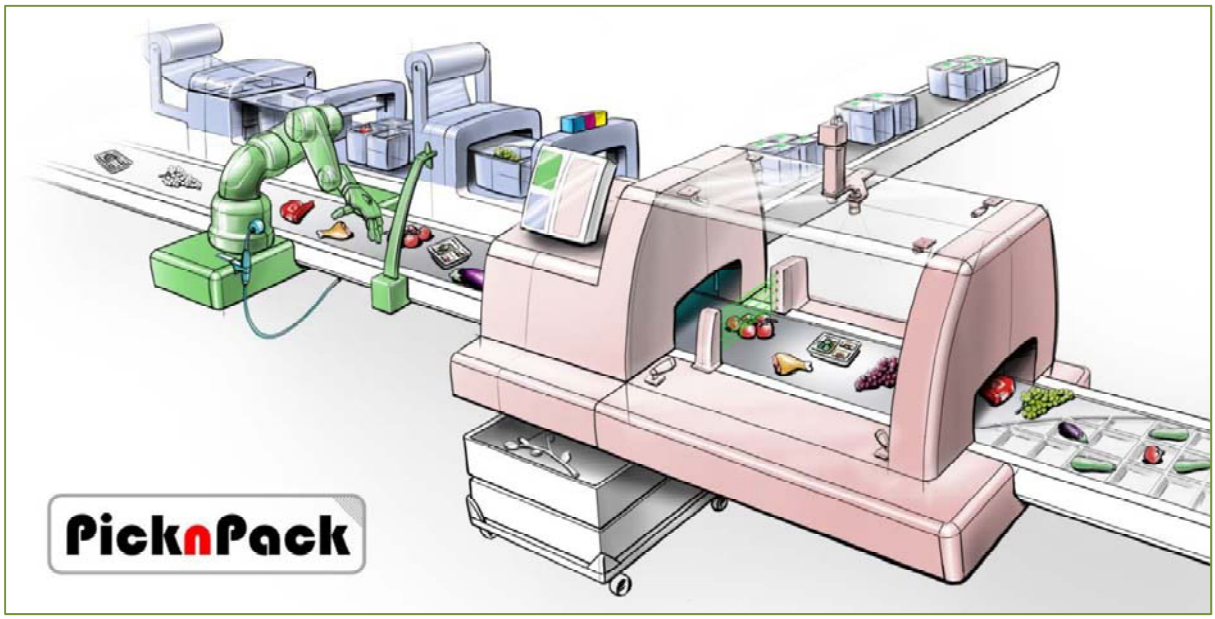
D3.4 – Report on RFID System Design and Implementation

Zhipeng Wu (UM), Zhaozong Meng (UM) and John Gray (UM)



Flexible robotic systems for automated adaptive packaging of fresh and processed food products

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Dissemination level		
PU	Public	X
PR	Restricted to other programme participants (including the EC Services)	
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Table of Contents

1. Introduction 1
2. Requirements Analysis 1
2.1 Why RFID? 1
2.2 Standards and Regulations 3
2.3 Requirements for RFID Traceability 4
3. Hardware Implementation 4
3.1 System Architecture Design 4
3.2 Hardware Module Selection 5
3.3 Network Connection 6
3.4 RFID Placing in Production Line 7
4. Functionality and Interface Design 7
4.1 Functionality 7
4.2 Process Model 8
4.3 Operation Interfaces 10
5. Implementation of RFID in Traceability Application 11
5.1 Tools and Methods 11
5.2 Functions 12
5.2.1 RFID Configuration 13
5.2.2 Container Registration 14
5.2.3 New Material Registration 15
5.2.4 Subdivision 16
5.2.5 Packaging 17
5.2.6 Logistical Unit 20
5.2.7 Delivery 21
5.2.8 Query/Search 22
6 Test 25
7 Summary 26
References 27
Appendix 28
1. Specifications of ALR-9900+ 28
2. Specification of ALH-9011 28
3. Specification of PN6-868LPC-1C-WHT-6 30

1. Introduction

This document outlines the progress of the traceability system design for WP3 on Radio Frequency Identification (RFID) system design and implementation and in particular the completion of the tasks defined in the WP3.3:

- Task 3.3: RFID Systems Implementation (M24)
  - System design and configuration
  - Hardware implementation of UHF and HF system
  - Software for interfacing with database
  - Remote data transmission
  - Laboratory testing

The associated milestone has been achieved and it is discussed in this report:

- M3.3: RFID System in place (M24)

A RFID enabled traceability system is developed by integrating the RFID hardware and software modules with the traceability application and database system. By locating the RFID hardware modules (readers and antennas) in the production line, the system can create records in database and provides interfaces to retrieve the information.

Further details are provided in the following sections.

2. Requirements Analysis

Before the design and implementation, this section illustrates some critical issues in the development for preparation. The critical issues needs to be considered regarding RFID for this project are:

- Why RFID? the feasibility
- Regulatory constraints on the use of RFID
- Requirements and objectives of the RFID traceability system

2.1 Why RFID?

The history of RFID can be traced to 1945. But the abbreviation 'RFID' is coined by Charles Walton in 1983 [1]. RFID is a wireless use of electromagnetic fields to transmit data, for the purpose of automatically identifying and tracking tags attached to objects. Due the technical progress in RFID and related areas, it is increasingly used in logistics, access control, smart cards, person and animal tracking, airport baggage tracking, etc.

(1) Advantages

The advantages of the RFID systems in relation to other identification systems currently in use and especially barcode are [2]:

- Battery-less, supply voltage derived from the RF field
- No line-of-sight required for the communication
- Large operating and communication range
- Read and write capability of the transponder memory
- High communication speed
- High data capacity (user memory)
- Data encryption/automation capability
- Multiple tag read capability with anti-collision (50-100 tags)
- Durability and reliability
- Resistant to environmental influence
- Reusability of the transponder
- Hands free operation
- Miniaturised (IC size < 1 mm^2)
- Very low power

In addition to the above items, the cost of RFID tags decrease with advance of technology. The current price of UHF passive tag is about $0.15 -$0.5. The low cost also promotes the wide use of RFID technology.

