medical services. Besides that, UTAR Hospital also provides clinical training and internships for MBBS, TCM and Health Science students. The development of the UTAR hospital project includes an initial phase featuring a hospital complex comprising 250 beds for Western Medicine and 100 beds for TCM. Additionally, there are plans for an additional 250 beds for a future phase.

Figure 1.1.1 The exterior view of UTAR Hospital

The expansion of beds at the UTAR hospital implies a significant surge in the demand for linen within the facility. Linen as a fundamental component of the hospital plays a crucial role in maintaining hygiene, comfort and sanitation standards such as bed sheets, pillowcases, surgical gowns, towels and others. Moreover, the cleaning of linen is crucial to enhance hospital quality care and hygiene in hospital, thereby preventing inflection and ensuring the safety of users. For instance, clean bed linen provides patients with a clean and comfortable patient room. Surgical drapes and gowns safeguard against inflection and maintain aseptic conditions during procedures of surgery in surgical suites. Therefore, effective linen management is an essential cornerstone of a well-functioning hospital.

Figure 1.1.2: Example of linen in a hospital

Linen management includes acquiring new linens to fill inventory, tracking their quantity and location within the hospital, ensuring a sufficient stock of clean linens readily available for patient use, collecting dirty linens for laundering to maintain hygiene standards and replacing old linens to maintain quality and comfort for patients and staffs. Manual linen management requires significant human resources and time. Currently, UTAR Hospital uses a manual system to track their linen throughout the hospital. Therefore, the burden of linen management will increase as UTAR Hospital expands its capacity to accommodate more patients.

In the last few years, RFID (Radio Frequency Identification) become the mainstream application and widely implemented in various industries to enhance efficiency. RFID enables the automation of identity objects by using radio waves. In the research [2], RFID will offer numerous benefits such as reduced human intervention, fewer constraints on use, longer read range, read/write memory capability, reading simultaneously and high tolerance to undesirable situations. The two basic components of RFID are an RFID reader and an RFID tag. Additionally, there are two types of RFID tags including active RFID tags and passive RFID tags. Active RFID tags have an internal power source to generate the signal while passive RFID tags rely on the power source given by the reader to generate the signal.

The workflow of RFID is worked together by the antenna, reader and RFID tags. First, a passive RFID tag will activate when passing through the electromagnetic area. The activated tags will release radio waves and be detected by the reader. Therefore, the reader can read the data stored in tags and transmit the data collected to the host computer. Figure 1.1.3 below indicates the workflow of RFID.

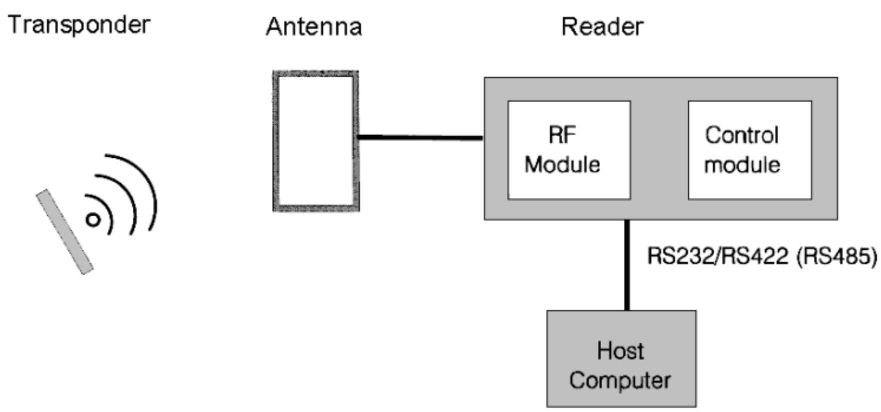


Figure 1.1.3: Workflow of RFID

1.1 Motivation and Problem Statement

UTAR hospital has been faced with several challenges to current linen tracking systems. The current linen tracking system used by UTAR Hospital heavily relies on manually tracking and inputting the data into the system. The current system for linen tracking relies on staff manual counting the linens that are used, returned and stored. This process is not only tedious and time-consuming but it also introduces the possibility of human error during data entry. This reliance on the manual method creates significant drawbacks. It consumes valuable time and human resources due to repetitive counting tasks.

Furthermore, the inaccuracy in the manual count often necessitates recounts. These inaccuracies can have significant consequences such as potentially resulting in lost linens and shortage of stock issues where the hospital may waste resources by keeping unnecessary extras. Linen loss is a significant widespread and costly problem issue for healthcare linen management [3].

Additionally, training staff on the complicated manual system can be time-consuming and repetitive. A staff with a thorough understanding of the linen tracking system's workflow is important to minimize the loss of linen and reduce the risk of error data input. Apart from that, manual linen tracking poses a potential health hazard to staff. According to [4], improving infrastructure and ensuring the availability of linen along with providing training for those directly involved in handling these linens is crucial to guarantee a safe healthcare environment. The process necessitates physically handling used linens, which raises the risk of infection if contaminated items are present.

This research project is motivated by an urgent need to improve the linen management of UTAR Hospital. UTAR Hospital is planning to make some changes to the current linen management system. A new project is purpose launched to implement an advanced automated linen management system by using the technology of RFID within UTAR Hospital. RFID tagging and tracking can streamline the data input process. RFID systems also can minimize the risk of human error. This will lead more accurate inventory of linens and reduce linen loss. Besides that, RFID systems can significantly mitigate the risk of staff infection by eliminating the need for manual handling of potentially contaminated linens. Therefore, the implementation of RFID systems will reduce linen loss and improve linen management. UTAR Hospital will reduce costs in linen replacement and use the cost savings to improve other crucial areas within the hospital such as upgrading equipment or enhancing patient services.

This forward-thinking approach aims to address the challenges with manual linen management system track such as human resource consumption and time-consuming. Apart from that, UTAR Hospital also can streamline linen tracking operations, optimize resource allocation and increase the efficiency and effectiveness of providing healthcare services to the public through the automation system implemented

1.2 Project Objectives

This project aims to enhance the linen management system at UTAR Hospital by addressing several key areas. The primary focus is on improving the accuracy and efficiency of linen tracking. To achieve this, the project proposes implementing an automated system utilizing RFID technology which will significantly reduce human error and eliminate delays commonly associated with manual tracking methods. RFID tags will be attached to each linen item and the system will automatically count the tagged linens to ensure accurate inventory and reduce discrepancies. This automated process will ensure that linen counts remain precise, leading to improved management and accountability within the hospital's linen handling procedures.

Additionally, the project aims to enhance trackability by implementing an RFID-based linen monitoring system. By leveraging RFID technology, the system will provide better control over linen management, enabling quick identification of linen conditions by tracking their movements throughout the hospital. Moreover, the system will offer detailed insights into linen processing including location data, the identity of the last person who handled the linen and other pertinent information. This improved trackability will allow for more effective oversight ensuring that linens are properly monitored and accounted for at every stage of the process.

Furthermore, one of the key objectives of the project is to provide comprehensive information about each linen item including category, status, location, and other relevant details. These insights will facilitate more effective linen management by enabling hospital staff to easily track and monitor the condition and movement of linens. This level of detail will help streamline operations that improve inventory control and ensure that linens are managed efficiently across various stages of use.

Given that the system will be used by a diverse range of users, it will be designed to provide a simple and intuitive experience. The user interface and functionality will be streamlined to ensure that individuals regardless of their technical expertise. Therefore, they can easily navigate and operate the system. The clear instructions and straightforward buttons will guide users in performing tasks such as scanning RFID tags and updating information. By prioritizing user-friendly design, the system ensures accessibility and ease of use for all users.

This project is planned to be completed within 8 months. The system development should be finalized within the first 7 months followed by a dedicated period for system testing to ensure functionality and reliability before full deployment.

1.3 Project Scope and Direction

The project scope includes the implementation of connection between each device, software development, implementation of authentication modules, data processing and storage and system testing.

1. Establish Connection

The integration system will establish connections between the RFID reader and the device using the REST API mechanism as well as between the device and the server. The unprocessed data will be transmitted from the reader to the device. After undergoing the filtering process, the processed data will be sent to the server through the REST API provided by the ERPNext system.

2. Software Development

The system architecture includes an RFID reader for capturing linen identities, a device running software to manage and process RFID data, and a server to store linen information for future retrieval and analysis. Given the need for different devices in the system, it is essential to ensure seamless control and coordination of these devices through an integrated software solution.

An integrated application will be developed to centralize control over these devices since this project involves multiple devices for tracking linens. The application will streamline the process to ensure the system remains user-friendly and efficient. The application will offer a user-friendly interface to make it accessible to users of all educational backgrounds including providing a clear table that shows the information of linen and the function buttons that are straightforward show function.

3. Implementation of functional module

Developing an authentication module is crucial to ensuring the security and traceability of the system. The authentication module should be capable of verifying users by accessing their credentials stored in the ERPNext system on the server. This module links authenticated individuals to specific actions to ensure that every action performed within the system is tracked and recorded for accountability and tracking.

In addition, the filtering module also is a crucial component of the system that is responsible for filtering the data stream transmitted from the reader. The identities of RFID tags detected will be sent from the reader to the device and the filtering process will be applied as the diverse data streams arrive to ensure unique data is processed.

4. Data processing and storage

Besides that, the ERPNext system is designed to store the information of linen such as status, latest checking time, location, categories and other relevant information. The information stored in the ERPNext system will be utilized to build a dashboard that displays linen statistics, enabling the generation of monthly or weekly reports.

5. System testing

Once the functionality and user interface are finalized, system testing will be conducted to verify the system's performance and functionality. Additionally, a soft launch will be carried out before formal deployment to gather user feedback. Based on this feedback, the system will be refined and adjusted to better meet user requirements and ensure a more user-friendly and intuitive application.

1.4 Contributions

Implementing automated linen tracking using RFID at UTAR Hospital will bring numerous of contributions to its operations. RFID tags can be attached to linens to provide unique identification for each linen. UTAR Hospital can accurately track the movement and status of each linen. This level of visibility enables real-time monitoring of linen movement and increases efficient inventory management. This approach will enhance the efficiency of linen management by allowing real-time linen tracking to detect the RFID tags on the linen. UTAR Hospital can promptly detect the presence of linens with RFID-enabled tracking to check for loss or theft. This not only saves costs associated with replacing lost items but also ensures that essential linens are always available when needed. It will contribute to patient comfort and safety.

Apart from that, the linen monitoring system also can reduce labour costs by implementing the RFID linen monitoring system to replace manual tasks such as counting, sorting and tracking linen inventory. Instead of dedicating staff time to counting, sorting, and tracking linen inventory, the RFID system automates these processes to free up staff to focus on more critical patient care duties. Besides that, this linen monitoring system can ensure that clean linens are readily available when needed. It can enhance staff productivity and morale.

Furthermore, the implementation of RFID-enabled linen monitoring streamlines hospital workflows, reducing the burden of linen management. The RFID linen monitoring system improves overall operational efficiency and ensures a seamless linen supply chain by automating tedious administrative tasks such as inventory tracking and restocking. This streamlined approach enhances the hospital's ability to meet patient needs promptly while minimizing disruptions to daily operations.

The deliverables of this project include a functional, user-friendly, and easy-to-use integrated application. Additionally, a server capable of performing storage and data analysis is also a key deliverable. These components together ensure seamless operation, data management, and analysis for the linen tracking system.

1.5 Report Organization

This report has been organized into several chapters, wherein each addresses a specific aspect of the project in a logical order.

Chapter 1 sets the stage for the project with background, motivation, objectives, scope, contribution and an overview of the report structure. Chapter 2 provides an extended literature review for associated research work and current technologies such as RFID and barcode systems and their application and limitations, particularly in healthcare. Chapter 3 presents the system methodology utilized in system development, including the development model that has been chosen, hardware and software requirements, functional specifications, project milestones, and cost estimates.

Chapter 4 focuses on system design. It describes the overall system architecture of the intended solution, design of principal functional modules, workflows of the system, and graphical user interfaces. Chapter 5 introduces the general system implementation and testing process. It includes hardware and software components integration, user interface installation, and evaluation of results from testing. Chapter 6 offers a discussion on the performance of the system, whether project objectives were achieved and system challenge encountered by the project.

Chapter 7 provides an overview of the key findings and project contributions and concludes the report by offering suggestions for future improvement.

CHAPTER 2

Literature Review

2.1 Previous work using RFID

RFID has been moved into mainstream applications and is widely used in various range of industries. Numerous previous works have used RFID technology. Linen monitoring was applied with the RFID technology to enhance efficiency and reduce linen loss. Linen monitoring has complicated processes that include collecting, sorting and tracking linen status and location. There are numerous challenges will be faced when linen monitoring is done by the staff of hospitals such as contact with contaminated lines will increase the risk of infection, inaccuracy of information of linens and time-consuming linen monitoring increases as the linen increases.

There is an example of using a UHF-RFID system to implement linen monitoring for the Somdech Phra Debaratana Building, Ramathibodi Hospital[5]. The main components of the UHF-RFID system include UHF-RFID tags, RFID gate with antennas, LAN network, a software system and database.

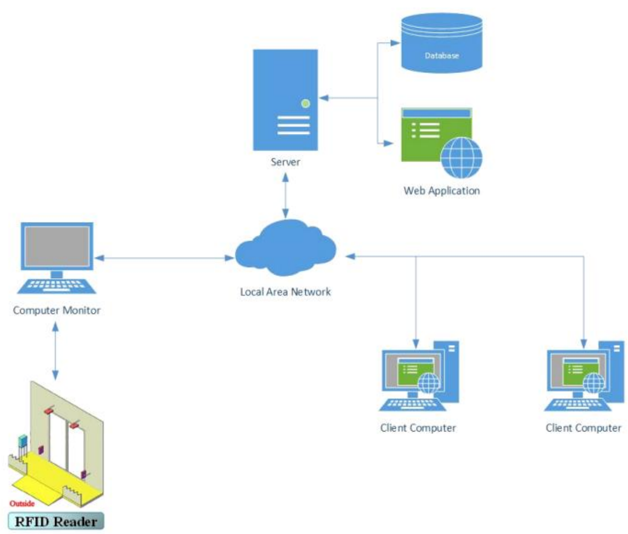


Figure 2.1.1: Diagram of UHF-RFID system

The RFID gate with four reader antennas was implemented to detect RFID tags on linens. The RFID tags will store detailed information such as unique identification, status and location. Besides that, the database was designed to store information on linens in the hospitals and easily accessed through a website application to display information about linens. The workflow of the system can be summarized as the data inside RFID tags will be read and collected by the antennas. Therefore, the data collected will be uploaded to the database designed through the LAN network for further processes.

Apart from that, RFID technology also can be applied in other fields such as laundry vendors. Not every customer of the laundry vendors needs to handle large volumes of garments. However, laundry vendors are essential to process a significant number of garments daily from various businesses to earn a profit. Applied RFID technology to automate various steps in the process can enhance efficiencies and customer convenience[6]. This project uses RFID-enable-based ATM-style interaction for drop-and-pick laundry. The overall process diagram is shown in Figure 2.1.2.

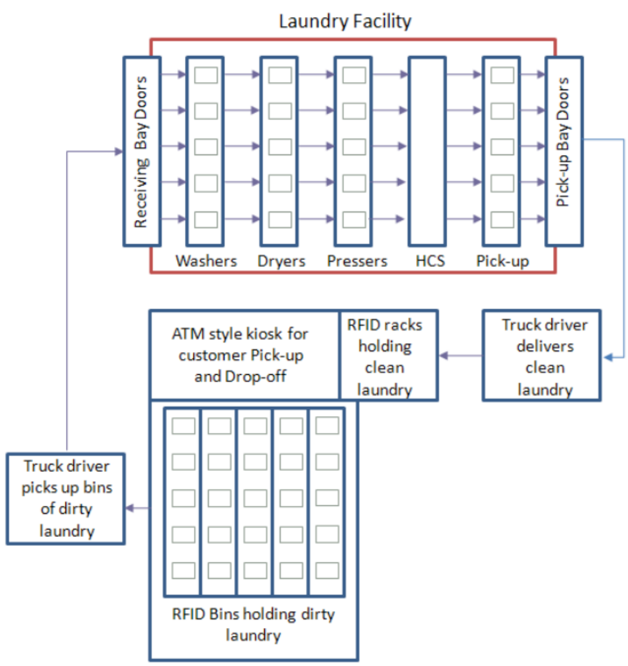


Figure 2.1.2: Overall process diagram in laundry

The application of RFID enables real-time tracking of the movement of the garments through the laundry loop[6]. RFID technology was implemented in this project for the garments, trucks, bins, kiosks, bay areas and key locations within each laundry facility. This ensures visibility in the process to allow customers to track the location and status of laundry. Additionally, customers also will receive an email to mention that the laundry is available at the location of the kiosk selected for pick-up.

2.2 Limitation of RFID

RFID become the mainstream application nowadays but there are still have numerous limitations on RFID that need to be addressed. The main limitations of RFID include economic and technological concerns such as environmental factors, signal collisions, durability of RFID tags and cost constraints.

The research [2] shows a limitation of RFID is the environmental factors. The properties of certain materials can pose a challenge to RFID applications at specific frequencies to corrupt the data transmission. This is because RFID uses radio frequency to transmit the data and the signal may be interfered with by the conductive material such as water or metal surface. The research [7] included measurement and simulation results demonstrating the impact of nearby metal and water on the impedance, read range, and power transfer of commercially-available UHF technology. Additionally, external signal sources such as cordless phones may lead to the problem of signal interference.

Apart from that, the signal collisions also is a limitation to the RFID system. The signal collisions will occur when several tags need to be read simultaneously. The result of signal collisions will cause the problem of data loss and inaccuracies in data stored in the system. This problem can be addressed by adding more antennas or presenting an anti-collision algorithm but it will lead to economic concerns.

The durability of RFID tags also is a limitation of RFID. The RFID may get damaged during use. The reasons for RFID damage can vary depending on the method used such as artificial damage and improper handling. This can result in antenna read failures or difficulty in reading the tags. Hence, there are economic concerns regarding the replacement of damaged tags.

Besides that, the authors of [2] indicate that a full set of RFID systems includes RFID tags(transponder) with a unique identification that can store information, a transceiver with a decoder that is used to collect information from the RFID tags and an antenna or coil. Besides that, the cost of active or semi-passive tags poses an obstacle to the cost. Therefore, cost constraints limit the feasibility of implementing RFID systems for linen monitoring in hospitals.

2.3 Barcode

Apart from RFID, the barcode also is a similar technology applied to inventory management. It also will enhance efficiency and better performance in inventory management compared to manual management in inventory management. The barcode system can help reduce human error in inventory management to reduce loss of inventory.

According to [8], a barcode, composed of bars and spaces, is a machine-readable representation of numbers and characters. The components of a barcode include a start character and a stop character representing the start and the stop of the barcode, data that consists of the message of this barcode and a check digit to ensure the correctness of encoded barcode data. Figure 2.3.1 shows the components and sequence of the barcode.

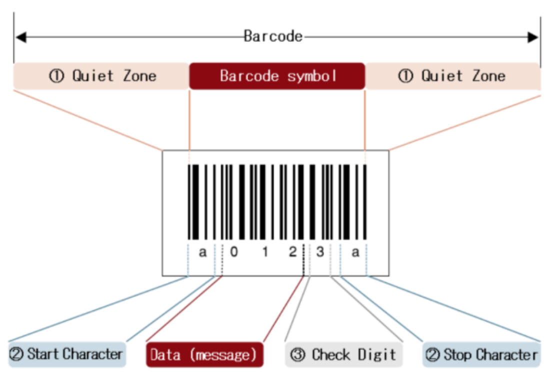


Figure 2.3 Components of barcode

The black and white bar will convert to binary digital signals to retrieve the data on the barcode[9]. There are three methods used by barcode scanners include CCD method, laser method and pen method. Table 2.3 shows the difference between those three methods of barcode scanners.

	CCD method	Laser method	Pen method
Structure	CCD and built-in light	laser light and laser photo detector	led light source
Advantage	fast reading, no movable parts and excellent impact resistance	allows reading of distant and wide barcode labels	simple and cheap

Table 2.3 Difference of three methods applied in barcode scanners

2.4 Comparison between RFID and Barcode

RFID and Barcode are two different technologies but they offer similar advantages such as increased efficiency and reduced inaccuracies in information. Additionally, both technologies are widely applied in many fields such as warehouses, laundry and other businesses that consist of various information that need to be tracked.

Due to economic concerns, the barcode will be the first choice for implementing the automation inventory management. Based on [10], an RFID tag can cost from one dollar to over 30 dollars depending on the type of RFID but the barcode costs a few cents for each. Table 2.4 directly indicates the comparison between RFID and barcode.

	RFID	Barcode
Read rate	High, multiple tags can be read simultaneously	Low, tag can read once at a time
Line of sight	No required	Required
Human resource	None	Large requirement because the barcode required scan manually
Capability	Able to read, write, modify and update	Read-only

Durability	High. Better protected and can read in difficult environments	Low. Easily damaged or removed. Cannot be read if dirty.
Cost	High	Low
Modifiable	Yes	No
Range	Within receiving range of the antenna	Must be close to the barcode scanner

Table 2.4 Comparison between RFID and Barcode

Although RFID offers numerous advantages over barcodes, barcodes remain the better choice for certain circumstances due to economic concerns. The authors of [3] indicate that the technology will be implemented in the inventory system based on three factors which are the nature of the business, ease of use of the system and budget. Therefore, it's necessary to develop a detailed plan based on key factors before implementing the system with the required technologies.

2.5 Development of RFID in Healthcare

In the research [11], an RFID-based solution is being presented to suggest using RFID technology to identify patients and make sure that medical data that is kept in different medical information systems is gathered. The solution may improve the safety of patients, reduce medical errors and reduce paperwork on the patient record based on the efficiency of managing medical information.