(2) EPC Gen2

EPC Gen2 is short for EPCglobal Ultra High Frequency (UHF) Class1 Generation 2. Electronic Product Code (EPC) is one common type of data stored in a tag. The EPCglobal Tag Data Standard defines representations of an EPC identifier, such as the tag-encoding URI format and a compact binary format suitable for storing an EPC identifier efficiently within RFID tags [3].

When EPC is written into the tag by an RFID printer, the tag contains a 96-bit string of data. The first eight bits are a header which identifies the version of the protocol. The next 28 bits identify the organization that manages the data for this tag; the organization number is assigned by the EPCglobal consortium. The next 24 bits are an object class, identifying the kind of product; the last 36 bits are a unique serial number for a particular tag. These last two fields are set by the organization that issued the tag. Rather like a URL, the total electronic product code number can be used as a key into a global database to uniquely identify a particular product [4].

2.2 Standards and Regulations

The use of RFID technology needs to follow some standards and regulations which are given as follows:

(1) Regulatory constraints on the use of RFID [5]

A number of organizations have set standards for RFID, including the International Organization for Standardization (ISO), the International Electro-technical Commission (IEC), ASTM International, the DASH7 Alliance and EPCglobal.

In principle, every country can set its own rules for frequency allocation for RFID tags, and not all radio bands are available in all countries. These frequencies are known as the Industrial Scientific and Medical (ISM) bands. The return signal of the tag may still cause interference for other radio users.

Table 1 Available Operating Frequency and Channels for UHF RFID in Different Regions

	Europe	North America	Japan	Australia	India
Band (MHz)	866-868	902-928	952-954	918-928	865-867
Power	2W ERP	4W EIRP	4W EIRP	4W EIRP	4W EIRP
Channels	10	50	TBD	16	10

Standards that have been made regarding UHF RFID include:

- ISO/IEC18000-6: Radio Frequency Identify for Item Management – Part 6: Parameters for Air Interface Communications at 860MHz-960MHz
- EPC Radio-Frequency Identity Protocol Generation-2 UHF RFID – Specification for Air Interface Protocol for Communication at 860MHz – 960MHz

(2) Human Exposure to Electromagnetic Compatibility and Radio Spectrum Matters (ERM) Standards [6]

Human exposure to electromagnetic fields from devices operating in the frequency range 0Hz to 10GHz, used in Electronic Article Surveillance (EAS), RFID and similar applications:

- EN 62369-1: 2009 - Evaluation of human exposure to electromagnetic fields from short range devices (SRDs) in various applications over the frequency range 0 GHz to 300 GHz. Fields produced by devices used for EAS, RFID and similar systems
- EN 50364 : 2010 - Limitation of human exposure to electromagnetic fields from devices operating in the frequency range 0 Hz to 300 GHz, used in EAS, RFID and similar applications

This is effectively a product compliance standard – requiring compliance with EU Council directives 72/23/EEC & 1999/5/EC.

2.3 Requirements for RFID Traceability

In addition to the standards and regulations, this RFID traceability also needs to fit the production line process. The requirements and also objectives of the RFID traceability system can be summarised as below:

- Fit the production line process seamlessly
- Tracing information efficiently without increasing human effort in operation
- Be compatible with the database system
- Be compatible with the traceability software application

To meet the above requirements, the RFID traceability system is designed based on the database established and the traceability software application developed which are reported in D3.1 and D3.2 of this project.

The RFID traceability module is added to and integrated with the functional modules of the traceability application. Details of the system design are given in the following sections.

3. Hardware Implementation

Based on the regulations and requirements, this section gives the major concerns on hardware implementation of the traceability system: system architecture design, network connection, hardware modules selection, and antenna placing in production line.

3.1 System Architecture Design

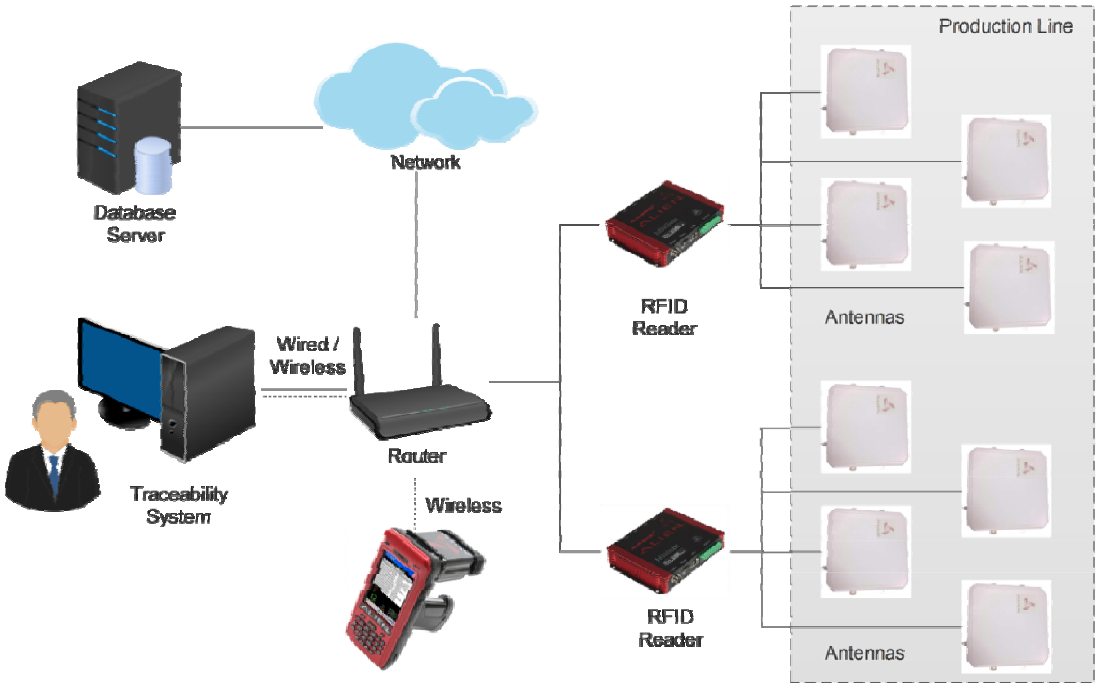


Figure 1 System Architecture of RFID Traceability System

The system architecture is designed as shown in Figure 1. The whole system is working within a local area network. The RFID readers with antennas located in the production line can be managed by the traceability application, and information is collected and processed by the application. Product information with tag IDs are recoded in the database which can be accessed by the traceability application and the handheld reader application.