Based on the advantages offered by RFID, RFID technology not only can be applied in linen monitoring but also in various other healthcare applications such as electronic medical records, asset tracking, RFID sensor healthcare applications and others.

Electronic medical records can store detailed information regarding the health state of patients. This is a crucial improvement in healthcare that quick access to the information of the patient even though the patient is unable to talk or unconscious. The medical staff can quickly gather essential details such as blood type, current treatments, medical history, and allergy history to gain valuable time for making decisions possible in an emergency instead of manually searching for the patient's record.

Apart from that, RFID-based asset tracking within a hospital is similar to RFID-based linen monitoring. RFID-based asset tracking may enhance asset trackability by enabling permanent localization of a mobile asset to lower leasing costs and the amount of time medical staff must spend looking for equipment. This approach can ensure that the treatment process runs smoothly and reduces the issue of inadequate medical equipment during treatment.

Additionally, RFID also can apply in medical measuring devices such as blood glucose meters, blood pressure monitors, pulse oximeters and others. Those medical measuring devices equipped with RFID technology can provide the capability to modify the information of the patients to minimize the likelihood of human error in incorrect data entry.

2.6 Concluding Remark

Based on the review of other previous work, a solution that RFID-based linen monitoring for UTAR Hospital will be proposed in this project. The RFID-based linen monitoring will offer visibility of the process of linen monitoring within UTAR hospital and accurate real-time information on the linen inventory. Additionally, this system also will provide a user-friendly interface to show the data retrieval from the designed database such as location, status and stock of available linen in real-time to ensure easily read by the administration. The system also will provide various analyses of the data collected such as the usage of linen to enable the linen in sufficient stock.

Apart from that, there are numerous limitations stated in the previous that should be addressed. First, an RFID-based gantry with four antennas in different directions will be implemented to address the limitation of signal collisions. The four antennas in different directions may ensure all RFID tags of the linen will be read properly.

Besides that, passive RFID tags should be attached to all of the linens within the hospital to reduce the cost of the RFID tags. This is because passive RFID tags are cheaper than active RFID tags. The substitution of the active RFID will help to reduce the burden of the cost in operation. The active RFID will be replaced a few years ago as the lifespan of active RFID tags is shorter. Hence, this project will use passive RFID tag instead of active RFID tag due to the economic concern.

CHAPTER 3

System Methodology

This chapter discusses the methodological decisions for the system and the model selected for this project. It also covers system requirements including software, hardware and other aspects related to the project. Additionally, the project milestones completed and estimated costs also will be discussed in this chapter.

The system methodology defines the approach and strategy for designing and modeling strategy a project. It serves as a blueprint for the development and management of the system throughout its lifecycle. There are many different approaches available based on varying requirements. For example, the Process-Oriented Approach (POA) emphasizes execution tasks and operational steps. This approach focuses on optimizing the workflow and ensuring that all processes are efficiently executed. Additionally, Behavior-Driven Development (BDD) prioritizes understanding and addressing the needs and experiences of the end-users. It emphasizes designing features based on user interactions and behavior to ensure the system meets the needs and expectations of its users. Each methodology offers a unique perspective and set of practices for addressing the complexities of system design and development.

3.1 System Development Models

System development models are crucial tools for systematically organizing and selecting the most effective system development approach. These models offer structured frameworks and methodologies that guide the development process, address challenges, and streamline workflows. A software project may involve multiple systems or development methods depending on the project's nature or scale [12]. Selecting the appropriate system development model not only ensures effective project execution but also helps achieve the project's objectives and deliver a successful outcome.

3.1.1 System Development Model 1: Waterfall Model

The first process model introduced is the Waterfall Model, also known as a linear sequential life cycle model. It is straightforward to understand and easy to use. [12]. his model divides the software development process into a series of linear, sequential stages which the next phase will begin only after the current phase is ensured to be complete. Each phase must be finished before moving on with no overlap or possibility of returning to previous phases—hence the name "waterfall," as the process flows downward without reversing. The output of each stage serves as the input for the next.

Refer to Figure 3.1.1, the phase of the waterfall model was divided into requirements, design, implementation, testing, deployment and maintenance. The advantages of the waterfall model include simplicity, ease of control and clearly defined deliverables for each stage. However, its disadvantages include the unsuitability for complex projects and the inability to make changes to previous phases once the previous phases are completed. For example, the design phase can only begin after all requirements have been finalized in the requirements phase.

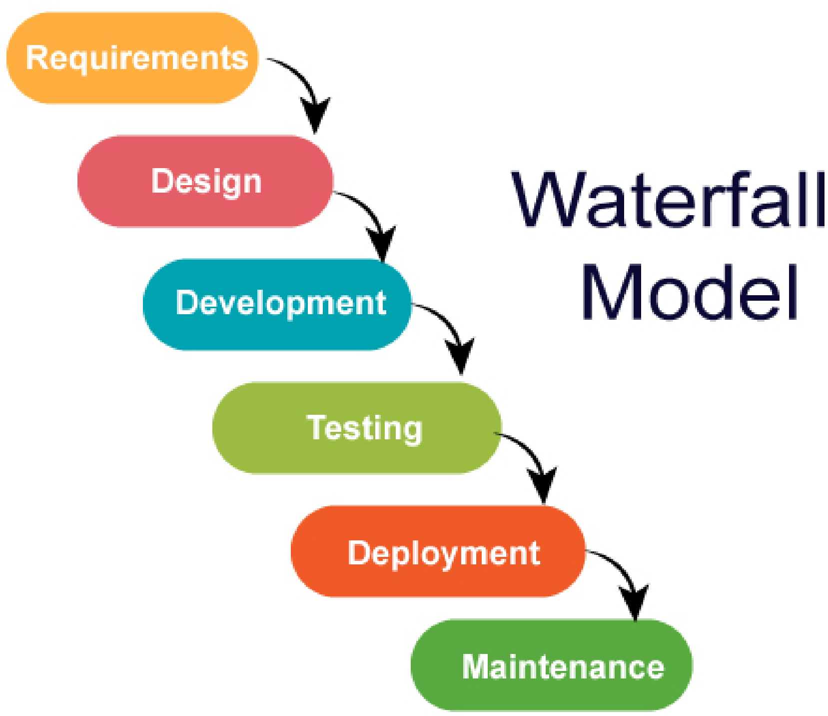


Figure 3.1.1 Phase of Waterfall Model

3.1.2 System Development Model 2: Agile Model

The Agile model organizes projects into dynamic phases and employs iterative and incremental cycles. The stages of the Agile model include planning, requirements analysis, design, implementation, testing and deployment (refer to Figure 3.1.2). Each stage operates concurrently to complete a development cycle while each cycle represents an iteration. The model is distinguished by its high degree of flexibility which allows for continuous adjustments between phases depending on customer feedback received after each iteration. The Agile model emphasizes product quality and usability to ensure that the product can evolve in response to feedback and adapt to changing requirements.

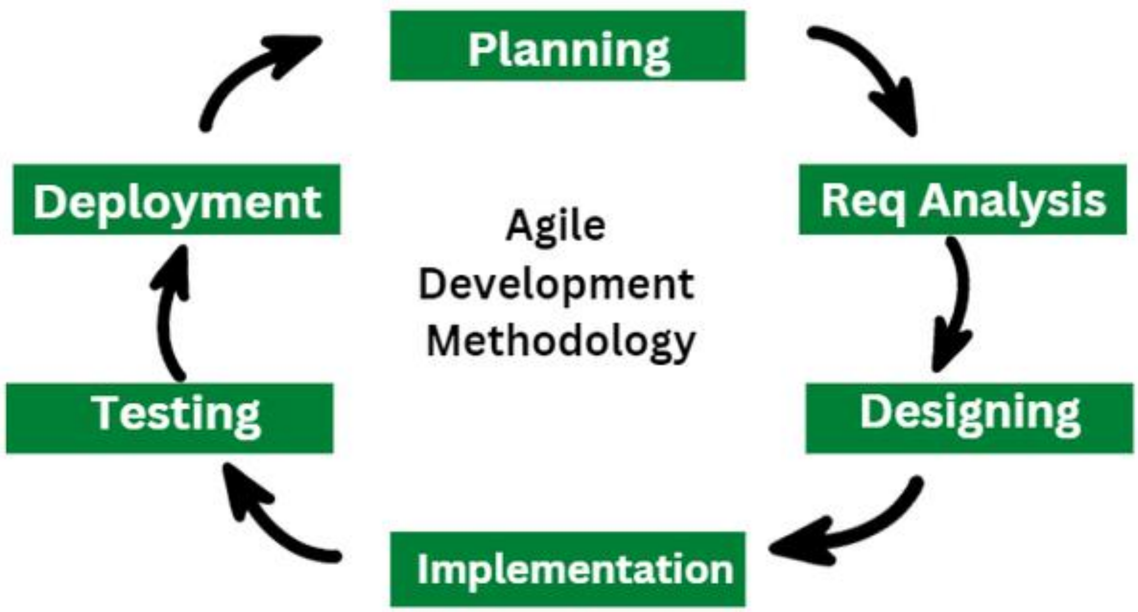


Figure 3.1.2 Phase of Agile Model

3.1.3 System Development Model 3: Rapid Application Development (RAD)

Rapid Application Development (RAD) is similar to the Agile model but differs in its emphasis on quickly delivering prototypes to gather customer feedback within a short timeframe. RAD showcases the system's basic functionality through prototypes to enable users to provide direct feedback. The RAD process consists of analysis, a prototyping cycle, testing, and deployment(refer to Figure 3.1.3). The uniqueness of RAD is the prototyping cycle which iterates through refinement, development, and demonstration phases. During this cycle, continuous adjustments are made to the project based on customer feedback until satisfaction is achieved. Once this is accomplished, the process moves into the testing and deployment phases to finalize the project.

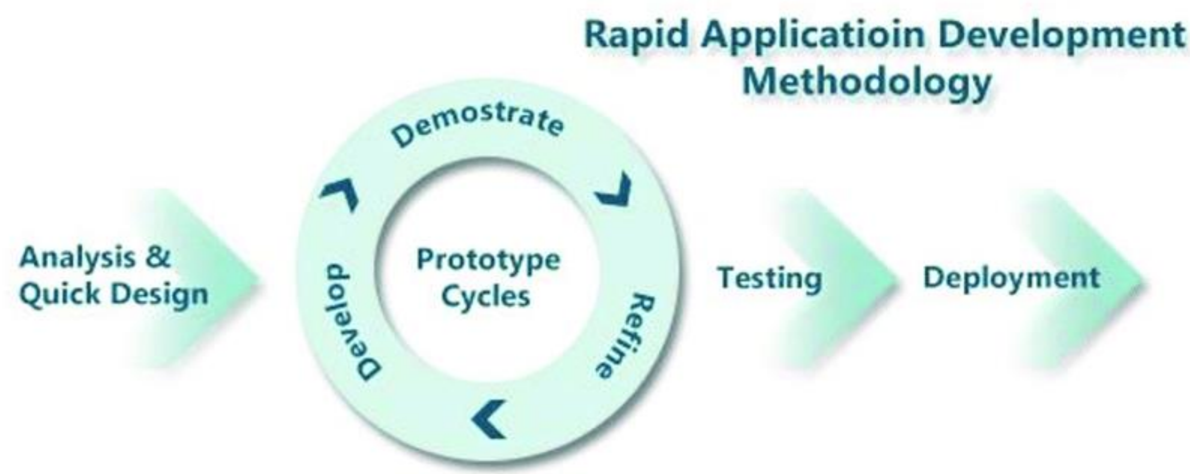


Figure 3.1.3 Phase of Rapid Application Development Model

3.1.4 System Development Model 4: DevOps Model

DevOps model is a software approach that unites the domains of operations and development with automated development, deployment and infrastructure monitoring. It integrates the development, production, and operation of business processes with appropriate technology that ensures continuous delivery through incremental upgrades rather than adhering to rigid, artificial process concepts [13].

DevOps model distinguishes itself from other models by enabling operations and development to proceed concurrently but it requires consideration of both the environment and product architecture. For example, upgrades can be planned and delivered on short notice. Additionally, the DevOps model also leverages legacy code and architecture and integrates them into the continuous delivery process. By emphasizing automation, continuous feedback, and close collaboration between development and operations, the DevOps model is well-suited for high-frequency releases and projects requiring stability.

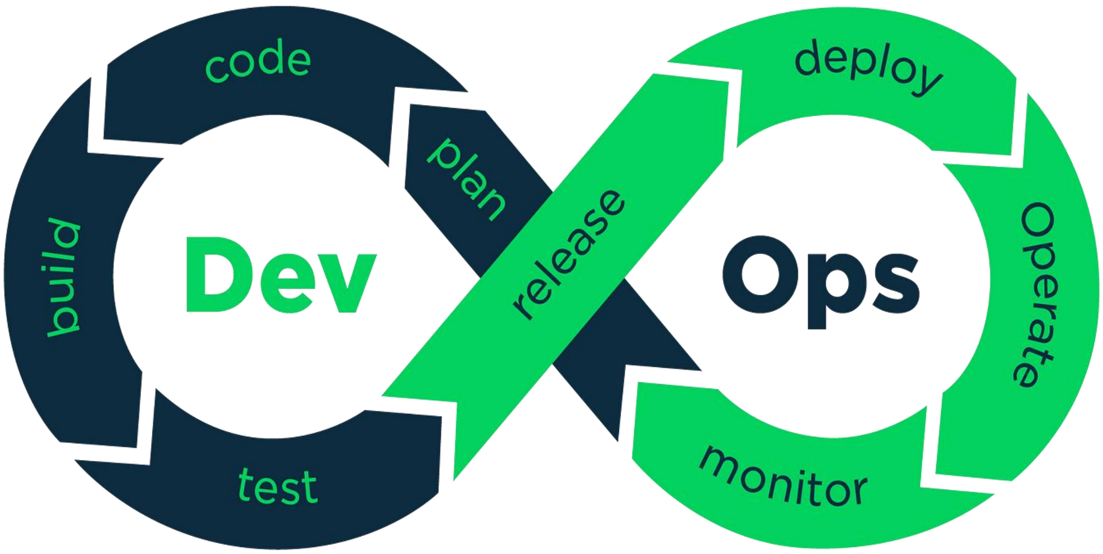


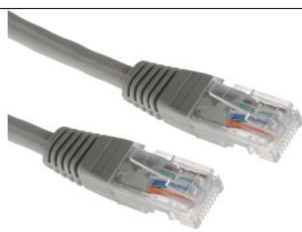
Figure 3.1.4 Phase of DevOps Model

3.1.5 Selected Model

The selected model for this project is the Rapid Application Development (RAD) model. The decision to choose RAD as the system development methodology is based on its advantages in prototyping, user feedback integration, and risk reduction. RAD facilitates the rapid creation of prototypes for testing and modification which is essential for demonstrating the system's capabilities and making adjustments based on real use cases. Additionally, RAD emphasizes iterative development driven by user feedback that ensures the system meets specific requirements and integrates seamlessly into the hospital workflow. This approach also enables the early identification of potential issues during the iterative development process. Therefore, the risk of system failure will be reduced significantly.

3.2 System Requirement

3.2.1 Hardware

Name	Picture	Description
Impinj R700 RAIN Reader		The RFID reader emit and receive the radio signals. The RFID reader also used to process the information
RFID Linen Tags		RFID tags store unique identifiers and must be activated when they receive RFID signals from an antenna.
SensRF-101 RFID Antenna		The antenna transmits and receives RFID signals.
Ethernet Cable		Connect the reader to the laptop to transmit the data stream. Connect the reader to an AC adapter to provide Power over Ethernet (PoE)

PHIHONG Single Port PoE AC adapter		Convert alternating current (AC) to direct current (DC) to provide power to the reader
Laptop		The laptop with PyCharm installed is used to run the Python environment. Additionally, the laptop serves as the intermediary for processing data from the reader and updating it to the server.
Printer		Printer used for print out the QR code that generated.

Table 3.2.1 Hardware requirement of system

3.2.2 Software

Name	Picture	Description
Pycharm		PyCharm is an IDE for Python, offering robust features such as code analysis, a graphical debugger, and more. It is user-friendly and comes with a variety of plugins that enhance its functionality.
Python		The develop language for this project. Python is concise and easy to read, suitable for beginners, and supports rapid prototyping. In addition, it has an active community and rich resources, making it very suitable for learning and practicing various projects.
Frappe		Frappe is a full-stack web framework written in Python and JavaScript, with MariaDB as its database. It is the framework that powers ERPNext and is quite versatile, allowing for the development of database-driven applications.

Table 3.2.2 Software requirement of system

3.3 Functional Requirement

No	Function	Description
1	Login Feature	The application provides a login feature for users to authenticate their identity.
2	Data receive	The application can receive the data stream passed from the RFID reader.
3	Fetch Data	The application can fetch the necessary data from the server
4	User's preferences	The application can store users' preferences.
5	Update information	The application can pass accurate data to the server to update the information.
6	Trigger function	The application provides different buttons for different processes.
7	Error handling	The application can handle errors when users perform irregular operations.
8	QR generate	The application can generate a static QR code.
9	Save file	The application provides different file formats to save the file with the selected QR code.
10	Logout	The application provides a logout function to enable users to logout from the server.

Table 3.3 Description of Functional Requirements

3.4 Project Milestones

FYP 1													
Task Description	**Week**												
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
Define the objective and scope													
Survey on the previous work													
Create a prototype and system flow													
Determine the hardware and software that will be used													
Set up the connection between the reader and laptop													
Create a function that gets data from the reader													
Testing													
Build a simple UI													
Write report													
Presentation													

Table 3.6.1 Project Milestones of FYP 1

FYP 2													
Task Description	**Week**												
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
Review of previous work													
Complete the other function required													
Testing													
Improve the function and logic													
Code refactoring													
Testing and Finalize													
Complete report													
Presentation													

Table 3.6.2 Project Milestones of FYP 2

3.5 Estimated Costs

The estimated costs provided are used for information purposes only. These are based on current information and assumptions at the time of preparation. These estimates are subject to change and may not reflect the final costs incurred. There are various factors including project scope, unforeseen technical challenges, market fluctuations, and vendor pricing adjustments can impact the final costs.

No.	Production	Quantity	Price (RM)	Total (RM)
1	Impinj R700 RAIN Reader	1	RM9,115.00	RM9,115.00
2	RFID Linen Tags	50	RM3.00	RM150.00
3	SensRF-101 RFID Antenna	4	RM750.00	RM3000.00
4	Ethernet Cable	2	RM8.80	RM17.60
5	PHIHONG Single Port PoE AC adapter	1	RM246.50	RM246.50
6	Zebra ZD230 Barcode Printer Label	1	RM890.00	RM890
Total				RM13419.10

Table 3.7 Table of estimated costs

3.6 Concluding Remark

This chapter has outlined the methodological decisions and system model selected for the project, detailing the system requirements, milestones, estimated costs, and expected challenges. The choice of the Rapid Application Development (RAD) model was made to leverage its strengths in rapid prototyping, iterative user feedback integration, and effective risk management. By employing RAD, the project aims to deliver a system that meets user needs through continuous refinement and adaptation.

The hardware and software requirements have been defined and described in detail to meet the requirements of the system and the role of each component. The project deliverables have been articulated for both the FYP 1 and FYP 2 phases to ensure there is a systematic approach to the development and implementation of the project.

CHAPTER 4

System Design

4.1 System Architecture

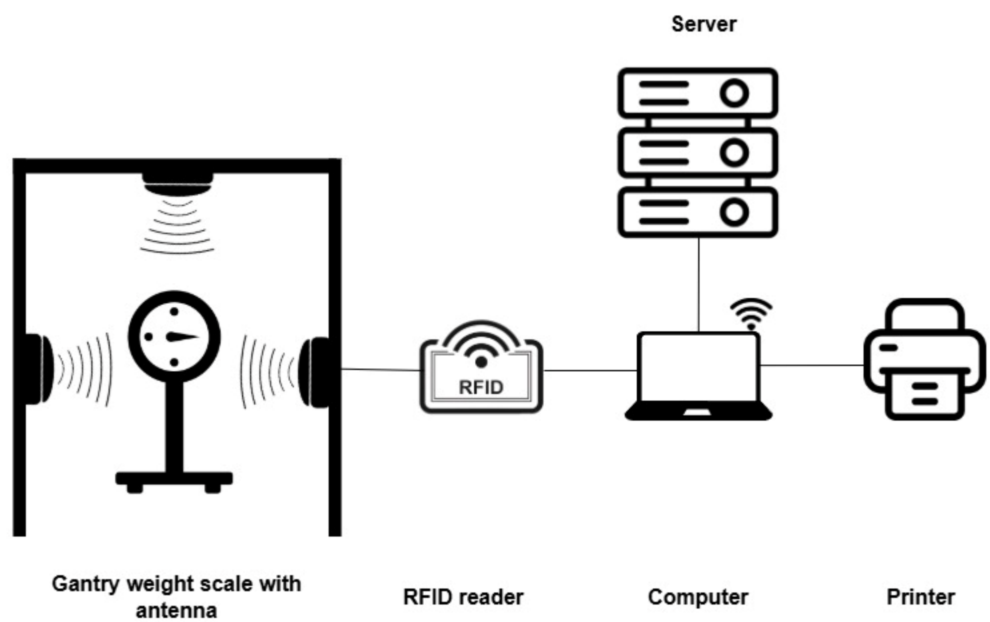


Figure 4.1 System architecture diagram

In this project, the computer functions as the core controller between the RFID reader, server and printer. The computer serves as the front end, interacting with the user while the server acts as the back end, storing information about the linen. The printer was used to print out the QR code to provide a quick view of the linen information. The antennas connected to the RFID reader emit and receive radio frequencies to capture the identities of the RFID tags. The RFID reader acts as a server to collect data from the antennas and outputs it to the computer through a REST API.