3.2 Hardware Module Selection

The performance of the traceability system is determined by the hardware modules, software, and the collaboration of them. To select the suitable hardware modules, some critical issues affecting performance of the system are given in Figure 2.

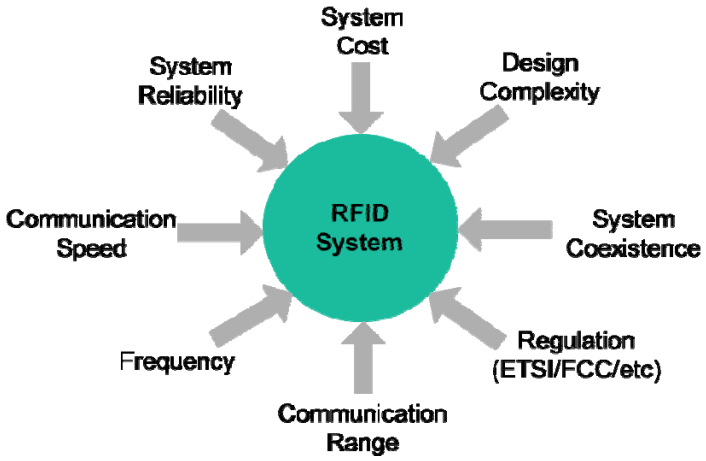


Figure 2 RFID Selection Parameters

Regarding the above concerns, some state-of-the art commercial hardware modules by leading RFID manufactures are selected to establish the system. The hardware modules selected are listed in Table 2.

Table 2 Hardware Modules Selection in the System

RFID Hardware	Model / Type	Manufacture
Fixed Reader	ALR-9900+	Alien Technology
Handheld Reader	ALH-9011	Alien Technology
Antenna	PN6-868LCP-1C-WHT-6	Mobile Mark
Tags	EPC Gen-2	

Specifications of the fixed reader, handheld reader, and antenna are given in the Appendix [6-8]. From the specification, the reader and antenna all supports the UHF frequency in Europe and both readers supports EPC Gen-2 tag data protocol.

The fixed reader ALR-9900+ supports multiple antennas, and it is strong in computation and communication. The handheld reader ALH-9011 with windows mobile 6.5 operating system supports barcode and QR code scanning, RFID recognition, and communication with Wi-Fi

and HSDPA. The device capability of both the fixed reader and handheld reader creates more space for the development of traceability system based on them.

3.3 Network Connection

The network topology of the system is designed as shown in Figure 3. The RFID modules, traceability applications are located in the production lines. All production lines create data in remote servers. Users just need to maintain the RFID hardware modules and the traceability applications and leave the servers to professional operators.

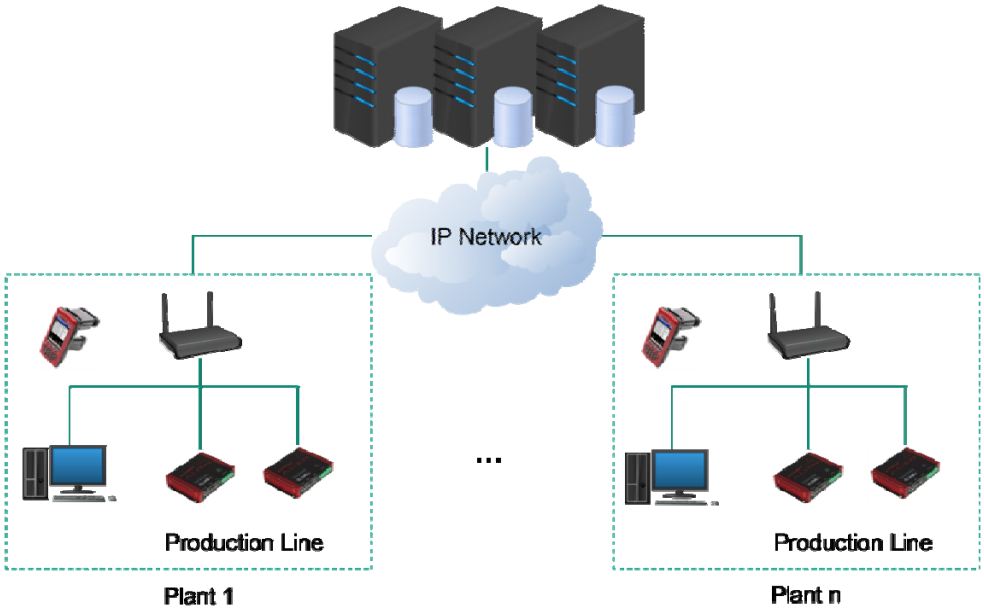


Figure 3 Network Topology

Between the components of the system, communication and command are conducted with TCP, UDP, and TCP/IP protocols. As shown in Figure 4, the RFID reader notifies the traceability application PC with UDP heartbeat signal in XML format [9]. The traceability application then establishes a TCP connection for configuration and tag information listening. The communication between PC and database server is through TCP/IP, which is not difficult to implement with Visual C# .NET environment.

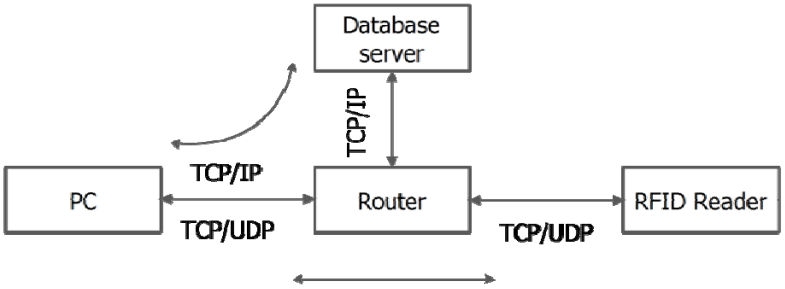


Figure 4 Component–level Communication Protocol

3.4 RFID Placing in Production Line

As shown in Figure 5, the RFID antenna is installed in the production line to read the tags stick on the product objects. The antenna should be installed in a location where the radiation can cover all possible locations that products may appear when they go through.