The computer needs to receive the data stream from the reader. Initially, the unprocessed data will be processed and displayed on the computer for the user. Subsequently, the data is ready to send to the server which updates the information stored in its database based on the received data from the laptop. On the other hand, the computer fetches the necessary data from the server to generate a QR code for each linen. After that, users can save the file by selecting a specific QR code or selecting all QR codes to print.

4.2 Functional Modules in the System

1. Authentication Module

The authentication module is essential to secure data access and enforce permission restrictions. It guarantees that only authorized users can access specific functions and information, thereby protecting sensitive data and maintaining system integrity. In addition, the authentication module can track user activities and maintain logs which are critical for monitoring interactions and auditing operations. This ensures a precise record of the type of data accessed and the time of access.

2. Scanning Module

The scanning module is designed to detect and capture RFID tag identities, allowing users to automatically read multiple tags simultaneously and eliminating the need for manual counting. This functionality significantly enhances efficiency, particularly when managing large volumes of linen. The module ensures accurate data capture by reliably reading each tag's unique identifier, processing the data in real time, and transferring it for storage. Its seamless integration with other system components enables precise tracking and management of linen, reducing errors and streamlining operations. Through accurate data capture, processing, and storage, the scanning module plays a vital role in optimizing workflow efficiency.

3. Filtering Module

The filter module is designed to eliminate duplicate data captured by the RFID reader, ensuring that unique tag information is processed. It combines multiple scans of the same RFID tag into a single entry, making it easier for users to verify the correct number of linen items detected. This streamlining enhances efficiency and reduces the likelihood of errors caused by redundant data. Additionally, the filter module continuously updates the timestamp for each tag to reflect the most recent scan by allowing for accurate tracking of when the linen was last detected and providing users with reliable and up-to-date information.

4. Data Storage Module

The data storage module is responsible for storing user preferences and essential information, such as the server's IP address, the reader's MAC address, and the sticker's dimensions (width and height). It offers flexibility by allowing users to configure certain settings through the user interface rather than modifying the code directly.

5. QR Generate Module

The QR generation module can create a unique QR code for each linen item using the corresponding information retrieved from the server. To enhance performance and avoid redundant processing, it also categorizes each linen and stores the generated QR codes locally, preventing repeated generation.

6. File Generate Module

The File Generation Module assists in generating PDF files and subsequently converting them into Word documents. The content is arranged and resized based on the specified settings to ensure the sticker layout is properly prepared for printing. This module provides users with flexibility by allowing them to choose their preferred file format.

4.3 System Flow

4.3.1 System flow for the application used for scanning

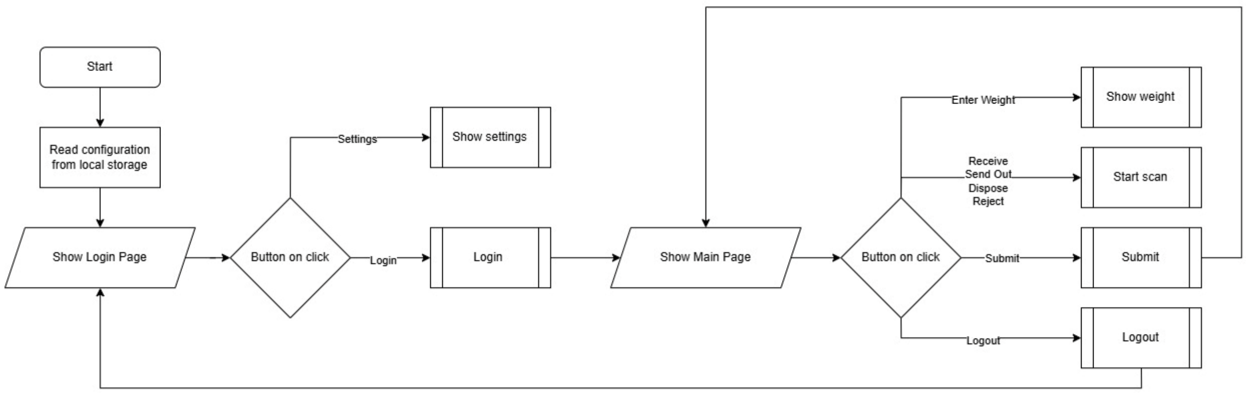


Figure 4.3.1 Flow for Scanning Application to Scanning

An overview of the scanning application is illustrated in Figure 4.3 above. Upon startup, the application loads basic configurations from local storage. Meanwhile, the login page is displayed, featuring two text fields and a gear icon in the top-right corner. The login button becomes clickable once both the username and password are entered. The users can click the gear icon to open the settings dialog box.

After a successful authentication, the application navigates the user to the main page. The main page contains four function buttons, including receive, send out, dispose, reject as well as the Enter Weight button, connection status indicator, list table, and a Submit button. Users can start a scan by clicking on any of the function buttons. The list table will be updated with the scanning result. Users can manually enter the weight displayed on the weight scale by clicking on the Enter Weight button. The submit button will become clickable only when the list table contains information and the weight is entered. After submission, both the scanning result and weight are reset to prevent duplicate records from being sent to the server. Additionally, users can logout from the current account by clicking the logout icon in the top-right corner.

4.3.2 System flow for application used for generate QR

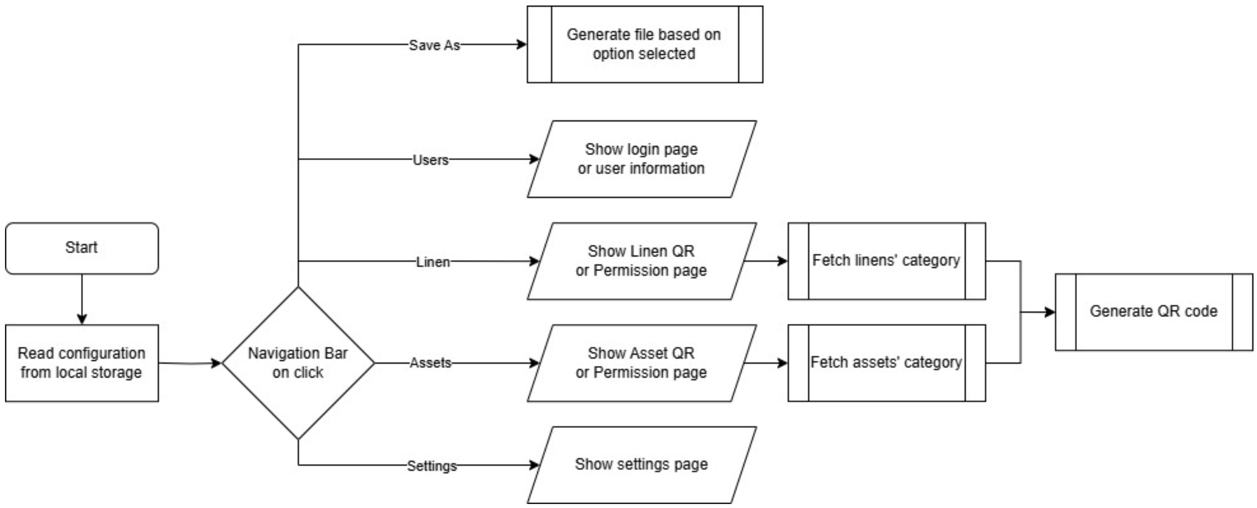


Figure 4.3.2 Flow for Application used to Generate QR code

An overview of the QR code generation application is shown in Figure 4.3 above. When the application starts, it loads configurations from local storage. Once the configurations are loaded, the login page appears along with a navigation bar on the left-hand side. The navigation bar includes five buttons, which are Save As, User, Linen, Assets, and Settings. Users can switch between different pages by clicking the respective buttons on the navigation bar.

To access full functionality, users must log in through the login page, after which their user information will be displayed. The QR codes for linens and assets are only accessible after a successful login; otherwise, a warning page will be shown.

Users can customize their preferences on the settings page by clicking the Settings button from the navigation bar. Additionally, users can click the Save As button to either select specific QR codes for printing or choose to print all QR codes within the same category. Upon clicking Save As, two file format options, which are PDF file and Word file will be available for saving the output.

4.3.3 Login Function

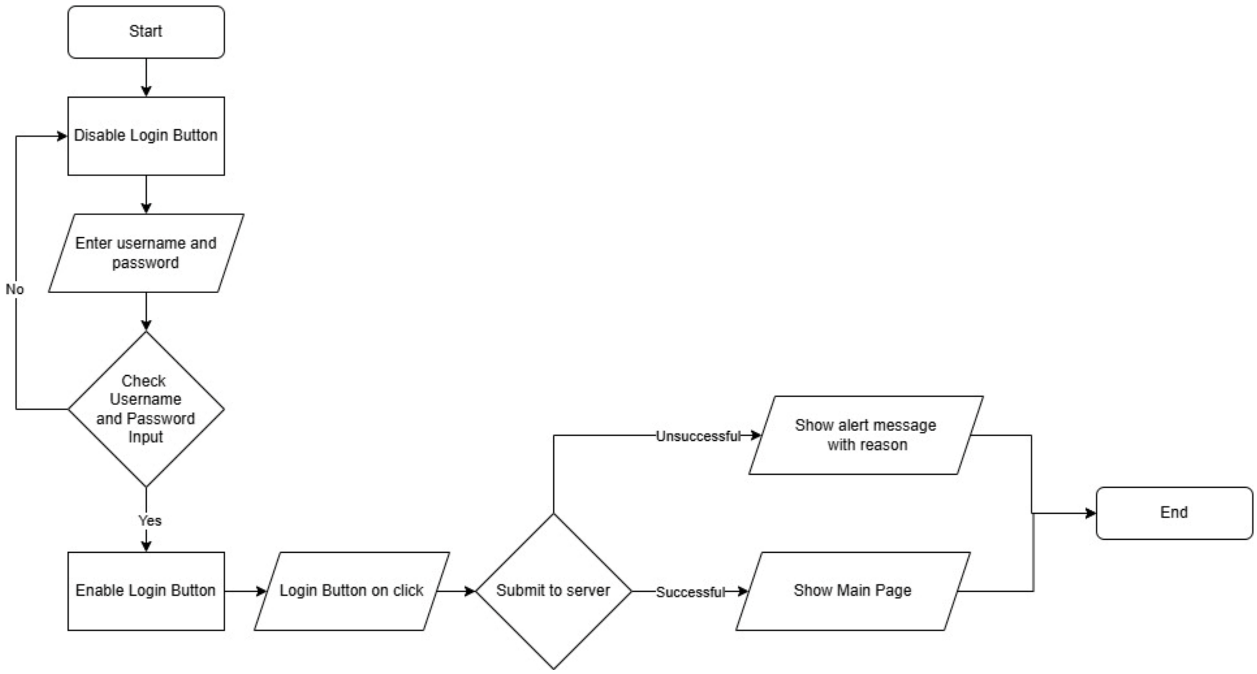


Figure 4.3.3 Flow for Login Function

The login function is triggered when users click the Login button. Initially, the button remains disabled and is only enabled once both the username and password fields are filled. The credentials of the user are sent to the server with an HTTP POST request when the Login button is clicked. Users will be redirected to the main page when login attempts are successful from the server. The alert message will be displayed indicating the reason when login attempts fail from the server.

4.3.4 Settings Function

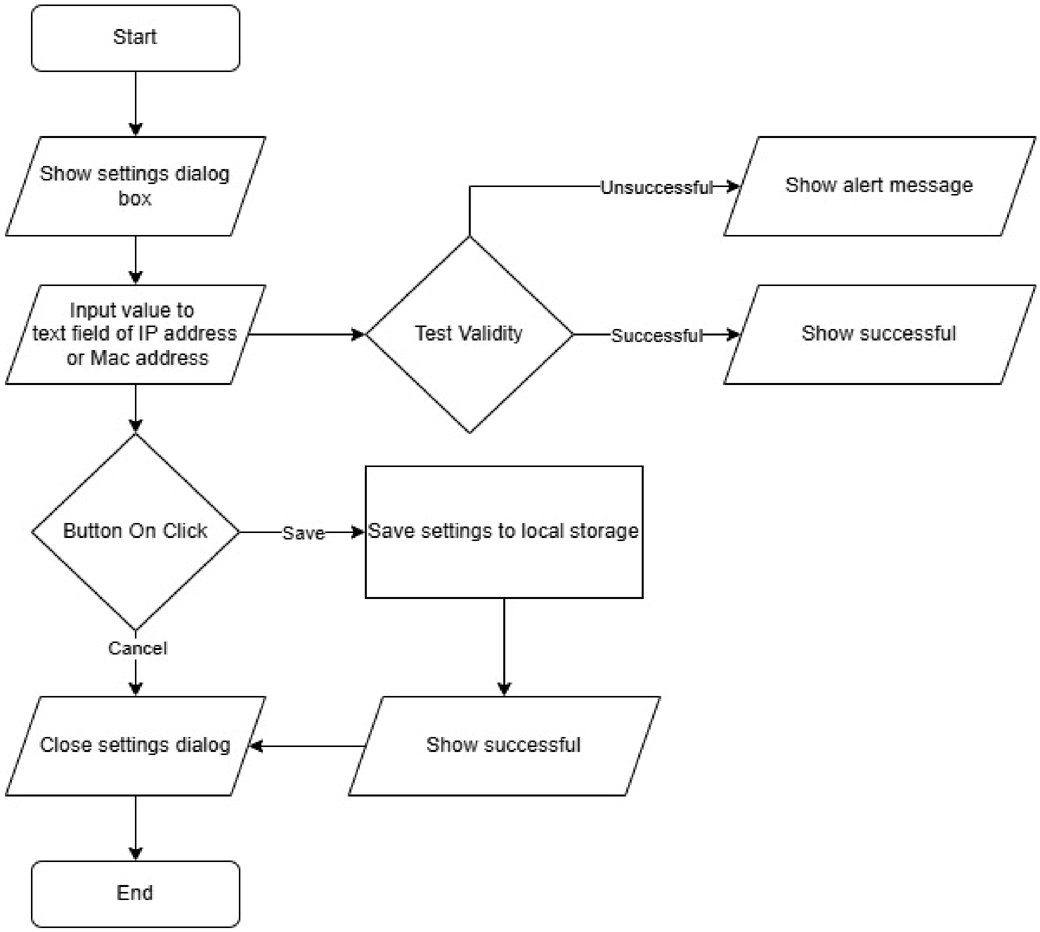


Figure 4.3.4 Flow for Settings Function

Figure 4.3.4 illustrates the settings function, which is activated when the user clicks the gear icon on the login page. This action prompts a settings dialog box containing text fields that provide for user input. Users can input the IP address and MAC address and test the validity of the connection based on the entered values. A successful message with a check icon will be displayed if the connection is successful. In the case of a failed connection, an alert message with a failure icon will appear. The configuration will only be saved if the user clicks the Save button. Otherwise, the existing configuration will remain unchanged.

4.3.5 Scan Function

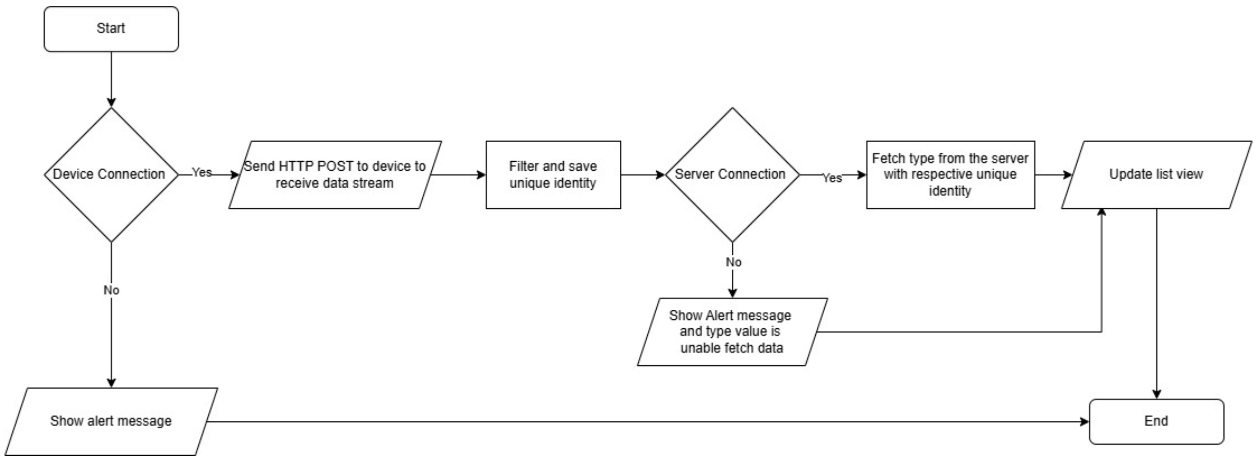


Figure 4.3.5 Flow for Scan Function

The device connection check is performed first to determine whether the operation can proceed. If the device is not connected, an alert message will be displayed and the function will terminate. Otherwise, an HTTP POST request is sent to the device to initiate scanning and the data stream is received in response. The incoming data will be filtered and stored in an array. After the scanning is complete, the server connection verification is required. If the server is disconnected, an alert will be shown, and the results will indicate that data could not be retrieved. If the server is connected, the relevant information is fetched and the list view is updated accordingly upon a successful scan.

4.3.6 Enter Weight Function

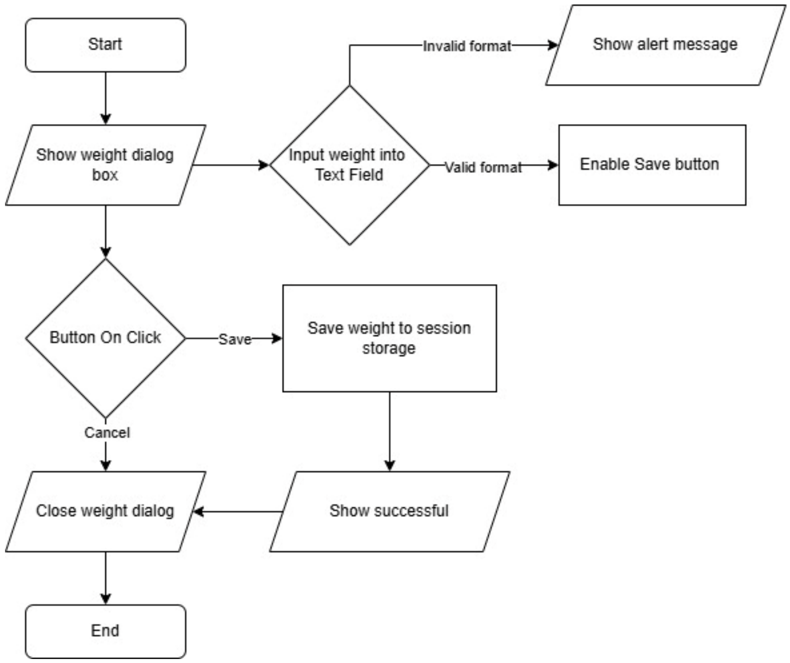


Figure 4.3.6 Flow for Enter Weight Function

The Enter Weight function operates similarly to the Settings function. The Save button is disabled if the input in the text field is either non-numeric or zero. Users are expected to input the weight as shown on the weighing scale. A validation mechanism checks the input format in real time. If the input is valid, the Save button becomes enabled and an alert message appears below the text field if an invalid format is entered to inform the user of the incorrect format. The entered value is only saved when the Save button is clicked.

4.3.7 Submit Function

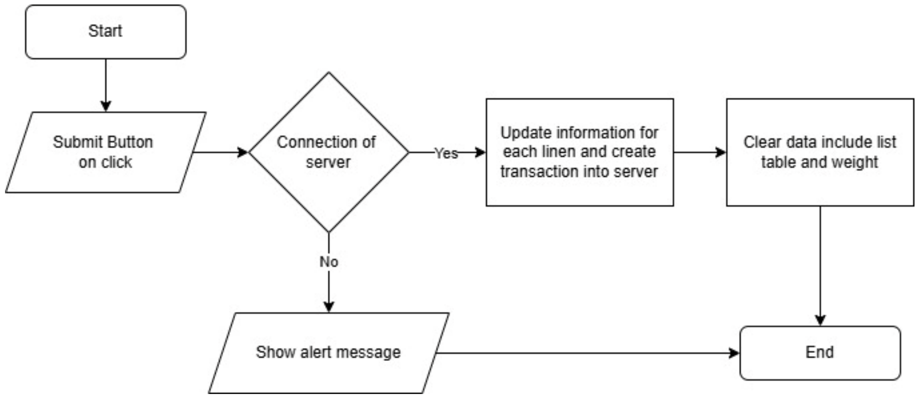


Figure 4.3.7 Flow for Submit Function

The Submit function is triggered when the user clicks the Submit button. It first checks the connection to the server; if the connection fails, the function terminates immediately. The subsequent operations proceed only if a valid server connection is established. The corresponding linen data is then updated on the server, and a transaction is created to record the scanning result. Once the submission is completed, the list table is cleared, and the weight value is reset to zero.

4.3.8 Fetch Category Function

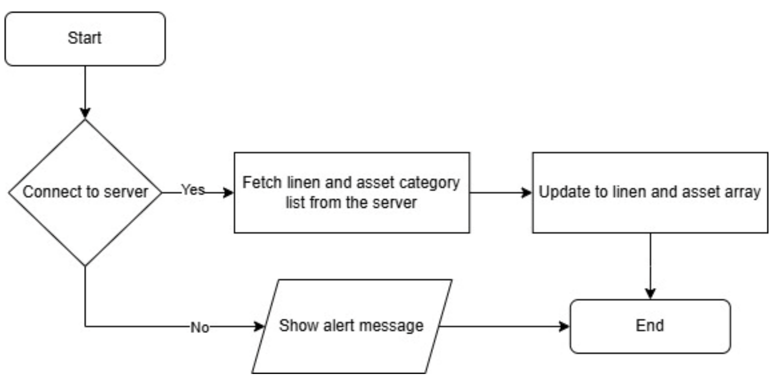


Figure 4.3.8 Flow for Fetch Category Function

The category only will be retrieved when the server is connected. Otherwise, an alert message will be shown and the function will be terminated. If the category information retrieved from the server successfully, the information will store into array for the following request to use.