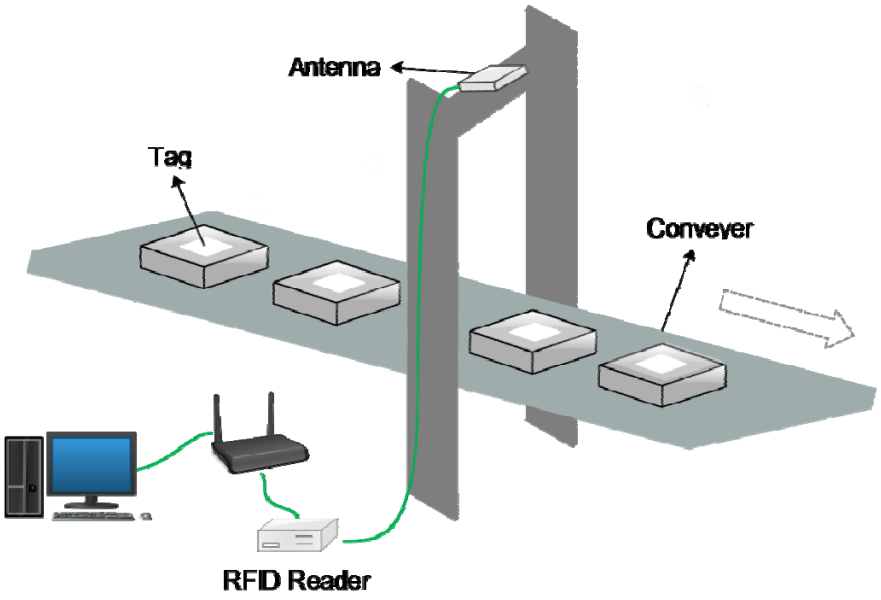


Figure 5 Antenna Placing

By placing the antennas in the appropriate location, all passing objects with tags can be recorded without human assistance.

4. Functionality and Interface Design

When the hardware system architecture and RFID module is in place, this section discusses functionality design, process model, and interface design of the system.

4.1 Functionality

The main task of the system is to track the RFID tag information, keep records in database, and assist the production line process. So, from the perspective of data flow and user operation, the system can be described with diagram in Figure 6. The system mainly consists of four modules: traceability software application, handheld reader application, database, and RFID module.

This system is required to be able to track the product information automatically when the production line is running. By locating the antennas in the production lines, the product with RFID tags are recorded and stored to the database automatically. Then, all related information such as supplier information, weight and quality, price, logistic unit information, and other optional information are linked together with few human assistants.

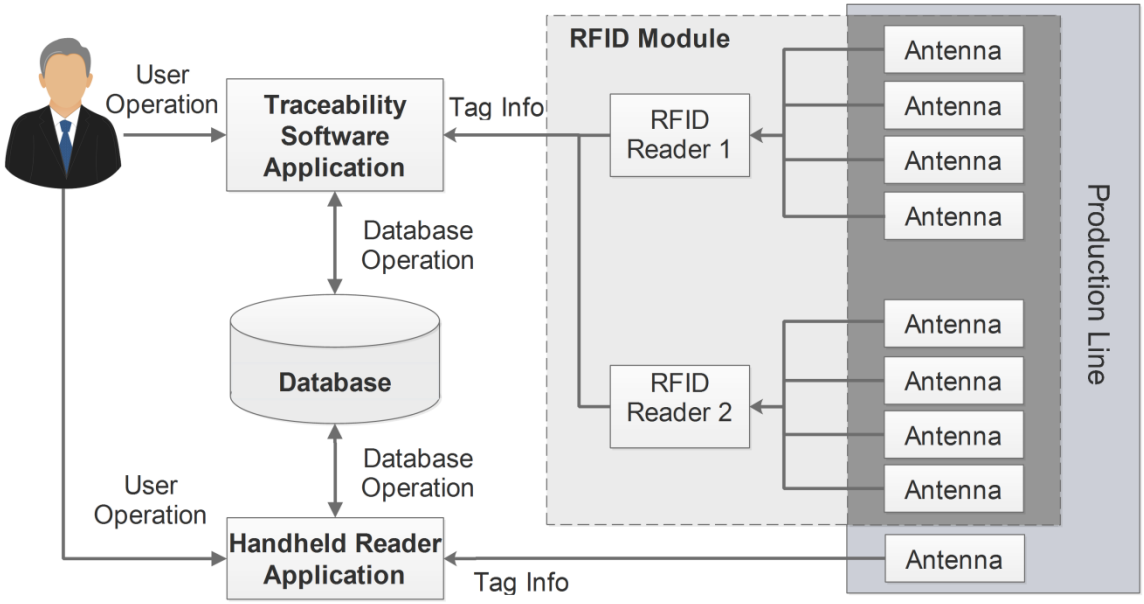


Figure 6 Functional Modules

The function of the RFID tracking system is to record tag ID at different procedures of the production line process, and then provide all related information with the tag IDs. The processes in the information tracking with RFID are summarised as follows:

- New material subdivision
  With the RFID detected containers, the source material can be put into containers before packaging.
- Packaging
  After providing the product information in 'Batch Setting' and 'Package Setting', user can start the system for packaging recording to create records in database.
- Logistic unit
  User can select detected available containers and register selected containers as a logistic unit.
- Delivery
  User can select a customer and sending place to create a database record of dispatching a logistic unit.
- Scan and Query
  With unique RFID tag IDs, all related information stored in database can be retrieved with the traceability application or a handheld reader.

In all the above steps, the RFID tag ID is unique information to associate the different process and track the objects automatically in the production line.

4.2 Process Model

(1) Process Model of Traceability Software Application

With RFID devices implemented in the traceability system, the production line process is then assisted with the RFID modules and product information is recorded in database automatically. The process model is designed as shown in Figure 7. The components with RFID icons are the processes enhanced with RFID tracing, and those without RFID icons are operated by human only.

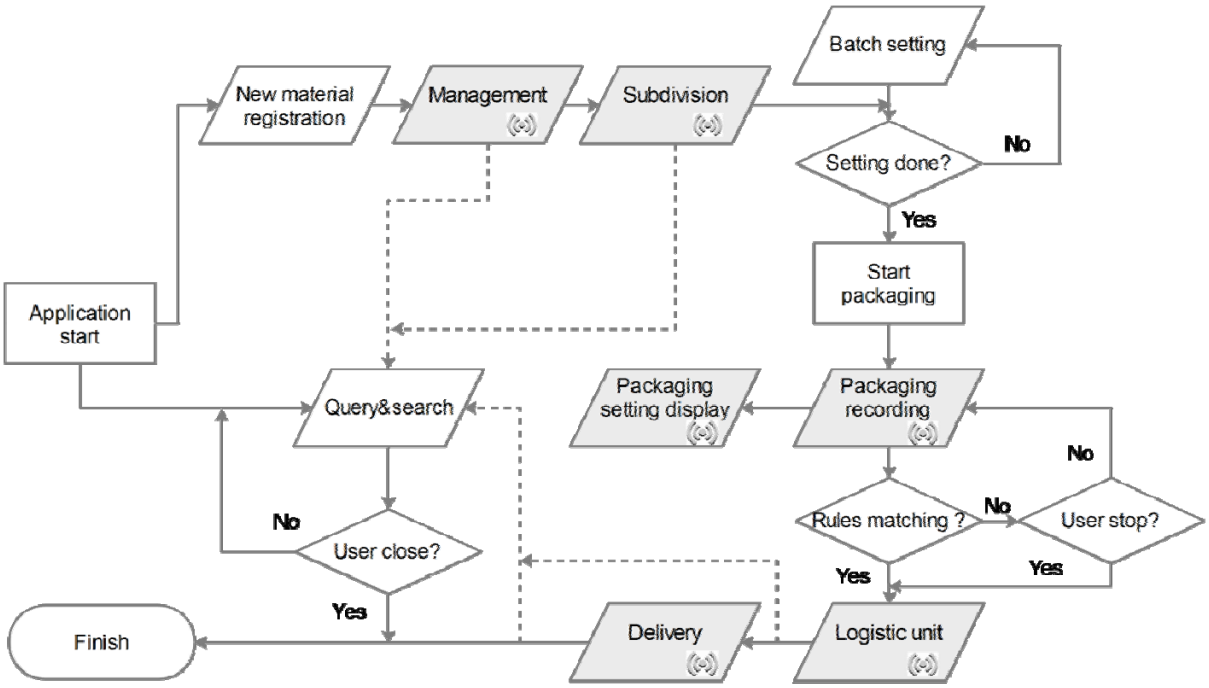


Figure 7 Process Model of the RFID Traceability System

When new material for packing arrives, users need to manually register the materials with the system. The containers are also registered with RFID tags in the management process. Then, after the batch setting, the packing job can be started by clicking the 'Start' button. The RFID detected available container can be registered as logistic units by clicking 'Register' button. Users can then select a valid customer and a sending place to create a record of dispatching a logistic unit by clicking 'Send' in delivery window.

All through the process, user can monitor the information by query & search function. The records of registered containers in management, containers for subdivision, packaging jobs, logistic units, and sent delivery units can be searched and checked by object IDs or tag IDs.

(2) Flowchart of Handheld Reader Application

For handheld reader, some lightweight functions are designed and implemented for object registration and information tracking. The flowchart of the handheld reader application is given in Figure 8. Users can register new materials and containers with RFID tag using the built-in RFID module. User can also use the handheld reader to track product and container information. The detail information of the RFID enabled object is displayed on the interface

once the RFID is recognised. In addition to RFID tags, handheld reader can also track basic product information by decoding QR code using built-in camera.

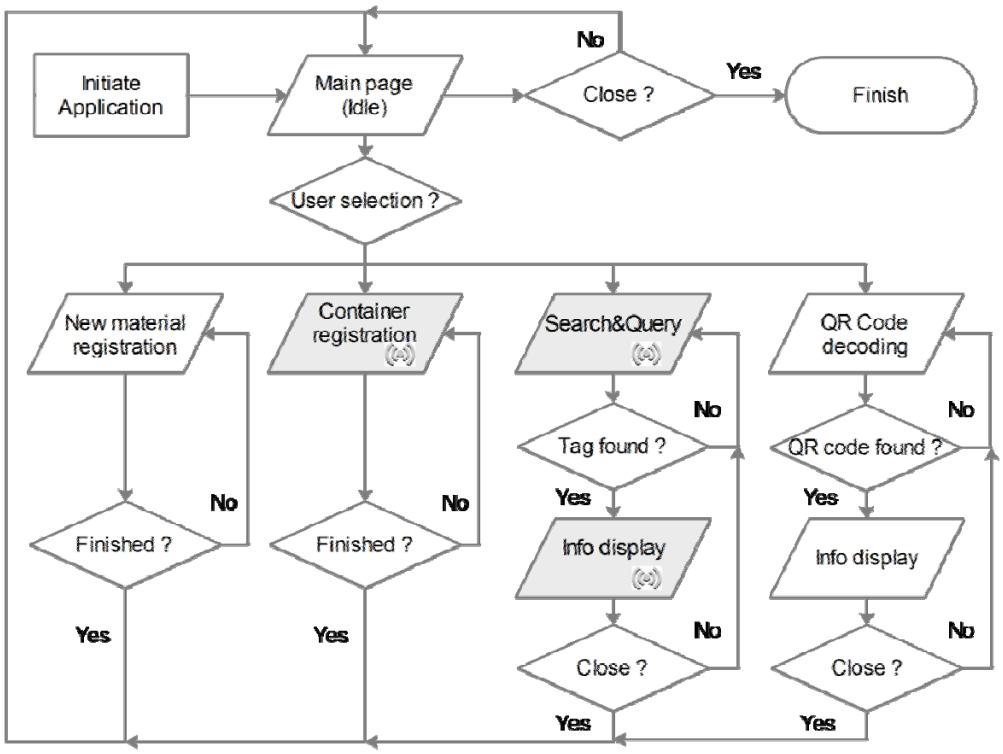


Figure 8 Program Flowchart of Handheld Reader Application

4.3 Operation Interfaces

According to the process model presented in the above sub-section, the main interface and interfaces for all the processes are designed. The design of the interface follows the guide lines as below:

- Easy to operate and user friendly
- Modular design for fast development and easy maintenance
- Separate interface for each operation process

The main interface of the RFID traceability system is as shown in Figure 9. There are interfaces for the processes of new material registration, subdivision, packaging setting, logistic unit, delivery, management, batch setting, scan & query, and RFID setting. The interfaces for each operation process can be called out by clicking the buttons on the top.