4.3.9 Generate QR code Function

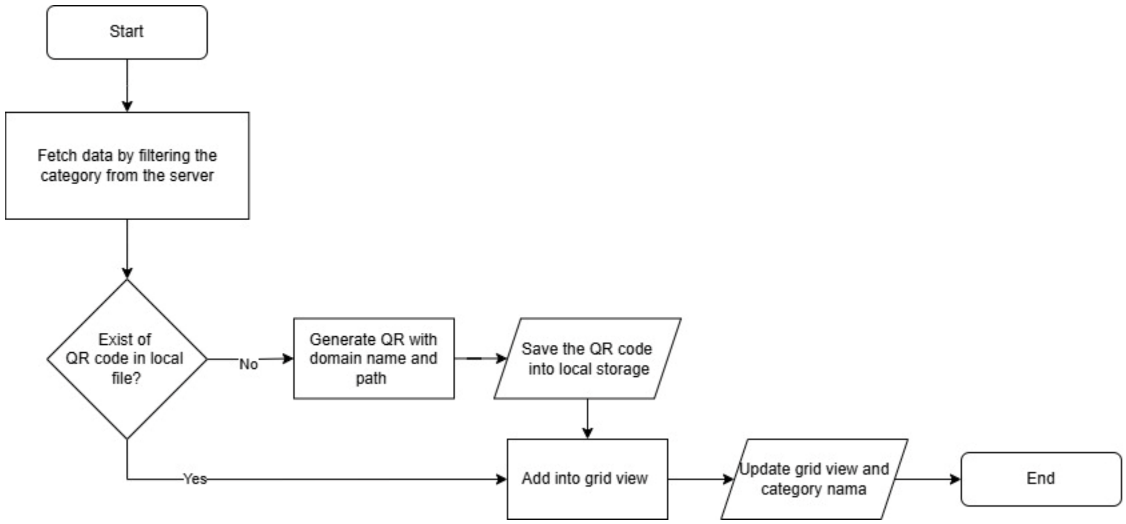


Figure 4.3.9 Flow for Generate QR Code Function

This function retrieves a list of items from the server based on the selected category. For each item, it checks whether a QR code has already been generated. If the QR code exists in local storage, its corresponding image is added to the content of grid view. If QR code not exist, a new QR code is generated using the domain name and its path and saved to local storage. Once QR codes have been generated or retrieved for all items, the grid view is updated to display all the QR codes.

4.3.10 Save As Function

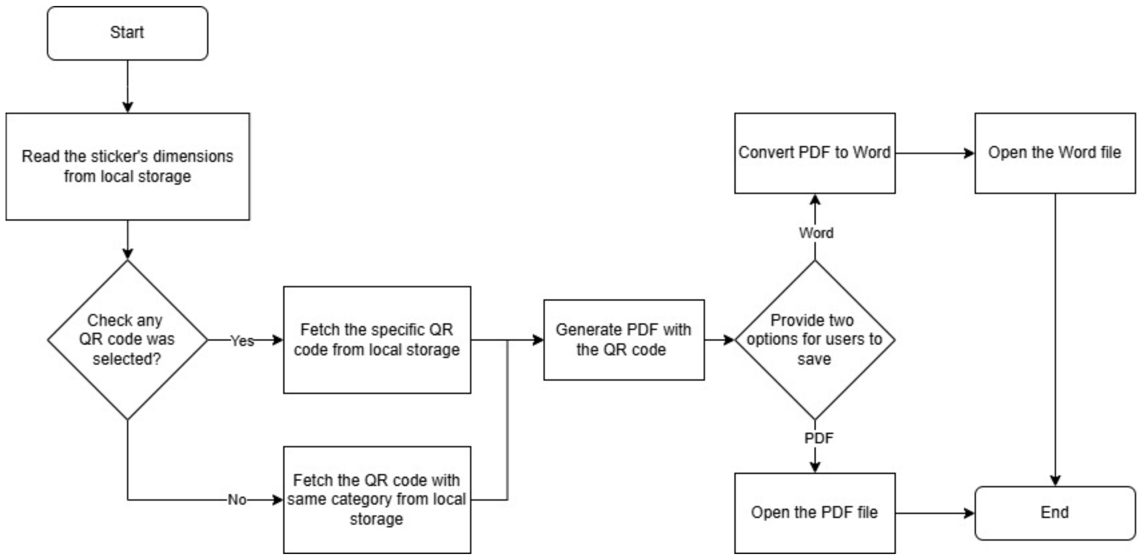


Figure 4.3.10 Flow for Save As Function

The Save As function is triggered when the user clicks the Save As button. It first loads the page dimensions from local storage to set the file layout. Then, it checks whether specific QR codes have been selected. A PDF containing all QR codes on the current page will be generated if no QR codes were selected. This function provides two file format options, which are PDF and Word for users to choose from. If the user selects to save the file as a Word document, the generated PDF will be converted to Word format and opened for preview.

4.4 GUI Design

4.4.1 Overview of LinenTrack's Login Page

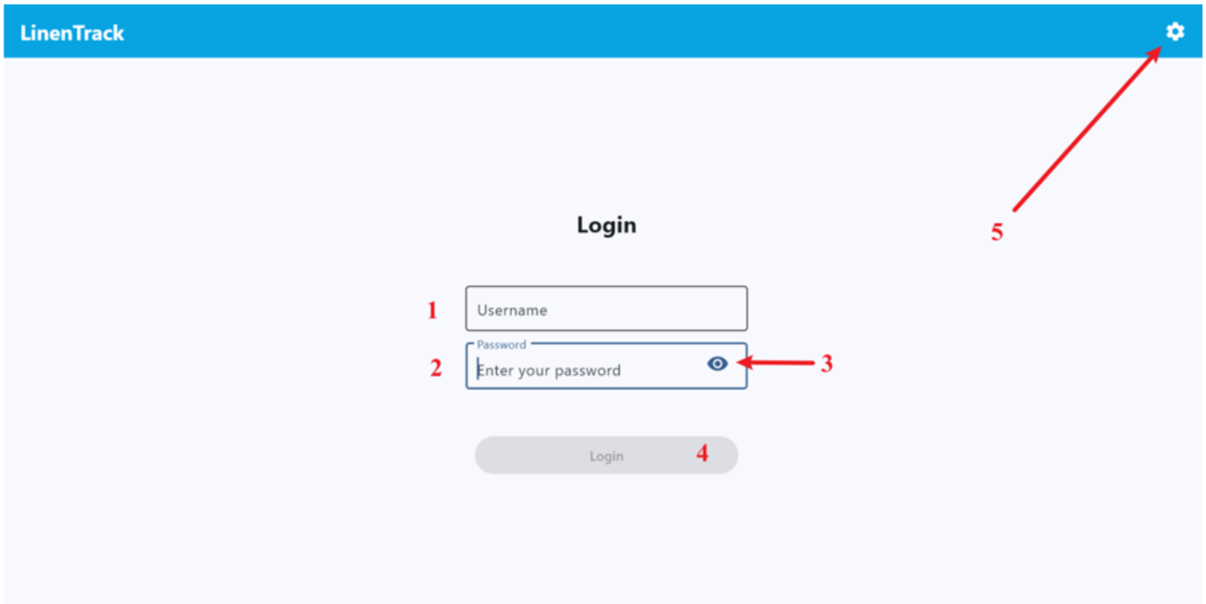


Figure 4.4.1 Overview of LinenTrack's Login Page

1. Username Text Field: Provide to enter a username that exists on the server.

2. Password Text Field: Provide for entering the password.

3. Visibility Toggle Button: Click to able checking the password that was entered.

4. Login Button: Click to proceed to login.

The Login Button is only available to click when the username and password has been entered.

5. Settings Button: Click to open the settings

4.4.2 Overview of LinenTrack's Home Page

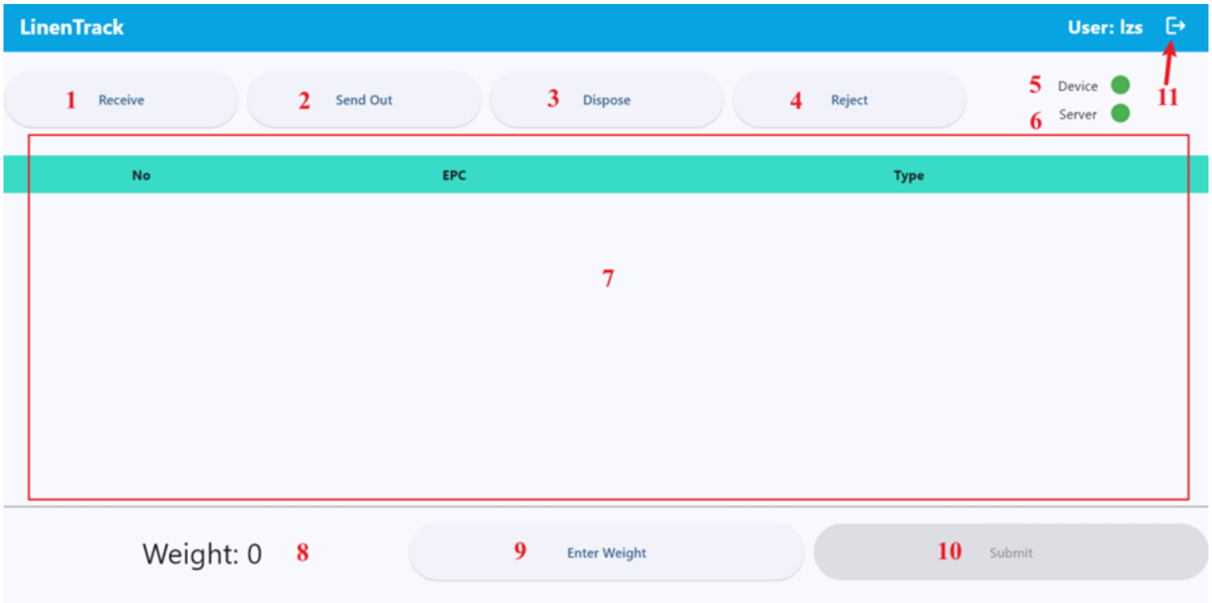


Figure 4.4.2 Overview of LinenTrack's Home Page

1. Receive Button: Click to start scan RFID tags

2. Send Out Button: Click to start scan RFID tags

3. Dispose Button: Click to start scan RFID tags

4. Reject Button: Click to start scan RFID tags

5. Device Status Indicator: Show status of connection between device and application. Green: connected. Grey: disconnected.

6. Server Status Indicator: Show status of the connection between the server and the application. Green: connected. Grey: disconnected.

7. Content List: A list includes the result of the scan

8. Weight Display: Show the weight that has already been entered

9. Enter Weight Button: Click to enter weight for this transaction

10. Submit Button: Click to submit the information to server

11. Logout Button: Click to logout and change to login page

4.4.3 Overview of LinenTrack's Settings

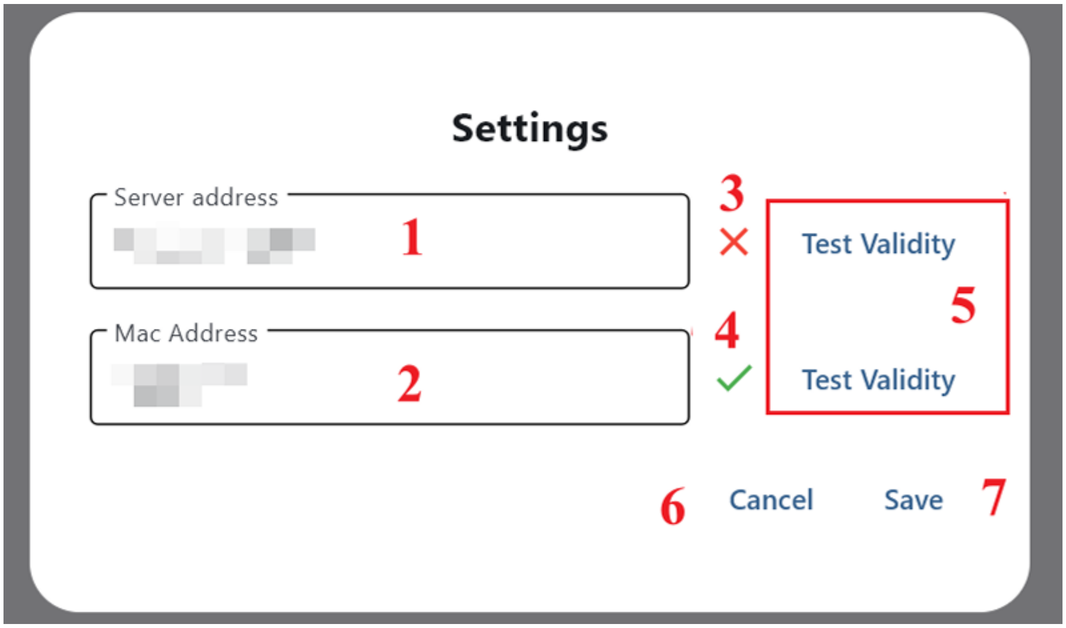


Figure 4.4.3 Overview of LinenTrack's Settings

1. Server Address Text Field: Provide to enter the server's IP address

2. Mac Address Text Field: Provide to enter the device's Mac address

3. Fail Icon: Show when the connection failed after clicking the Test Validity Button

4. Success Icon: Show when the connection is successful after clicking the Test Validity Button

5. Test Validity Button: Click to test the connection

6. Cancel Button: Click to close settings

7. Save Button: Click to save the configuration and close the settings

The configuration will take effect after clicking the Save button.

4.4.4 Overview of LinenTrack's Enter Weight Dialog

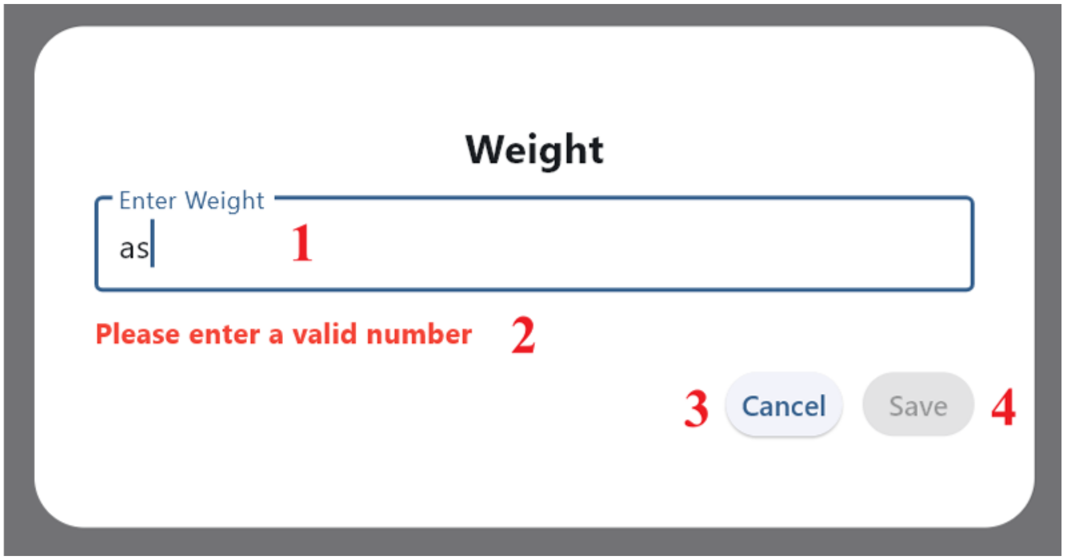


Figure 4.4.4 Overview of LinenTrack's Enter Weight Dialog

1. Weight Text Field: Provide to input the weight.

2. Error Message: This only shows when input is not in a number format.

3. Cancel Button: Click to close the weight dialog.

4. Save Button: Click to save the weight entered and close the weight dialog.

The Save Button is available to click only if a non-zero number is entered and the format is correct.

4.4.5 Overview of QRTrack's Login Page

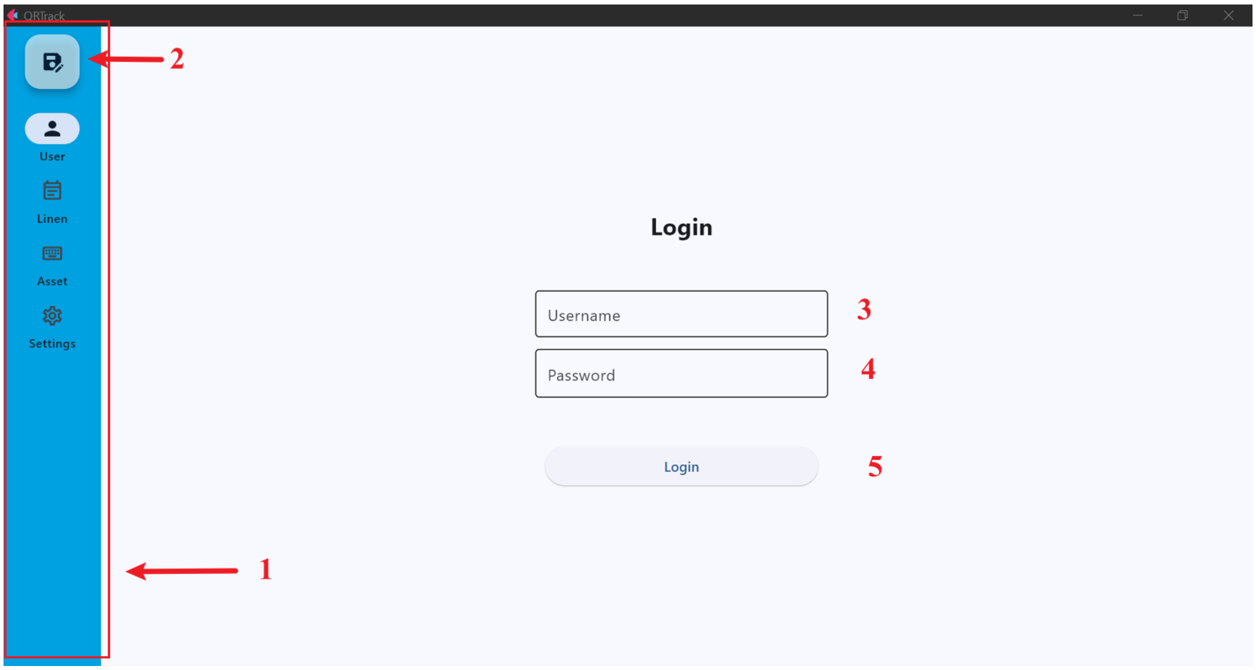


Figure 4.4.5 Overview of QRTrack's Login Page

1. Navigation bar: The user can navigate to different pages by selecting the icon within the navigation bar.

2. Save As Button: Click to generate the PDF or Word file.

3. Username Text Field: Provide to enter a username that exists on the server.

4. Password Text Field: Provide for entering the password.

5. Login Button: Click to submit the credentials to the server and proceed with the login.

4.4.6 Overview of QRTrack's User Info Page

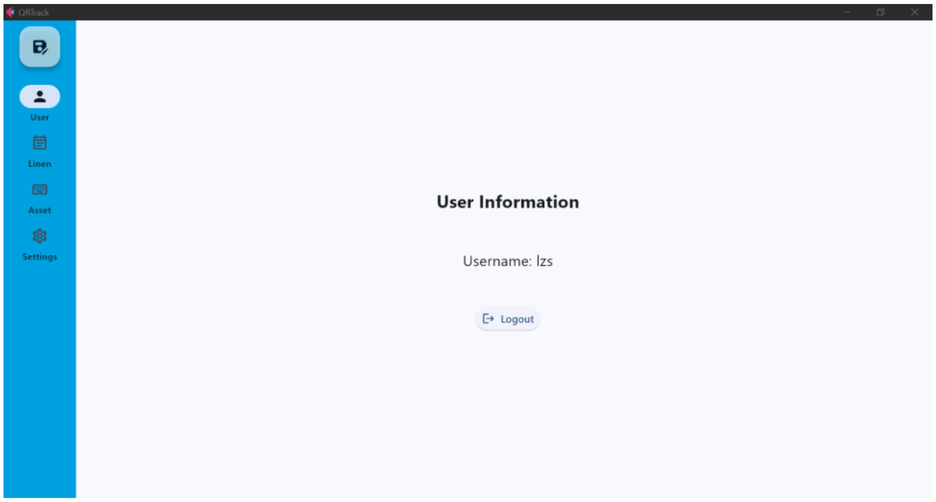


Figure 4.4.6 Overview of QRTrack's User Info Page

This page is displayed only after a successful login. The username is shown to indicate the currently logged-in account.