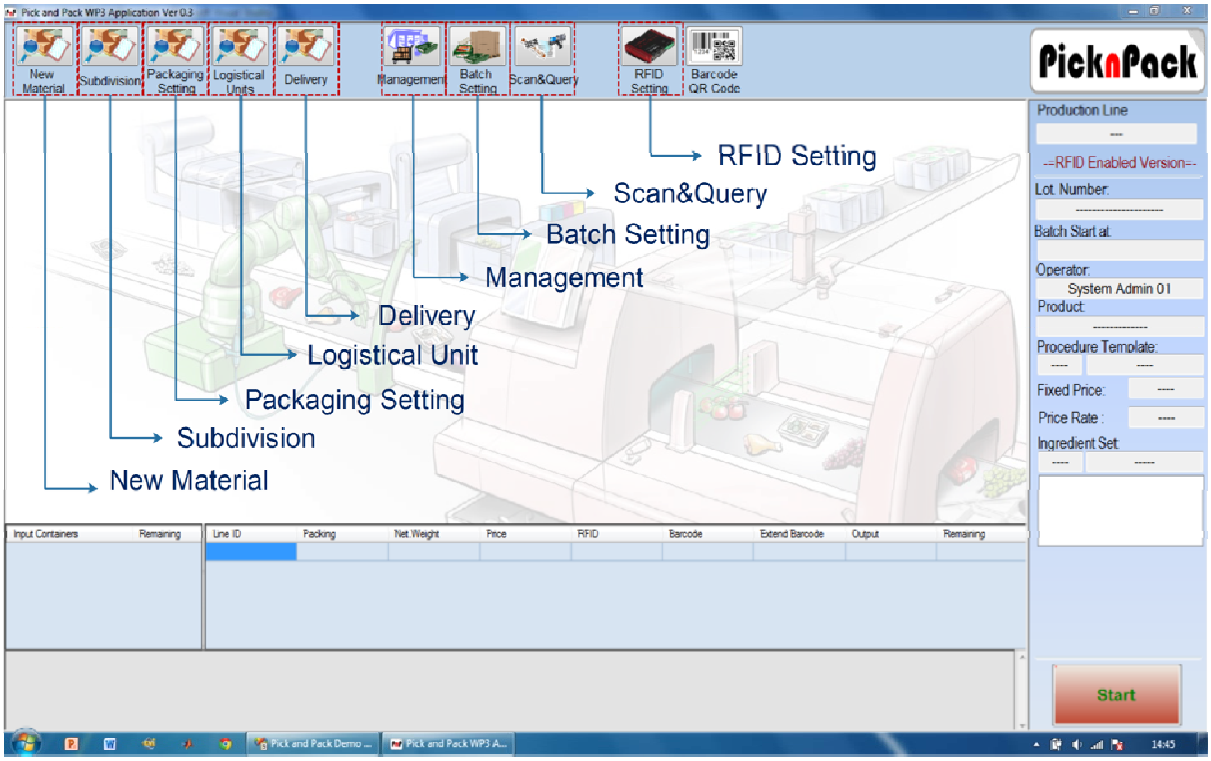


Figure 9 Main Interface

The separate interface for each operation process is given in the following section.

5. Implementation of RFID in Traceability Application

5.1 Tools and Methods

(1) Development Tools

The RFID traceability application is implemented with the Visual C# .NET and the database is implemented with SQL Server 2008. The handheld reader application is also implemented with Visual C# .NET.

Alien Technology provides the Dynamic Link Library (DLL) files for RFID reader development [10, 11]:

- AlienRFID2.dll - DLL for programming fixed readers operation in .NET
- CRfidApi.dll - DLL for programming handheld reader RFID recognition in .NET
- CBarcodeApi.dll - DLL for programming handheld reader barcode scanning in .NET

With the DLL files, some classes and methods can be used directly by importing the libraries. Developer can focus on the software framework, functionality, and user interface of the software to guarantee the efficiency and user experience of the system.

(2) RFID Reader Management

The flowchart of the traceability application managing the RFID reader is given in Figure 10.

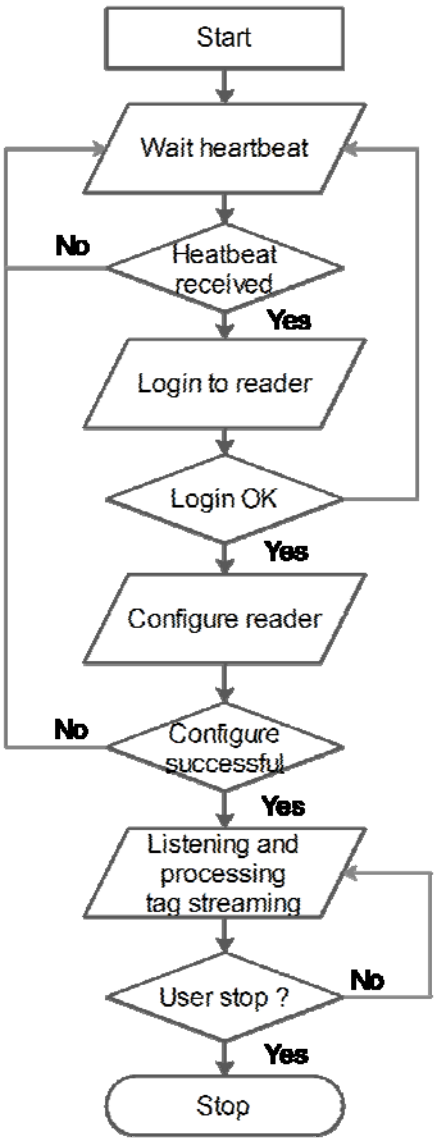


Figure 10 Flowchart of the RFID Reader Management

When the reader is switched on, it sends out heartbeat information (containing reader name and IP address, etc.) in XML format to specific port in the sub-net. The PC with the traceability application can then receive the heartbeat signal and build connection with the reader. When the connection is established, the traceability can configure the reader to a particular working mode and then listen to the signal from the reader. The RFID reader is then successfully configured and the tag information in streaming can be received by the traceability application with specified data format.

5.2 Functions

The functions of the system mentioned in section 4 are implemented. The details of the functions are given as follows with screenshots.

5.2.1 RFID Configuration

Before the RFID hardware modules can be used for information tracking, they need to be configured. The configuration consists of two steps:

- RFID reader initiation, and
- Reader/antenna location setting

RFID reader initiation is to connect to the RFID reader and configure some parameters with protocols and command sets of the reader. This process is completed with a background thread automatically without users' attention. When the initiation is finished, the readers and their state are shown in the interface for the user to perform the further operations.

In order to provide an interface for the users to observer the RFID readers and the tags recognised, a 'RFID Configuration' window is designed as shown in Figure 11. In this interface, (1) is shows the reader information, (2) lists the state change of the readers with timestamp, (3) shows the raw tag messages, (4) gives the unused tag items with locations, (5) provides the object item messages, such as internal containers and external containers.

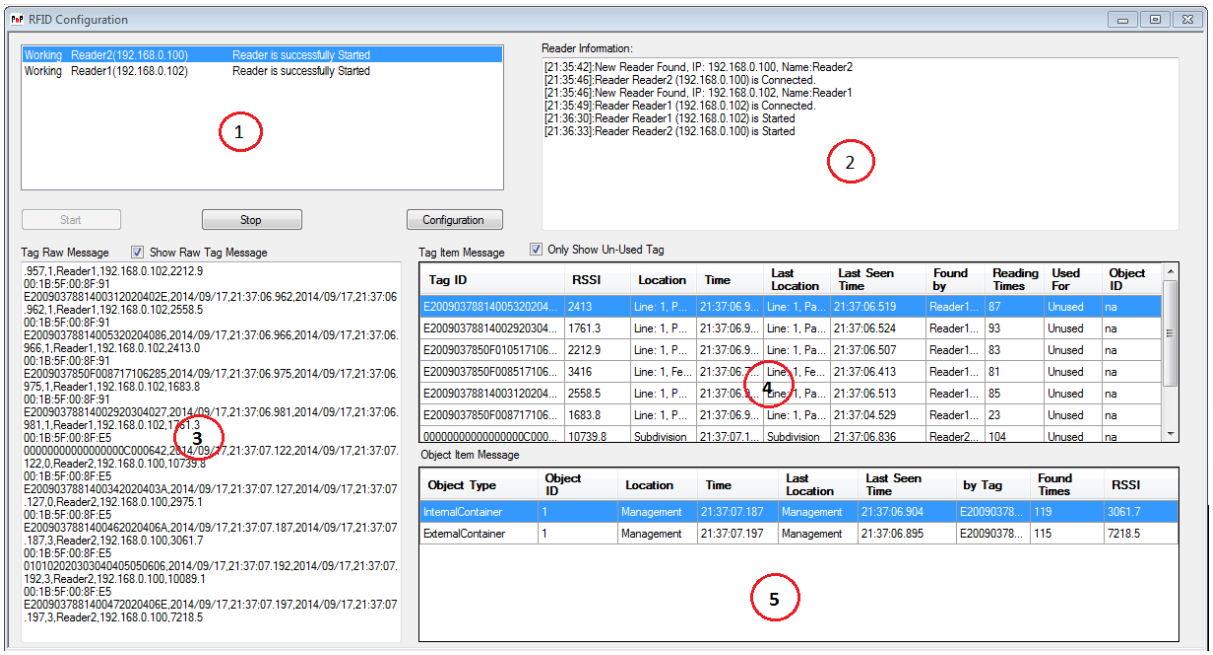


Figure 11 RFID Configuration Interface

Figure 12 gives the operation interface for reader/antenna location setting in the production line. The user can specify the plant and production line first, and then set the reader and antennas in the format 'Reader Name:Antenna ID;'. The input data is accepted as the valid setting for the operations and the data is stored until new setting is initiated.