4.4.7 Overview of QRTrack's Warning Page

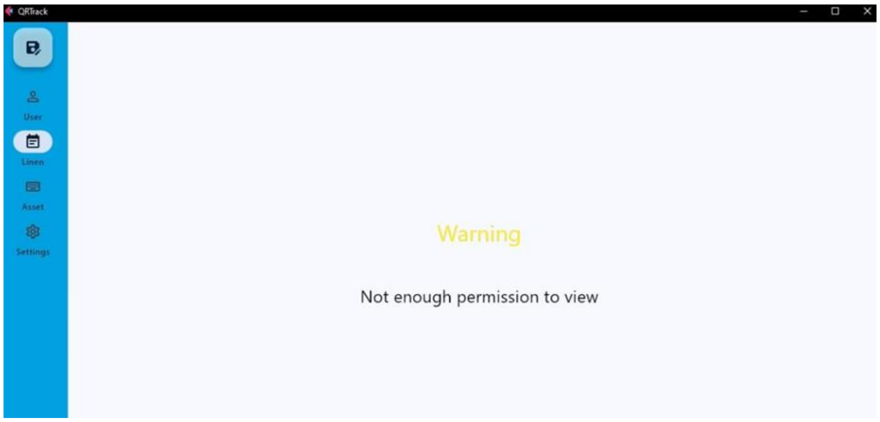


Figure 4.4.7 Overview of QRTrack's Warning Page

This page is displayed when a user attempts to view the QR code without having sufficient permissions to access the data on the server.

4.4.8 Overview of QRTrack's Linen Page

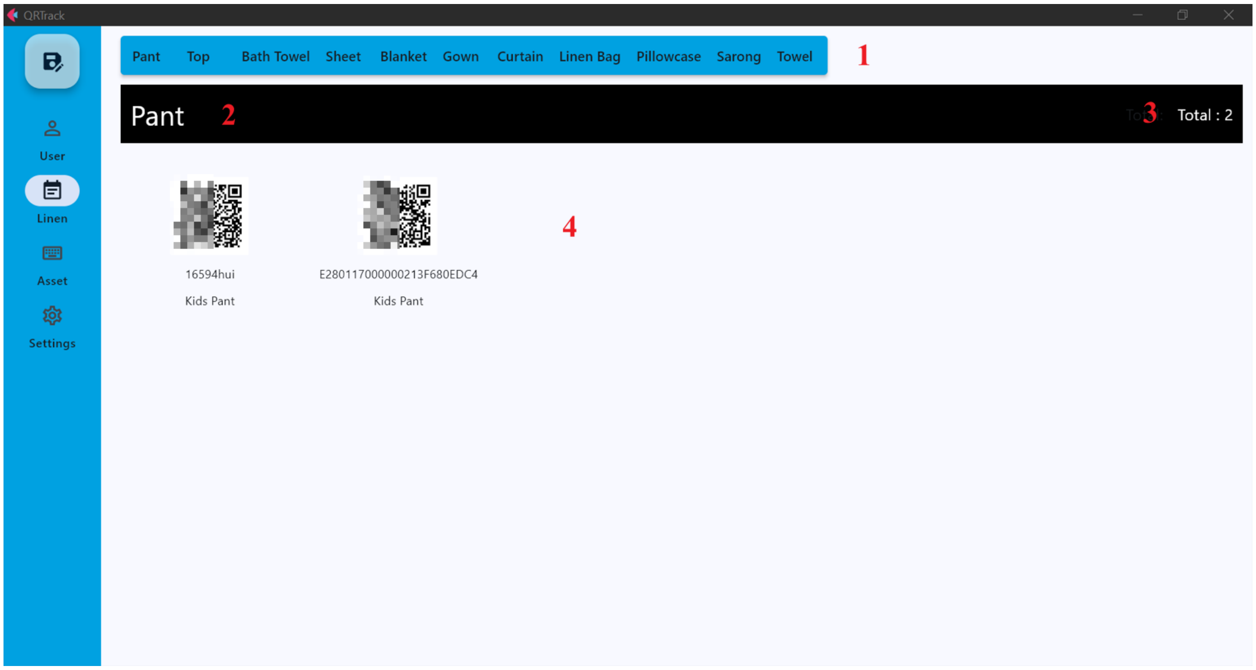


Figure 4.4.8 Overview of QRTrack's Linen Page

1. Category list: Show the categories that exist in the linen list.

2. Category name: Show the category that is currently selected.

3. Total items of the current category: Show all items that exist in the linen list within the category that is currently selected.

4. Grid view: used to place the QR codes that were generated.

4.4.9 Overview of QRTrack's Asset Page

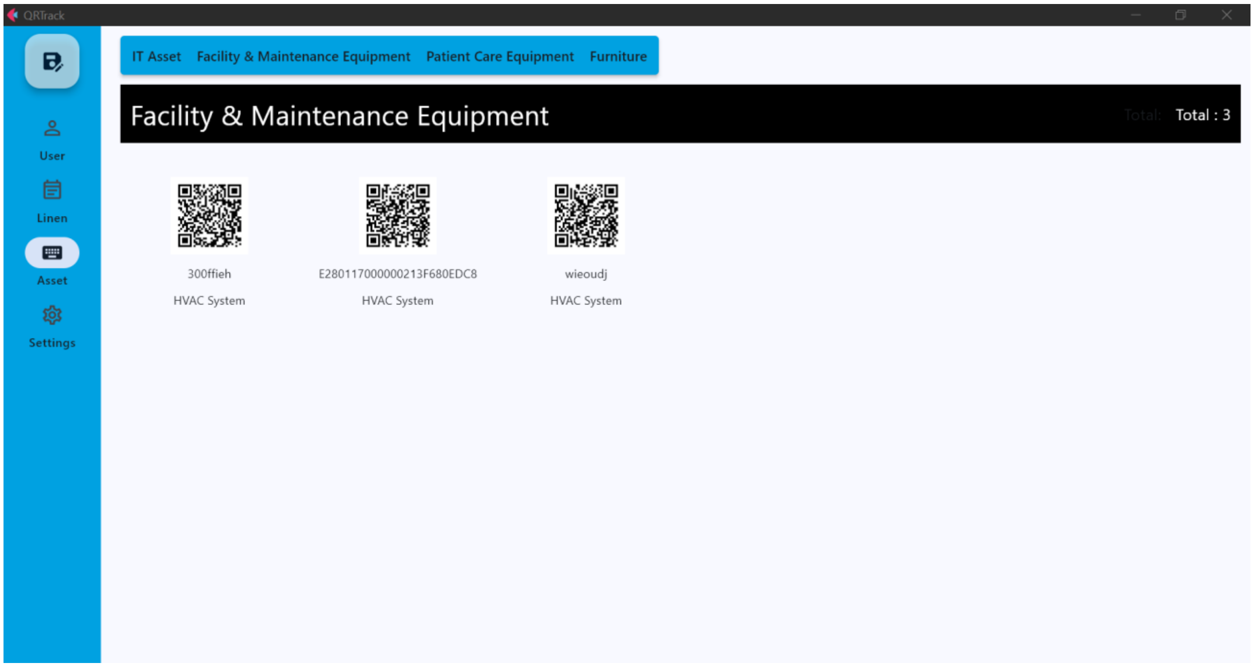


Figure 4.4.9 Overview of QRTrack's Asset Page

This page uses a similar design to QRTrack's Linen Page, but the content is different. When the user clicks "Asset" in the navigation bar, the category list is updated; each time the selected category changes, the displayed QR code is also refreshed.

4.4.10 Overview of QRTrack's Settings

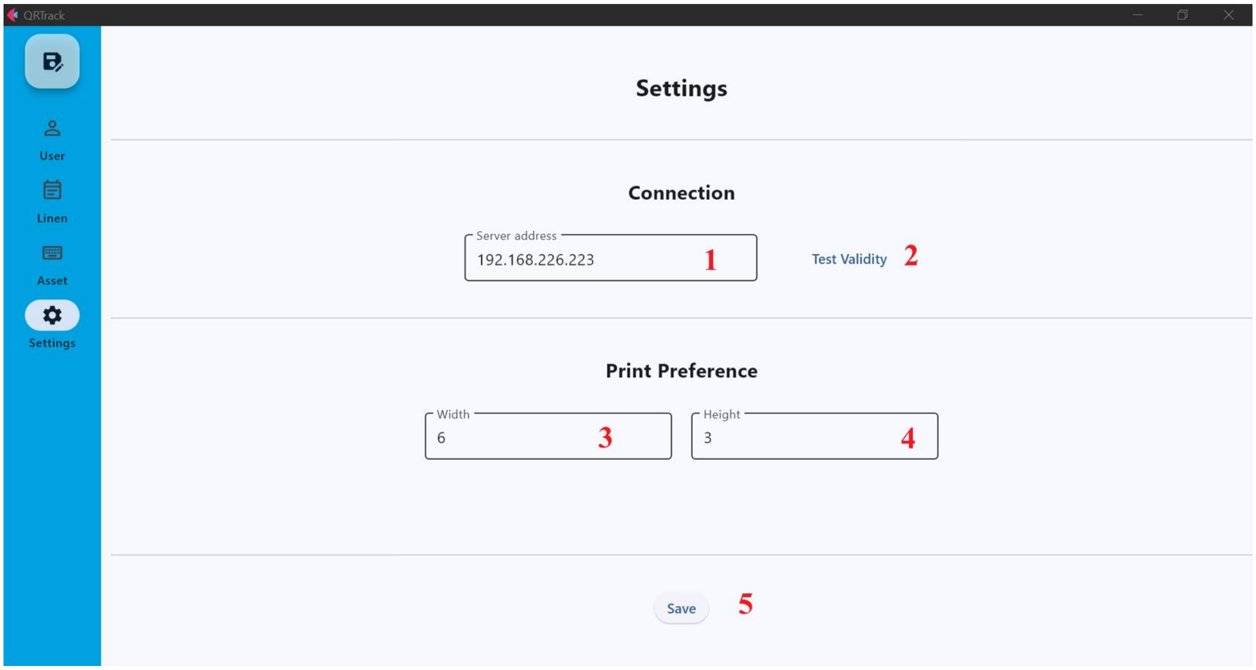


Figure 4.4.10 Overview of QRTrack's Settings

The settings page allows users to configure the server's IP address and adjust the sticker dimensions.

1. IP address Text Field: Users can enter a new IP address if the server has changed.

2. Test Validity: Clicking this button checks whether the server connection is valid.

3. Width Text Field: Allows users to adjust the desired width of the sticker for printing.

4. Height Text Field: Allows users to adjust the desired height of the sticker for printing.

5. Save Button: The new configuration settings will only take effect when this button is clicked.

4.4.11 Overview of QRTrack's Save As Dialog Box

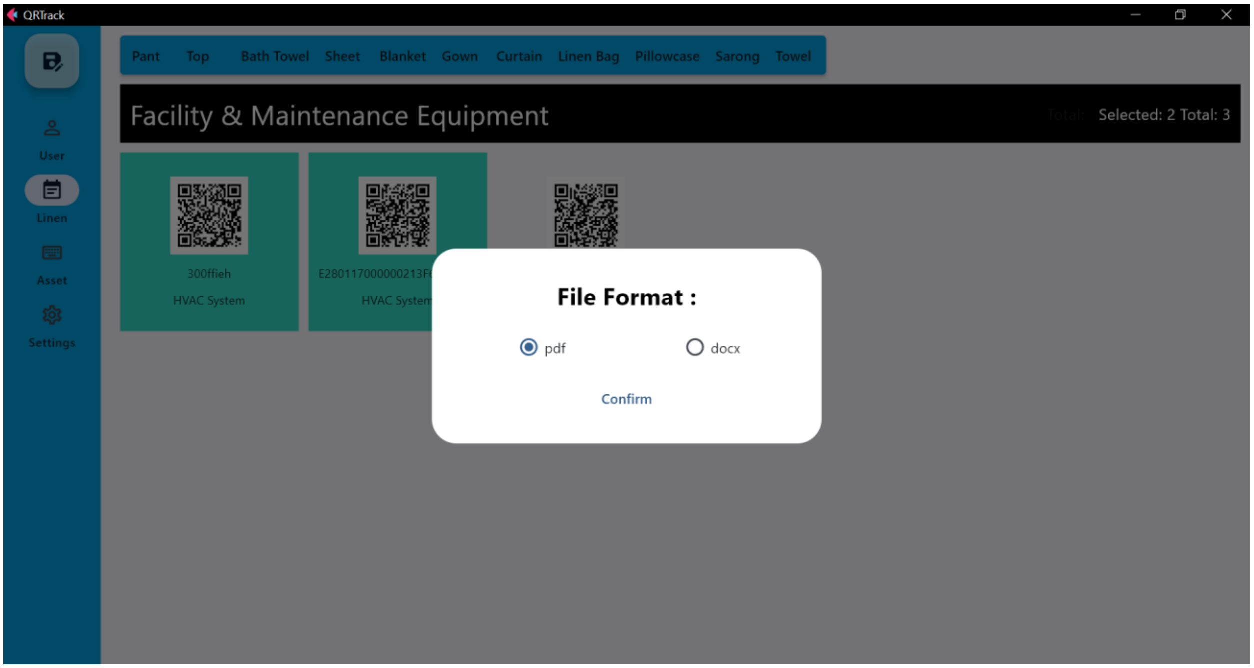


Figure 4.4.11 Overview of QRTrack's Save As Dialog Box

After selecting a category or specific QR codes to print, the user can click the Save As button. A dialog box offering two file format options will be displayed for the user to choose from. The generated file will automatically open for the user once the desired format is selected and the Confirm button is clicked.

4.5 Concluding Remark

This chapter presents the system architecture, module requirements, system flow, and graphical user interface (GUI) design. The system leverages RFID technology in conjunction with a server to streamline the linen management process and enhance operational efficiency. Additionally, information is encoded into QR codes to allow users quick and convenient previews. The main modules of this project include authentication, scanning, data filtering and storage, QR code generation, and file generation.

The system comprises two independent applications which are LinenTrack and QRTrack. LinenTrack is primarily responsible for scanning RFID tags and updating the latest linen information to the server. On the other hand, QRTrack is designed to display QR codes generated from the server data, allowing users to quickly access linen information by scanning the QR codes.

This chapter also provides a comprehensive overview of the Graphical User Interface (GUI) design for both applications. The interface of the applications was designed with a focus on intuitiveness and user-friendliness in order to provide an efficient user experience. Besides that, the application focus on ease of access and navigation to be usable by all user segments.

CHAPTER 5

System Implementation

5.1 Hardware Setup

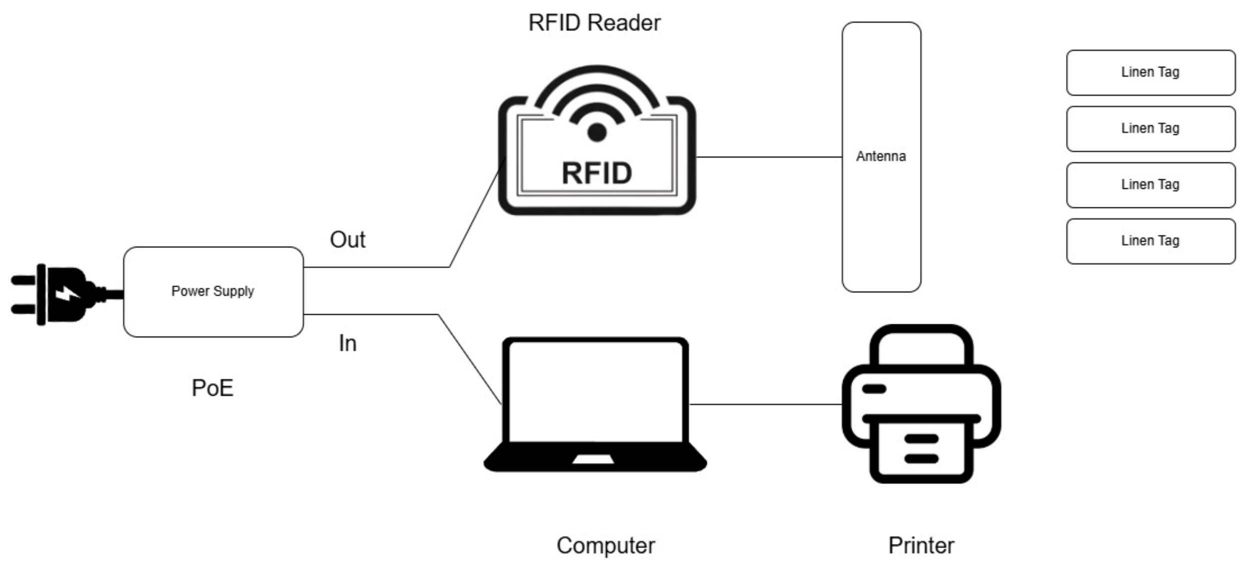


Figure 5.1 Hardware setup

The 'Out' port of the PoE (Power over Ethernet) AC adapter was connected to the RFID reader using an Ethernet cable. This connection not only provided a data link but also supplied the necessary electrical power to the RFID reader. The 'In' port of the PoE AC adapter is connected to a computer via another Ethernet cable to establish a communication pathway for transmitting the data collected by the RFID reader to the computer system for processing. The RFID reader was also linked to an external antenna. This antenna is controlled by the reader which is responsible for transmitting and receiving radio waves during scanning operations. Once powered, the RFID reader was capable of emitting radio frequency signals through the antenna to detect and read nearby RFID linen tags.

Furthermore, a printer was connected to the same computer system. The printer can print QR code stickers based on the data provided by the computer that retrieved from the server.

5.2 Software Setup

After the RFID reader is physically connected, several configuration steps must be performed to enable further processing. Open a web browser and navigate to http://impinj-14-2f-d9 once the connection between the RFID reader and the computer has been established. The default login credentials for the Impinj RFID reader are as follows:

Username: root

Password: impinj

Upon successful login, change the Regulatory Region setting to FCC Part 15.247 and set the Reader Interface to Impinj RESTful Interface. Once these changes are made, reboot the RFID reader to apply and save the new configurations.

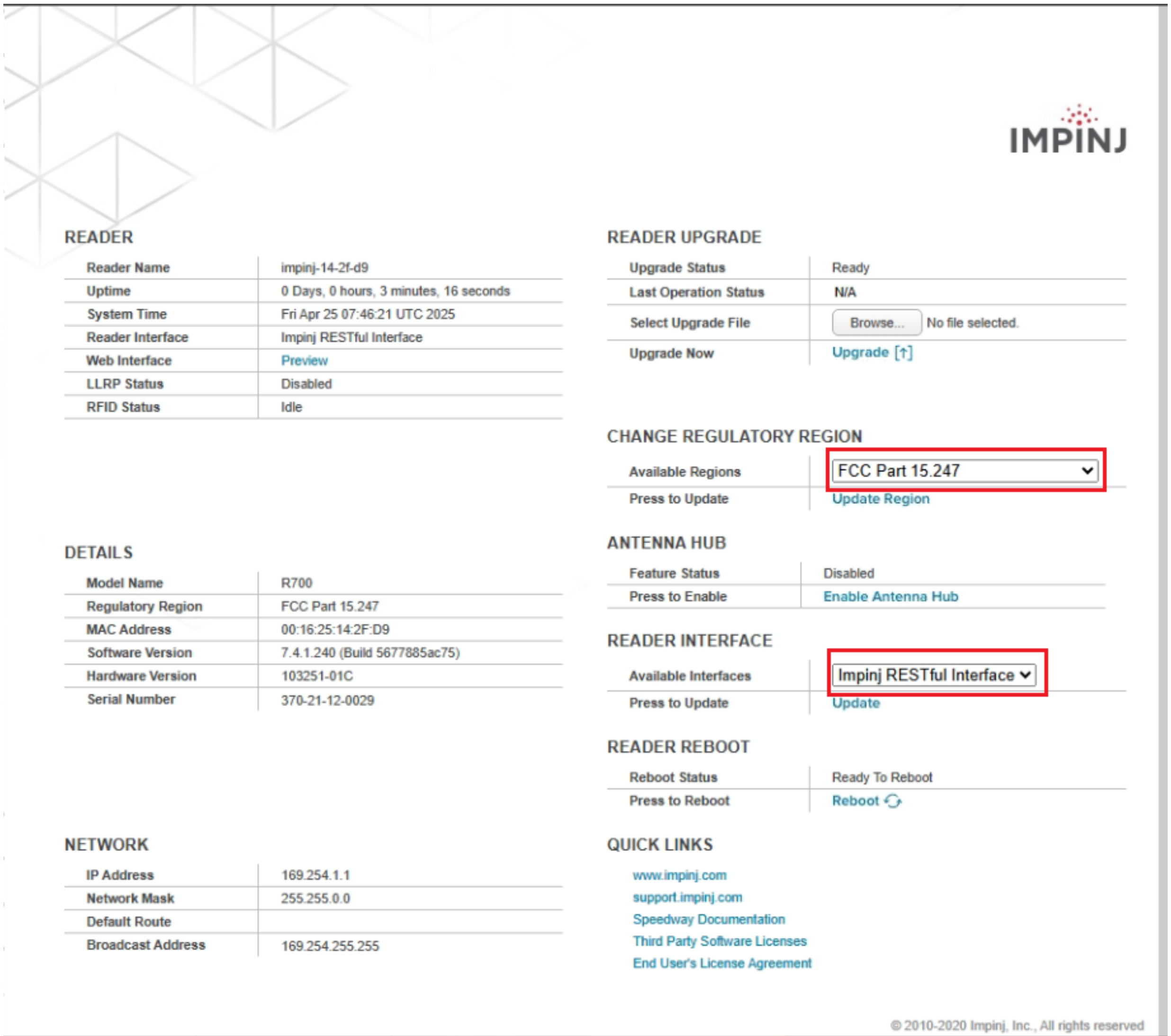


Figure 5.2 Configuration of RFID reader

After the basic configuration was done, a customized inventory preset was needed to read the necessary data from the RFID linen tags. The inventory preset can be customized at web interface. The information of the inventory preset for this system are as follows:

Preset ID: LinenTrack

Antenna Configurations

Antenna Port: 1

Transmit Power: 3000

Session: 2

Population Est.: 32

Search Mode: Dual Target

RF Mode: 1110

Additionally, ensure the EPC Hex is selected under the Event Reporting configuration. This setting enables the system to capture the unique identifier associated with each RFID linen tag in hexadecimal format.

5.3 Setting and Configuration

To ensure that LinenTrack and QRTrack function properly, certain initial configurations need to be completed. The LinenTrack settings provide input fields for both the IP address and MAC address. The user must enter the IP address of the server to authenticate and retrieve the necessary data. If the server is not connected, the application will be unable to function as expected as fail to login. Additionally, the user must enter the last 6 digits of the MAC address of the RFID reader to ensure that the device can correctly read the identifiers from the RFID linen tags. The list table will remain empty, as no data can be fetched if the RFID reader is not connected.

In addition, QRTrack also relies heavily on the information stored on the server. If the server is not connected, most of the functions within QRTrack will become inaccessible. The IP address required to establish a connection to the server can be configured within the settings of QRTrack.

5.4 System Operation (with screenshot)

5.4.1 System Operation of LinenTrack

The system sends the user's login credentials to the server using an HTTP POST request. It includes error handling in case the server fails to respond (refer to Figure 5.4.1). Upon successful authentication, the system retrieves essential information from the server to verify user permissions. In addition, the system provides a "Test Validity" function to verify the availability of both the application server and the RFID reader. This is achieved by sending HTTP POST requests to both endpoints and checking for valid responses.

Figure 5.4.1 Show when login failed due to invalid credentials

The system sends an HTTP POST request to the RFID reader when the user initiates scanning. This request triggers the RFID reader to transmit radio frequency signals through the antenna and return scanned EPC data for a duration of approximately three seconds. Since the RFID reader may capture multiple instances of the same linen tag during the scan session, the system performs filtering to eliminate duplicate EPCs. Only unique identifiers are retained for display in the list table. For each unique EPC, the system sends an HTTP request to the server to retrieve additional metadata (such as item description or location). Once retrieved, this data is displayed alongside the EPC in the list view (refer to Figure 5.4.2). After reviewing the scanned data, the user can proceed with submission. The system performs a connectivity check before submission. An HTTP POST request containing the processed data is sent to the server to update the corresponding records if the connection is valid. The processed data includes the EPC, last appearance time, status, and location. The status of linen will be changed based on the different buttons were clicked. For instance, the status of a linen will be updated to "Dispose" when the dispose button is clicked. Upon successful submission, the current data including the EPC, timestamp, and total number of linen, is compiled into a transaction record and sent to the server for logging and storage.

Figure 5.4.2 Content list updated after scanned

5.4.2 System Operation of QRTrack

Upon successful login, the system retrieves linen and asset category details from the server. The categories are stored in arrays for later use in navigation. When the user navigates to the linen or asset page, the system dynamically binds the respective category list using the already retrieved category details. When a user selects a category, the system updates the page with the selected category name and total number of items associated with it.

The system retrieves the list of items of the selected category from the server and attempts to locate their corresponding QR code images within the local file system. For each item whose QR code image is not available locally, the system generates a new QR code dynamically and saves it in the given local folder using the qrcode library.

When the "Save As" button is pressed, the system generates a PDF document using the ReportLab library (refer to Figure 5.4.3). The PDF will include the selected QR codes or all codes displayed on the page**.** The PDF layout matches the page size specified in the application settings.

Figure 5.4.3 Output of QR Code in PDF

5.5 Concluding Remark

The implementation of the linen and asset tracking system, comprising both hardware and software components, has been included in this chapter. The integration of the RFID reader with the LinenTrack module enables efficient scanning and identification of RFID-tagged linen items, while the QRTrack module facilitates streamlined QR code generation and management for inventory items. Through effective communication with the server, both modules demonstrate reliable data retrieval, user authentication, and real-time system feedback.

The system's design prioritizes user interaction, automation, and accuracy, which significantly improves the tracking and management process within the operational environment. Overall, the successful implementation validates the feasibility of using RFID and QR technologies in hospital linen and asset tracking applications.

Chapter 6

System Evaluation and Discussion

6.1 System Testing and Performance Metrics

The RFID linen management system needs to undergo comprehensive functional and integration testing to ensure its reliability and effectiveness. Key indicators for system performance evaluation include duplicate RFID identifier filtering accuracy, scanning accuracy, and data retrieval efficiency.

Duplicate RFID identifier filtering accuracy ensures that only unique linens are processed and recorded in the server. RFID scanning accuracy ensures that linens of the same batch can be read completely by the system to ensure correct statistics. In addition, the system successfully obtains necessary data from the backend server by applying filters based on unique RFID identifiers. This ensures that only relevant and valid records are retrieved, thereby reducing unnecessary data load and improving the overall responsiveness of the system.

These results test the system's ability to handle key tasks in an automated linen tracking environment, laying the foundation for further deployment and scalability testing.

6.2 Testing Setup and Result

Hardware testing environment requires essential components such as an RFID reader, antenna, RFID linen tags, computer, and server. Hardware components are supposed to be assembled accurately and in line with the given hardware setup process. Accurate assembly ensures the system functions as anticipated and the test outcome is accurate, consistent, and reliable.

6.2.1 Duplicate RFID identifier filtering accuracy

A total of 30 different RFID linen tags were used during the testing process. These tags were strategically placed within the effective coverage area of the RFID antenna to ensure optimal signal reception. This setup was designed to verify that all RFID linen tags could be accurately detected and scanned without omission, thereby validating the system's ability to handle multiple items simultaneously under real-world conditions.

Total RFID linen tags	Displayed after the filter	Accuracy percentage (%)
30	30	100
30	30	100
30	30	100
30	30	100
30	30	100

Table 6.2.1 Table of testing on duplicate RFID identifier filtering accuracy

Based on the results from the five testing cases presented in Table 6.2.1 indicated that the system achieved 100% accuracy in duplicate RFID filtering. This confirms that the system is fully capable of accurately identifying and eliminating duplicate RFID identifiers, ensuring that only unique entries are processed during operation. These results demonstrate the effectiveness and reliability of the duplicate filtering mechanism implemented in the system.

6.2.2 Scanning result accuracy

55 different RFID linen tags were used during the test. To test the detection capability of the system at various distances, the RFID linen tags were placed at different distances between the antenna and the RFID linen tags. Each set of tags was scanned for 3 seconds and only one antenna was used. This testing setup was designed to verify that all RFID linen tags could be accurately detected and read at different distances without any omissions. The objective was to assess the effective

scanning range of the system under real-world conditions and confirm its ability to maintain performance consistency across varying proximities.

Total RFID linen tags	Distance (cm)	Result	Accuracy percentage (%)
55	1	52	94.55
55	1	53	96.36
55	25	52	94.55
55	25	51	92.73
55	50	29	52.73
55	50	34	61.82
55	100	15	27.27
55	100	12	21.82
55	125	5	9.09
55	125	3	5.45
55	150	0	0
55	150	0	0

Table 6.2.1 Table of scanning result accuracy

Since this test was conducted using only a single antenna, the results are intended for reference purposes only and may not reflect the performance of a fully scaled system. As shown in Table 6.2.1, the system maintained high accuracy in detecting RFID linen tags within the 1 cm to 25 cm range. However, beyond this distance, the detection accuracy began to decline gradually. Insufficient equipment to increase the scanning coverage meant that some tags were undetected at farther distances. This highlights the need for additional antennas or optimized antenna positioning in future implementations to ensure consistent performance across a wider area.

6.2.3 Data retrieval efficiency

This test was designed to evaluate the relationship between the number of RFID linen tags and the time required to retrieve data from the server. By incrementally adding more tags and measuring the corresponding data reading time, the test was aimed at verifying the performance with larger numbers of items. This helps determine how the system performs under different loads and if the response time is still acceptable as the number of tags increases.

RFID linen tags scanned	Time required to retrieve data (seconds)
5	2
10	3
15	5
20	7
25	7

Table 6.2.3 Table of data retrieval efficiency

The data presented in Table 6.3.3 above demonstrates that as the number of RFID linen tags being scanned increases, the total time required for the scanning and data retrieval process also increases. This is expected as a higher number of tags leads to more data being processed. Additionally, the number of existing records stored on the server impacts the retrieval time. This is because the system performs individual queries for each RFID tag using its unique identifier which can result in longer processing times when the server holds a large volume of records. These findings highlight the importance of optimizing both scanning efficiency and database query performance for handling larger-scale operations.

6.3 Project Challenges

One of the most significant challenges faced by this RFID Linen Management System is the limited access to adequate hardware resources. Due to the high cost of essential components such as antennas. It is difficult to set up an environment that is very close to real-life environments. This limitation restricts the ability to fully evaluate system performance under typical deployment scenarios.

Another critical hardware-related issue is the instability of the RFID reader. The reader was frequently disconnected from the system when using. It will interrupt the data collection process. This instability made debugging particularly challenging during the development phase. Intermittent outages hamper the ability to quickly and consistently identify and resolve issues

Besides the hardware constraints, the testing process also faced certain limitations. The system was tested by the developer instead by the end users. As a result, the system may not be fully optimized for usability or user experience. This could lead to potential usability concerns or workflow inefficiencies that will need to be addressed through iterative feedback and refinements during actual deployment.

Furthermore, the choice of Python as the development language also brings some challenges. Python is suitable for rapid development and ease but the platform lacks standardization, particularly concerning packaging programs for different platforms. Cross-platform compatibility remains limited, and the application often requires numerous external libraries and dependencies. Consequently, packaging the software results in large file sizes, even for relatively simple user interfaces, which may impact deployment and performance on resource-constrained devices.

6.4 Objectives Evaluation

The project objectives were largely met. The primary goal of developing a semi-automated linen monitoring system using RFID technology for the UTAR hospital was successfully achieved. The system demonstrated the capability to detect and retrieve linen tag data within an acceptable range, fulfilling its core objectives of accurate linen tracking and minimizing human error.

Additionally, the project achieved traceability of linens and assets through the generation of QR codes. By scanning these codes, users can quickly access related information stored on the server. This will significantly enhance traceability and operational efficiency.

The system also provides a good user experience through a very simplified user interface and straightforward usage. This ensures usability across all user levels and avoids imposing unnecessary restrictions on usage by different classes of users.

Despite limitations such as hardware constraints and occasional delays in server response, the system successfully integrated with a backend server to manage and retrieve data. Though extensive testing was possible only to some extent due to limited resources, the result reaffirmed the basic principle and demonstrated its feasibility. Overall, the project closely met its desired objectives and provided a good basis for further improvement.

6.5 Concluding Remark

Overall, the Linen Monitoring System through RFID presents an efficient solution for the improvement of linen management in hospitals. The issues of hardware and deployment apart, the project attests to the potential of RFID technology in streamlining and optimizing inventory management functions. Experience garnered from pilot running and development reveals that this system can prove very useful as far as saving time, the precision of data, and openness are concerned upon more tuning and enhancement. This project addresses a real-life issue and sets the stage for further applications of IoT in the healthcare sector.

Chapter 7

Conclusion and Recommendation

7.1 Conclusion

This project successfully explores and implements the use of RFID technology to enhance hospital linen management through semi-automation. From the initial research and literature review stages to prototype development and testing, the project has addressed and overcome various technical and resource-related challenges. Its primary goal is to significantly improve the efficiency and accuracy of linen handling within the hospital environment.

A key achievement of this project is the development of a functional prototype that integrates RFID readers with a backend server. This system enables real-time data retrieval and provides a user-friendly graphical interface for monitoring linen activities. The application supports connectivity between the RFID hardware and the server, ensuring seamless communication and data flow. Designed with simplicity in mind, the interface caters to users of varying educational backgrounds and facilitates efficient linen processing.

Testing results confirmed the system's effectiveness in detecting and managing linen tags within a controlled range. Although certain hardware limitations exist, the project presents a strong proof of concept with practical potential.

The entire project is scheduled for completion within eight months, aiming for a swift and impactful implementation that enhances the hospital's linen workflow.

7.2 Recommendation

Future work should focus on scaling the system for real-world deployment. This includes acquiring additional antennas and higher-grade RFID readers to enhance the scanning coverage and stability.

Incorporating user feedback from actual hospital staff will also be critical in refining the user interface and system usability. Additionally, transitioning the backend to a more scalable and standardized platform could help resolve current limitations in packaging and deployment. Further optimization of server-side performance and database queries will be essential to maintain speed and reliability as the number of RFID tags increases. Expanding the system to integrate with hospital ERP systems could provide even greater automation and data centralization.

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APPENDIX

User Manual

LinenTrack

User Manual

Table of Contents

1. Set Up

1.1 Hardware Requirements

1. RFID reader: emit radio waves and receive signals back from the RFID tag

2. Antenna: captures and transmits radio electromagnetic waves.

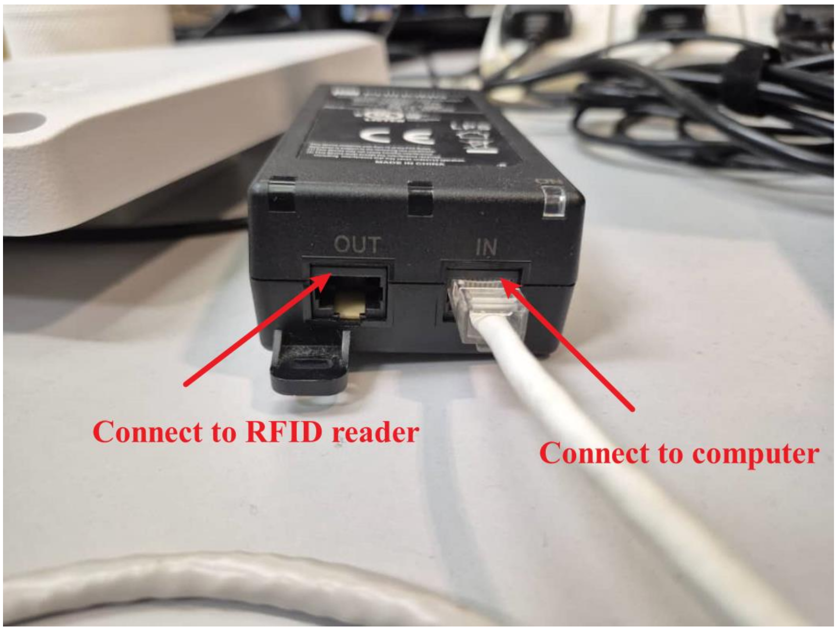
3. Ethernet cable: provide connection between two devices.

4. PPPoE power supply: provide power for the RFID reader.

1.2 Hardware Set Up

1. Connect **In** to the computer to provide a connection.

2. Connect **Ou**t to the device to provide power supply.



1.3 Software Set Up

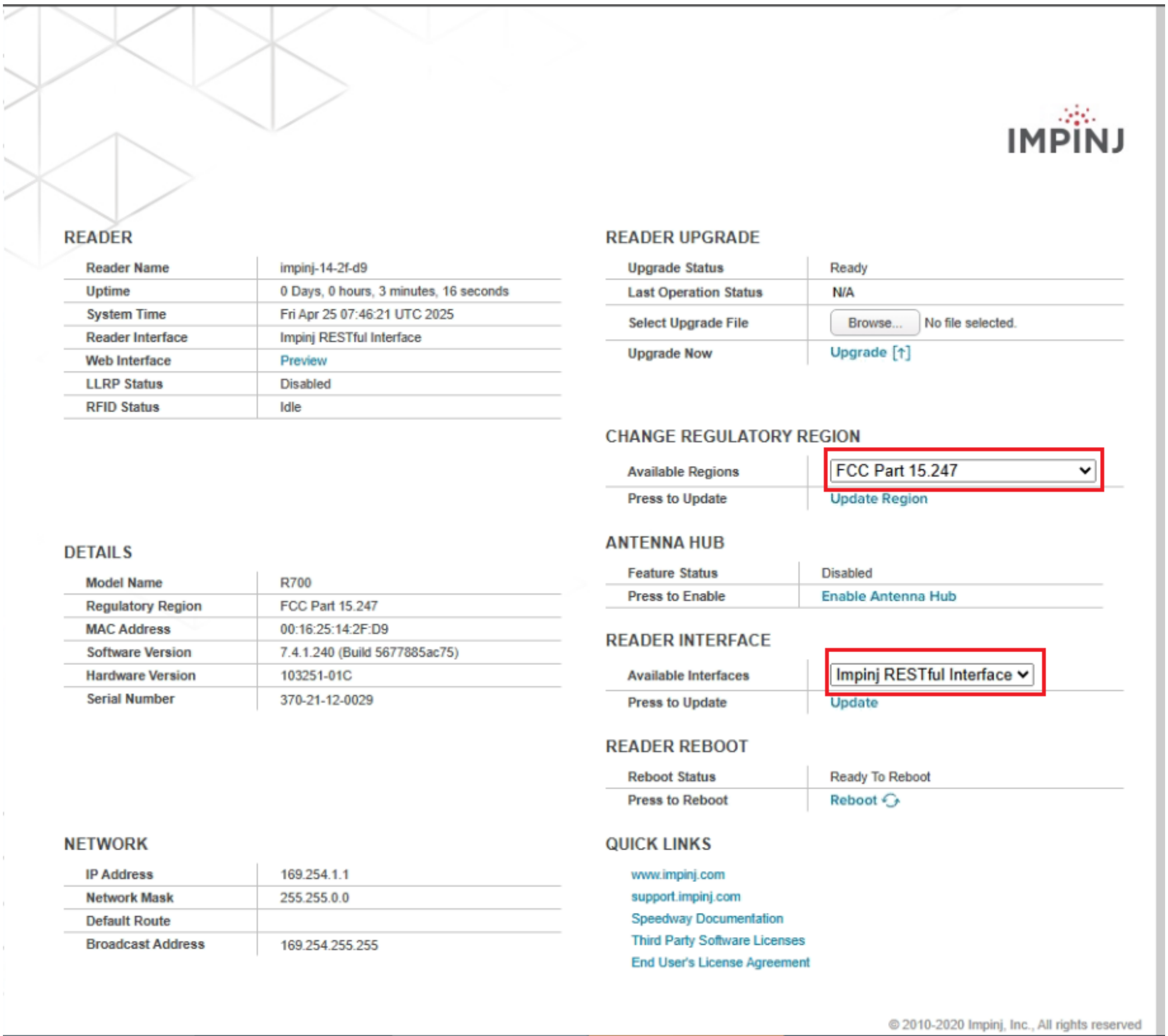
1. Check the connection between computer and RFID reader.

2. Open browser and enter http://impinj-xx-xx-xx.

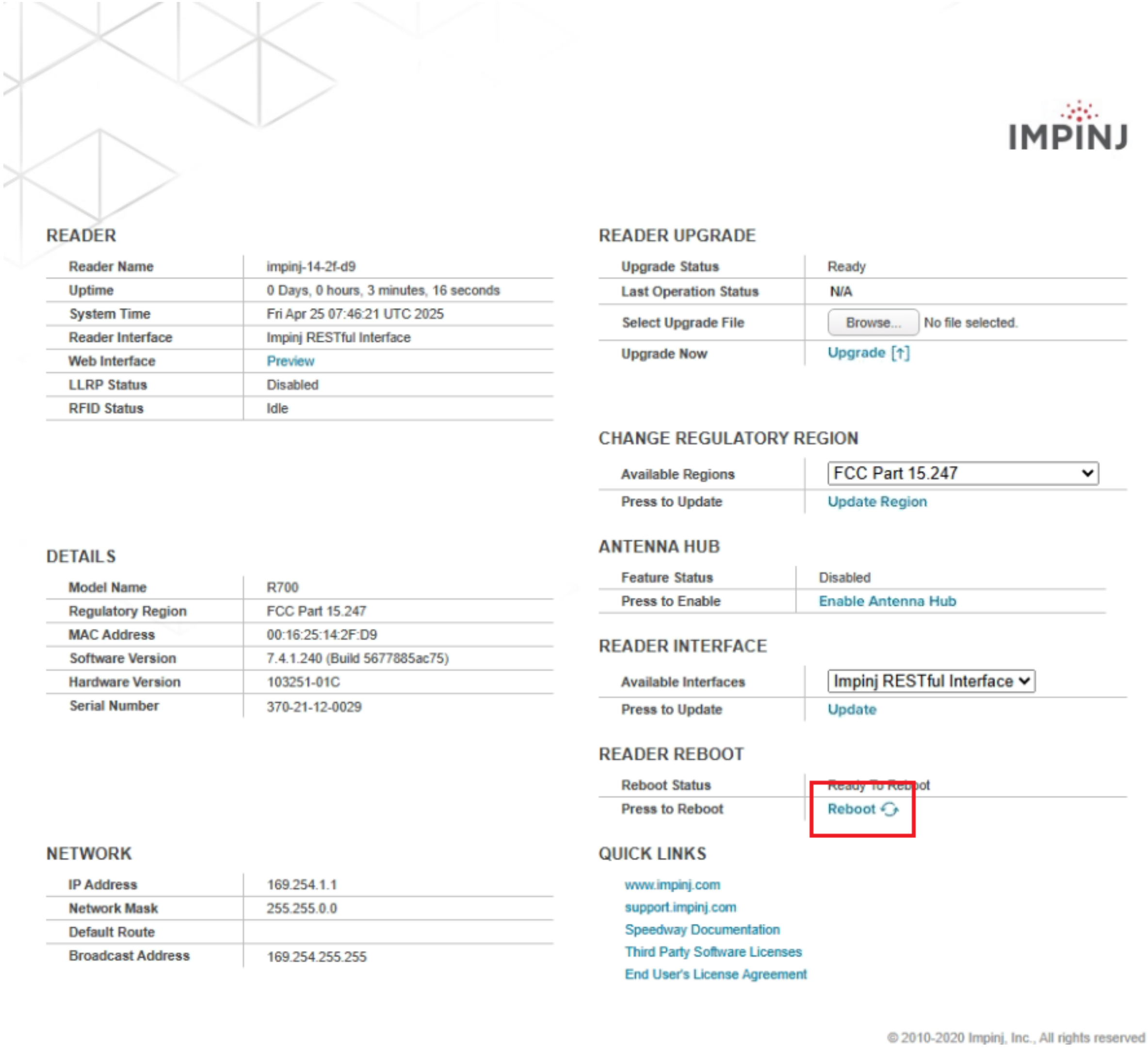
*** xx-xx-xx : Last 6-digits of RFID reader's Mac Address.**

3. Enter the default username and password. **Username: root, Password: impinj**

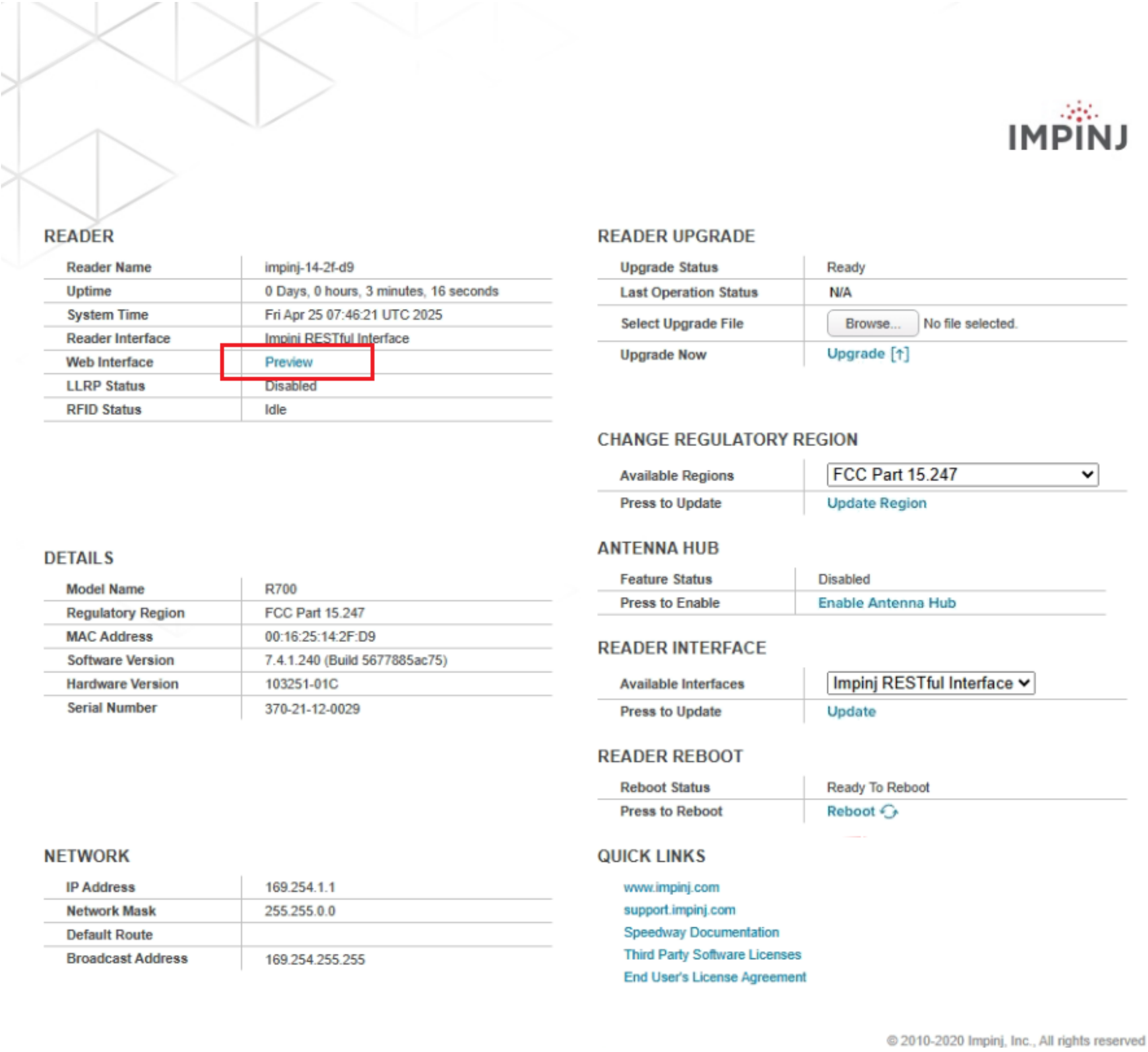
4. Change regulatory region to **FCC Part 15.247** and Reader Interface to **Impinj RESTful Interface.**



5. Click Reboot to activate the configuration that configure just now.



6. Click **Preview**.



7. Create New Inventory Preset by following

Preset ID: LinenTrack

Antenna Configurations

Antenna Port: 1

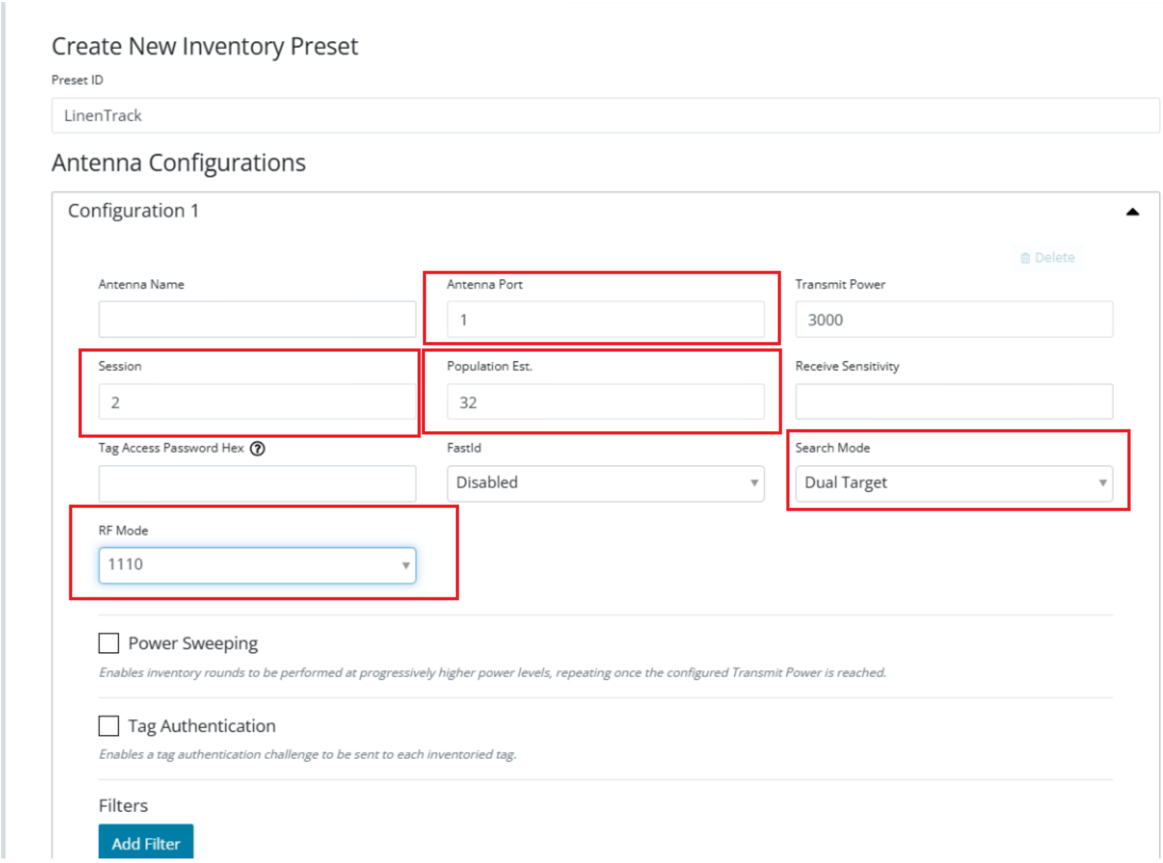
Transmit Power: 3000

Session: 2

Population Est.: 32

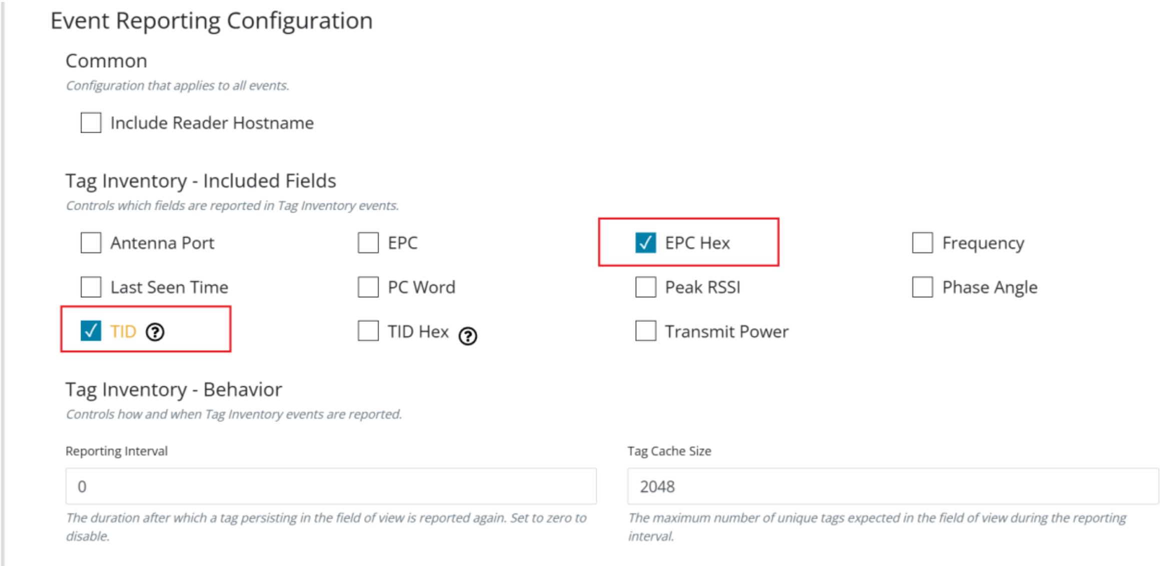
Search Mode: Dual Target

RF Mode: 1110



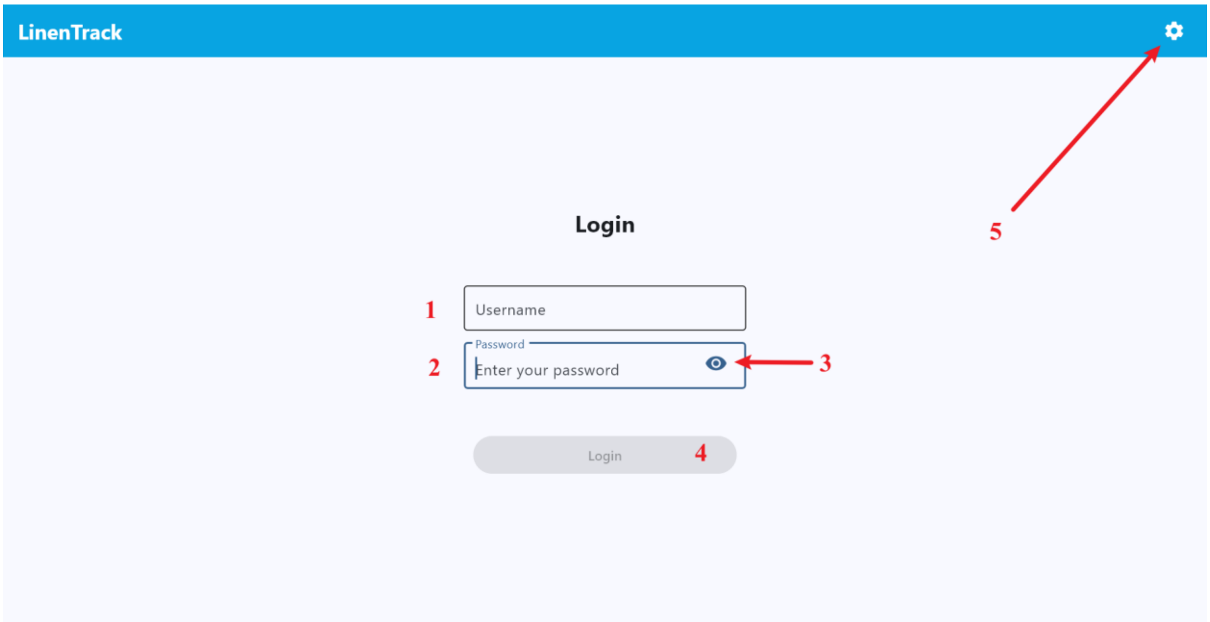
Event Reporting Configuration

Change **Tag Inventory** to **EPC Hex**.


Event Reporting Configuration
Common
Configuration that applies to all events.
Include Reader Hostname
Tag Inventory - Included Fields
Controls which fields are reported in Tag Inventory events.
Antenna Port
EPC
EPC Hex
Frequency
Last Seen Time
PC Word
Peak RSSI
Phase Angle
TID
TID Hex
Transmit Power
Tag Inventory - Behavior
Controls how and when Tag Inventory events are reported.
Reporting Interval
0
The duration after which a tag persisting in the field of view is reported again. Set to zero to disable.
Tag Cache Size
2048
The maximum number of unique tags expected in the field of view during the reporting interval.

2. Overview of User Interface

2.1 Login Page



1. Username Text Field: Enter username that exists on server with enough permission

2. Password Text Field: Enter password properly

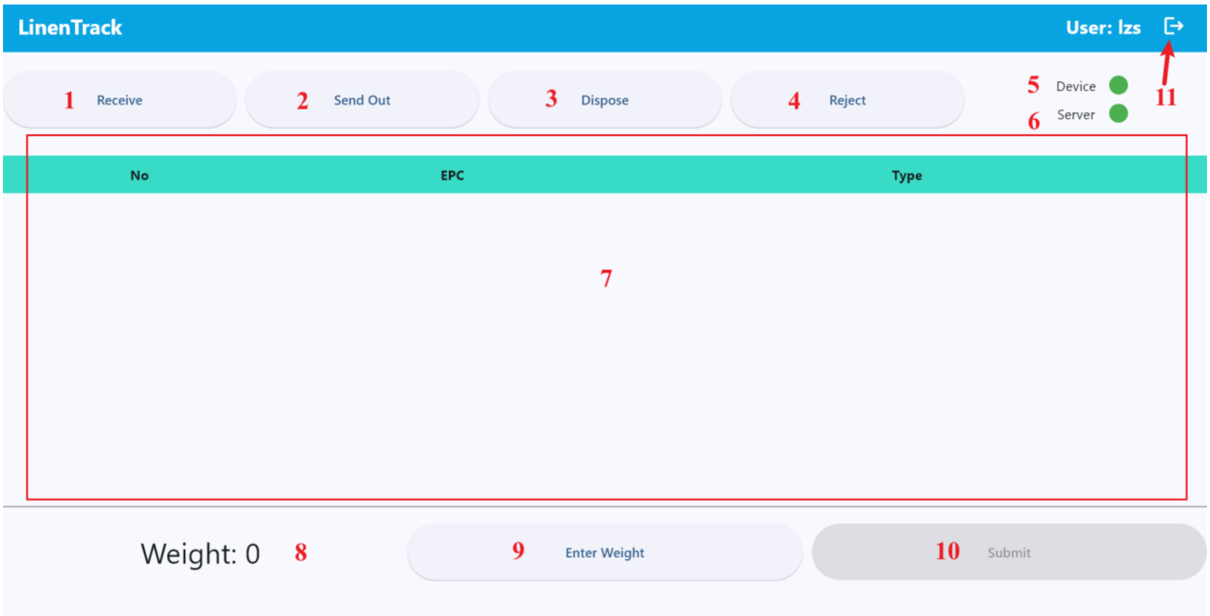
3. Visibility Toggle Button: Switch to show password in text form

4. Login Button: Click to proceed to login

*** Login Button only available to click when username and password was entered.**

5. Settings Button: Open settings

2.2 Home Page



1. Receive Button: Click to start scan RFID tags

2. Send Out Button: Click to start scan RFID tags

3. Dispose Button: Click to start scan RFID tags

4. Reject Button: Click to start scan RFID tags

5. Device Status Indicator: Show status of connection between device and application. Green: connected. Grey: disconnected.

6. Server Status Indicator: Show status of connection between server and application. Green: connected. Grey: disconnected.

7. Content List: A list includes the result of the scan

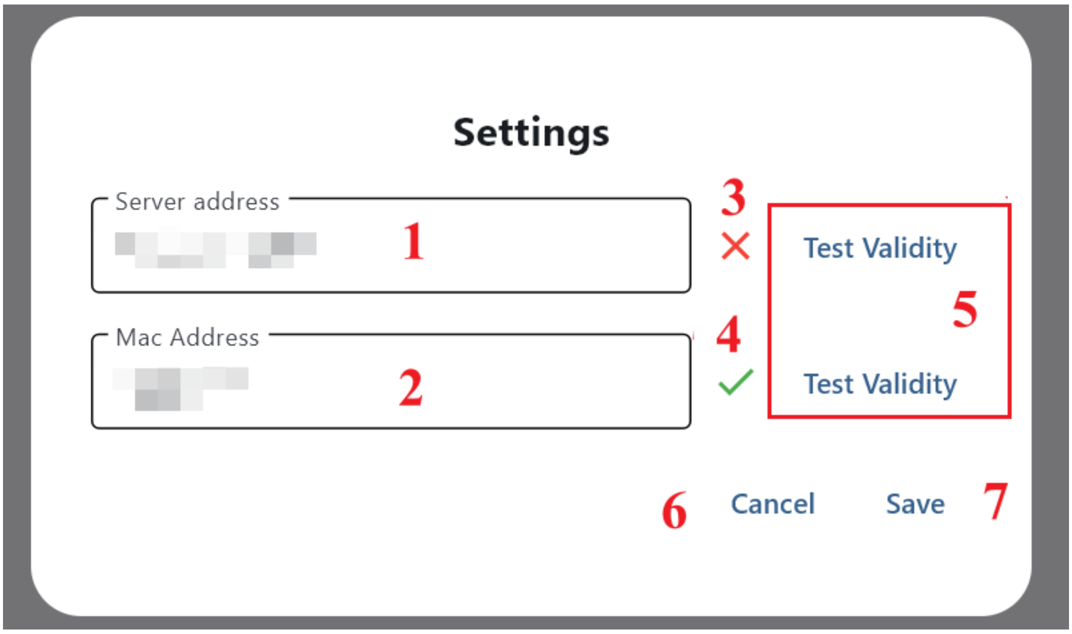
8. Weight Display: Show the weight that already enter

9. Enter Weight Button: Click to enter weight for this transaction

10. Submit Button: Click to submit the information to server

11. Logout Button: Click to logout and change to login page

2.3 Settings Dialog



1. Server Address Text Field: Enter server's IP address

2. Mac Address Text Field: Enter device's last 6 digit Mac Address

3. Fail Icon: Show unable to connect

4. Success Icon: Show connect successfully

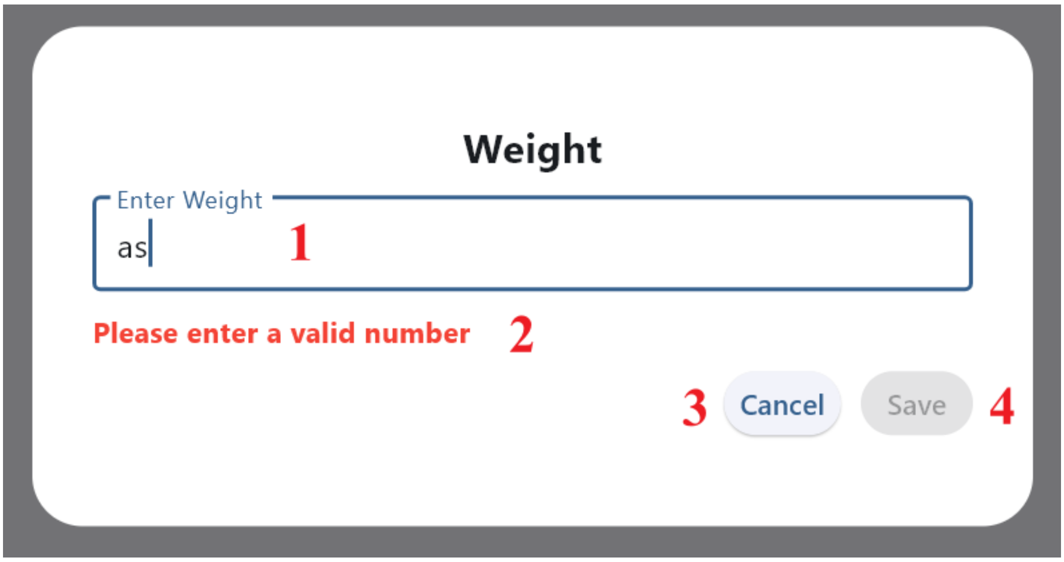
5. Test Validity Button: Click to test the connection

6. Cancel Button: Click to close settings

7. Save Button: Click to save configuration

***Configuration will take effect after clicking save button.**

2.4. Weight Dialog



1. Weight Text Field: Enter the weight

2. Error Display Field: Only show when input none of number format

3. Cancel Button: Click to close weight dialog

4. Save Button: Click to save the weight enter.

*** Save Button available to click only if a non-zero number is entered and the format is correct.**

3. How to Use

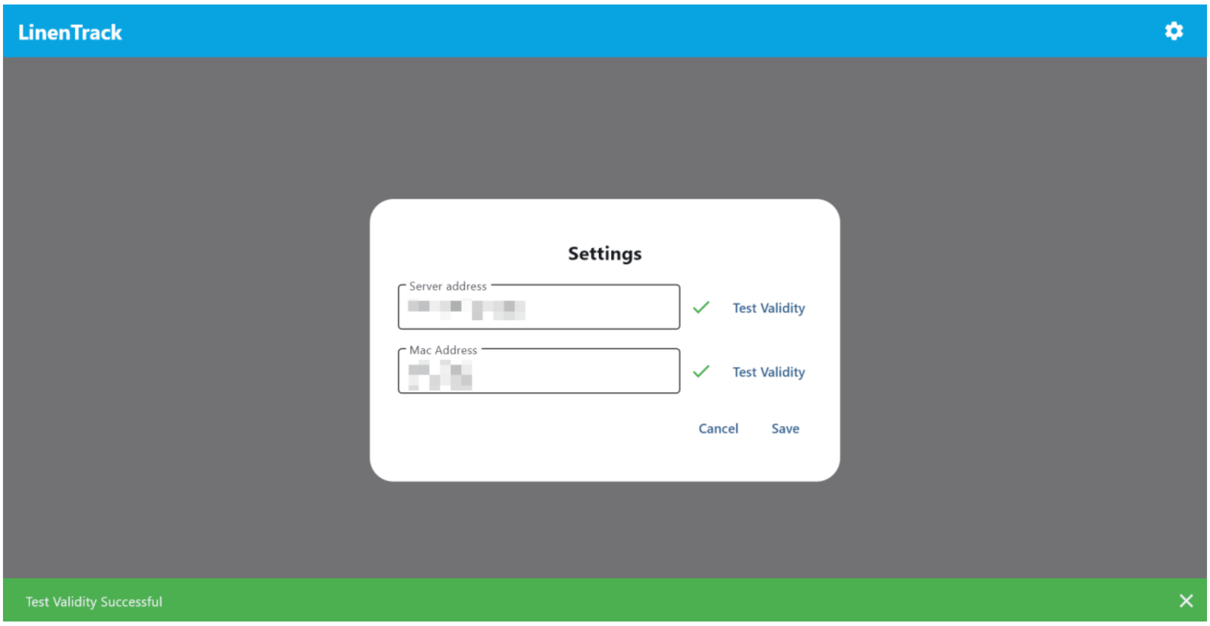
3.1 Step to setup application before use

1. Launch **LinenTrack.exe** application

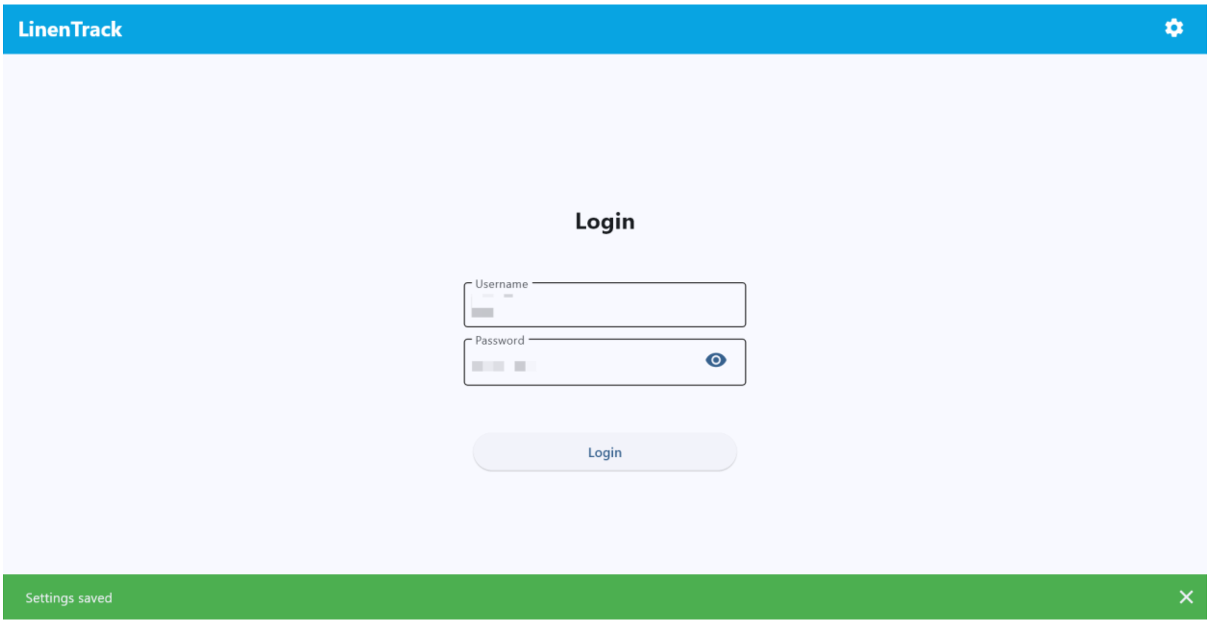
2. Click the **Settings** button.

3. Enter the **server IP address** and the **device MAC address**.

4. Click the **Test Validity** button to verify the connection.



5. Click **Save** to apply the configuration. A confirmation message will appear.



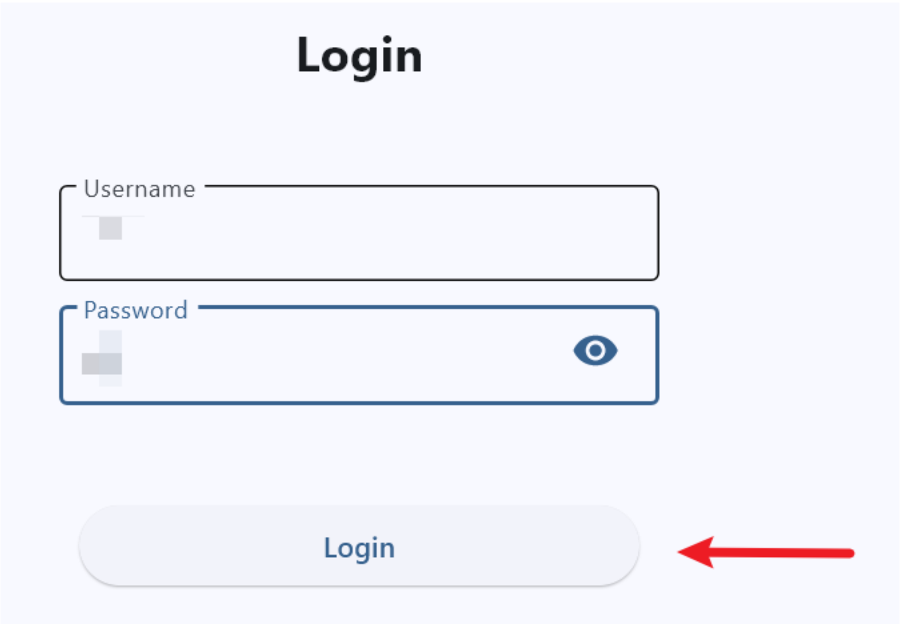
3.2 Logging In

1. Enter your username in the Username field

2. Enter your password in the Password field.

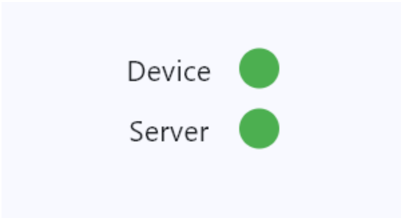
3. Once both fields are filled, the **Login** button will be enabled.

4. Click **Login** to sign in.

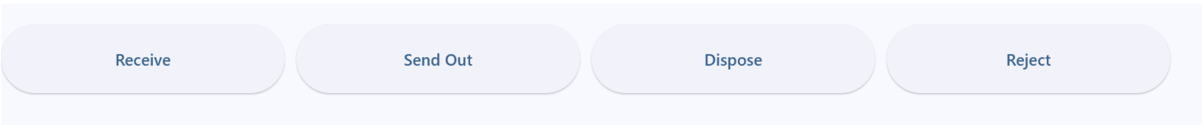


3.3 Scanning RFID Tags

1. Ensure the device indicator shows green (ready).



2. Select the desired function (Receive, Send Out, Dispose, Reject).



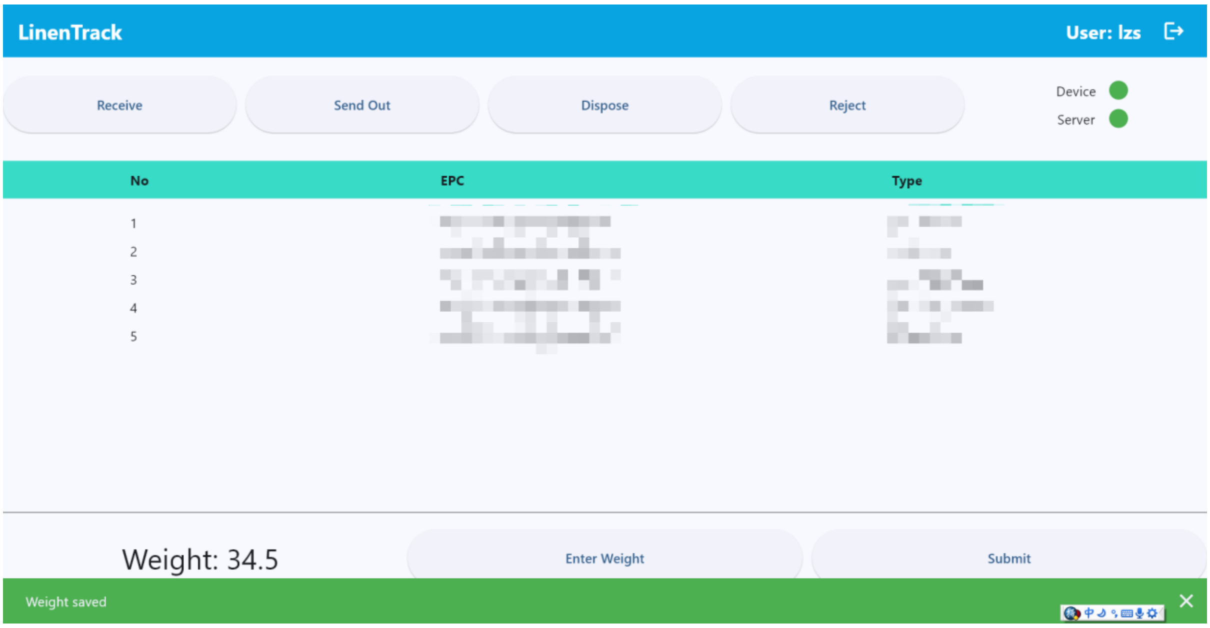
3. Wait a few moments for the content list to update.

3.4 Entering Weight

1. Click the **Enter Weight** button to open the weight dialog.

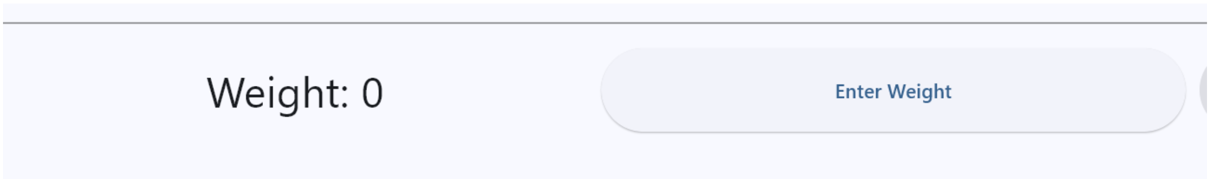
2. Input the weight (numerical format only).

3. Click **Save**. A confirmation will be displayed.

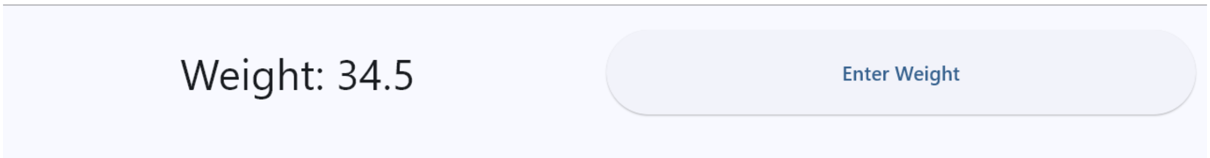


4. The weight display will update accordingly.

Before saved:



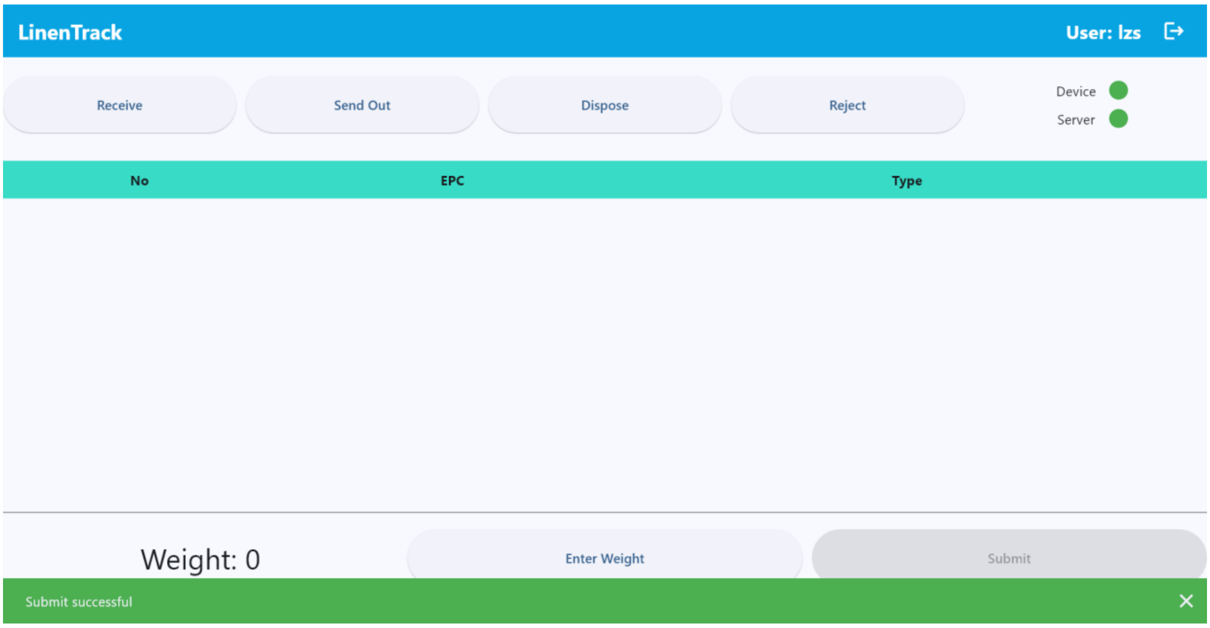
After saved:



3.5 Step to submit information

1. The **Submit** button will be enabled after scanning tags and entering weight.

2. Click **Submit** to upload the information to the server.



3.6 Steps to Logout

1. Click the **Logout** button.

2. You will be returned to the login page.

4. Common use cases

4.1 Receiving clean linen from the laundry.

1. Click the Receive button.

2. Ensure the RFID device indicator and server is green.

3. Scan the linen tags. The content list will populate.

4. Click Enter Weight, input the total weight, then click Save.

5. Click Submit to record the received linen data.

4.2 Sending used linen to the laundry.

1. Click the Send Out button.

2. Ensure the RFID reader and server is ready (green status).

3. Scan the outgoing linen tags.

4. Enter the weight and save.

5. Submit the data to update the server.

4.3 Handling broken or damaged linen.

1. Click the Dispose button.

2. Ensure the RFID reader and server is ready (green status).

3. Scan the broken/damaged linen tags.

4. Enter the disposal weight and save.

5. Submit the data for record-keeping.

4.4 Processing rejected or miscellaneous linen.

1. Click the Reject button.

2. Scan any rejected or uncategorized linen.

3. Ensure the RFID device indicator and server indicator is green.

4. Enter the corresponding weight.

5. Submit to finalize the status update.

5. FAQ

5.1 Failed connect to server

A: Check the server address and click Test Validity.

5.2 Internet connection Error

A: Ensure your computer is connected to the internet.

5.3 Invalid username or password

A: Double-check your login credentials.

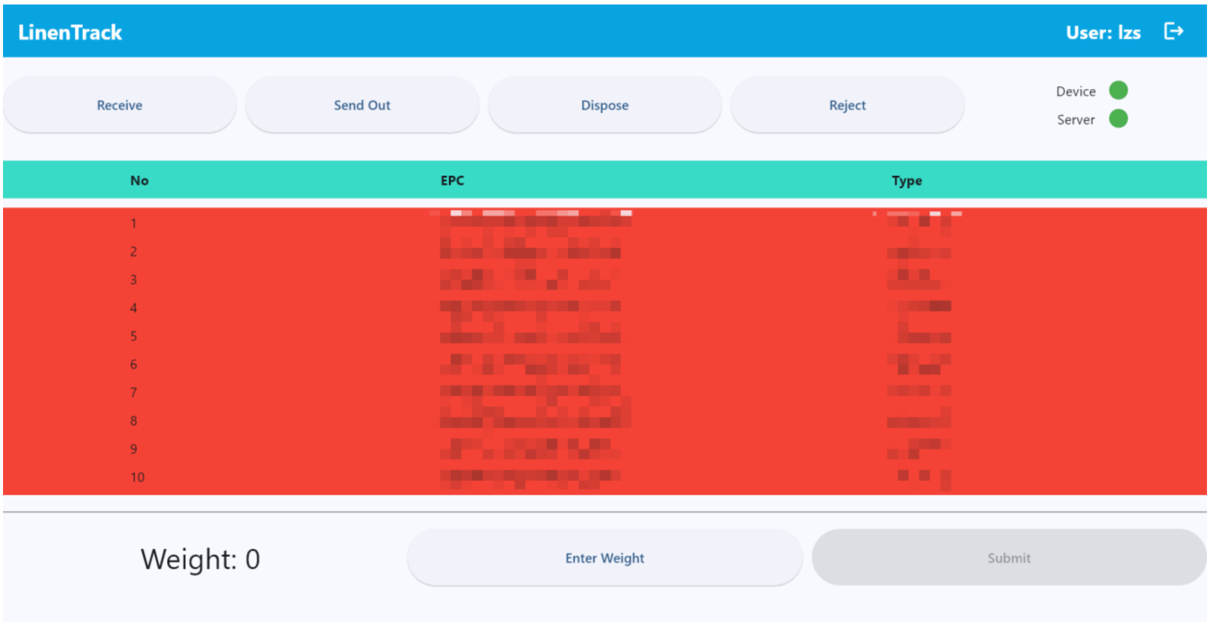
5.4 Not enough permission

A: Your account may lack necessary permissions. Contact your administrator.

5.5 No EPC detected

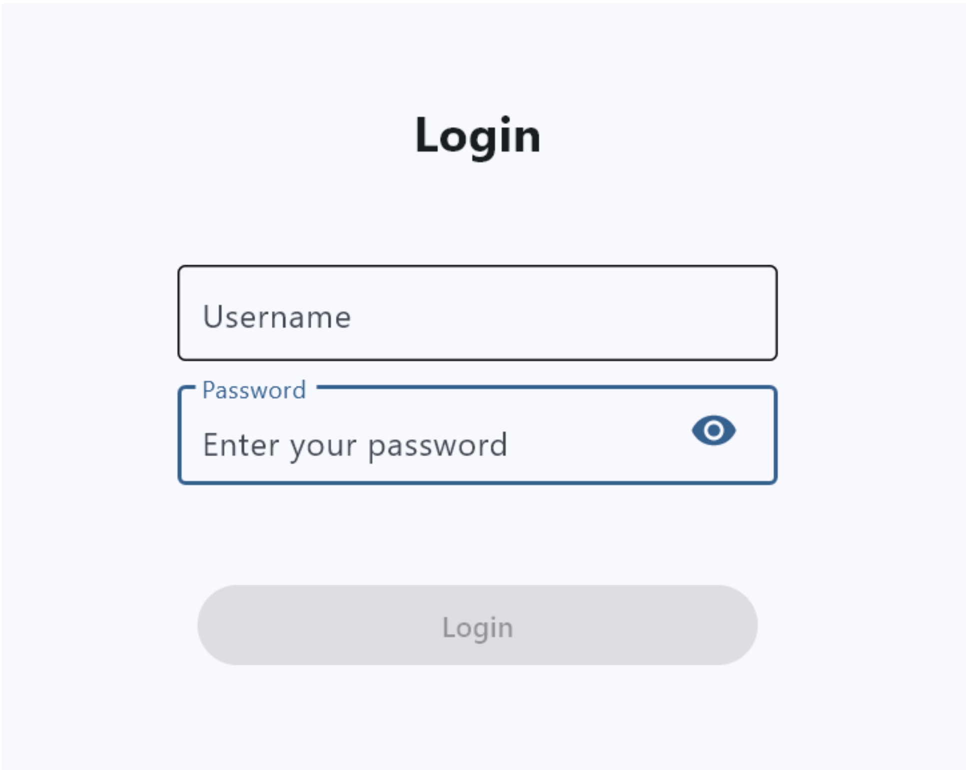
A: Ensure linen tags are within range of the RFID antenna.

5.6 Items highlighted in red



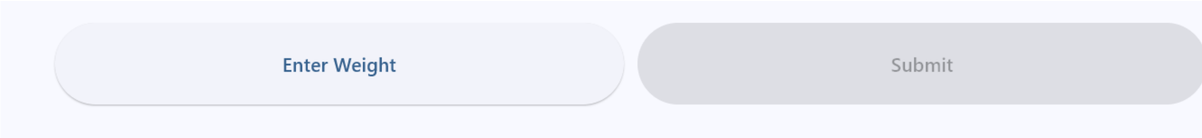
A: These tags may be unregistered or could not fetch data from the server.

5.7 Login button unable to click



Enter both username and password to enable the button.

5.8 Submit Button unable to click



A: Ensure you've scanned the tags and entered the weight.

5.9 Server disconnected during scanning

A: The server connection was lost. Please check your network and try again.

APPENDIX

POSTER