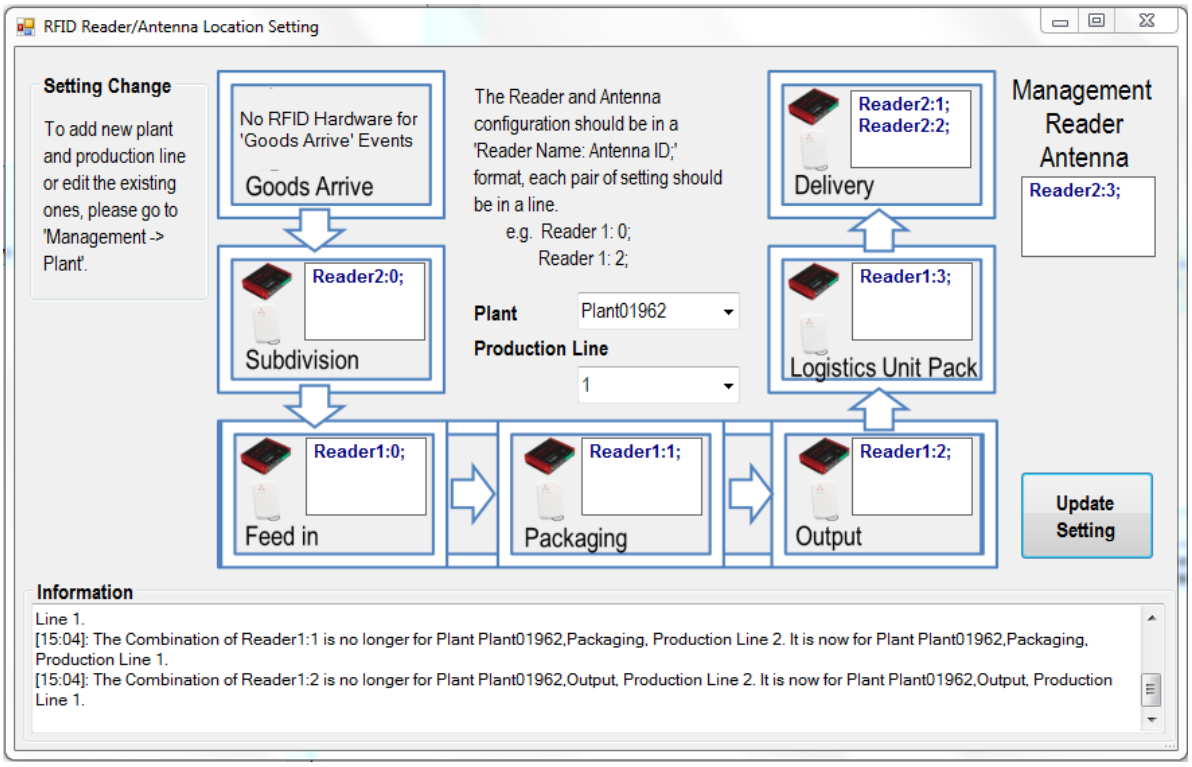


Figure 12 RFID Reader/Antenna Location Setting

5.2.2 Container Registration

The container registration interface is in the 'Management Window', which could be called out by clicking the 'Management' button in the main interface of the traceability system.

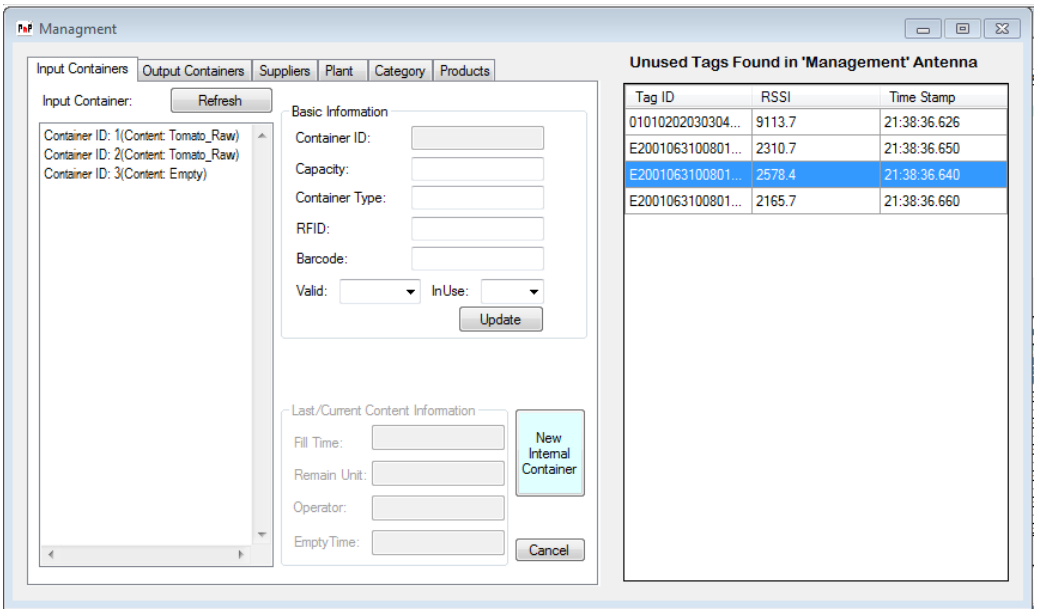


Figure 13 Input Container Registration Interface

As shown in Figures 13 and 14, on the left are the input/output containers and on the right are the list of detected Tag IDs. User can select a container and then assign a tag ID by double click one of the IDs in the list and click 'Update' button to confirm. Only the unused tag IDs are displayed in the list and it is updated in real-time.

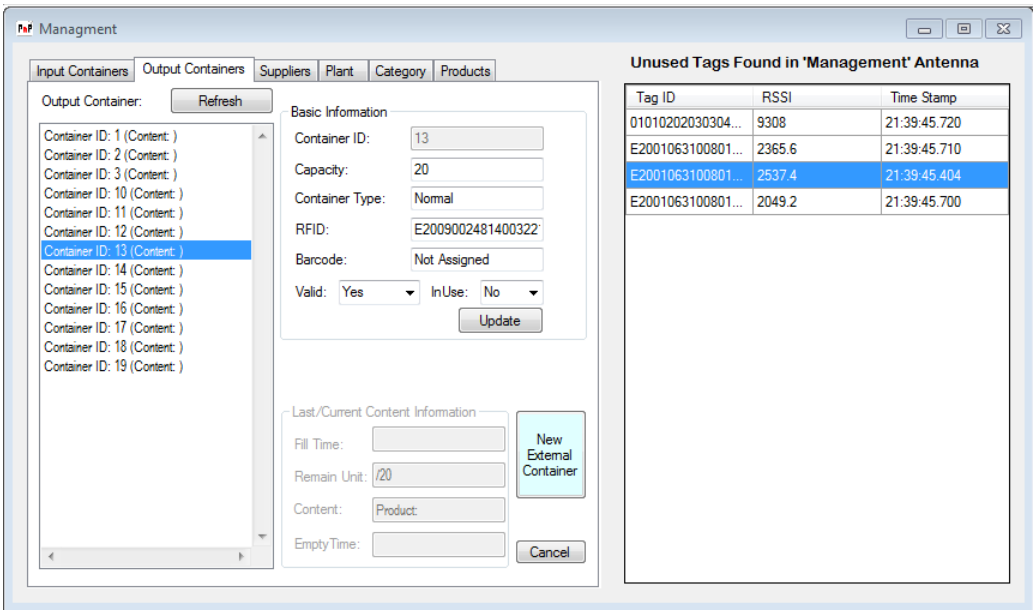


Figure 14 Output Container Registration Interface

In addition to container registration, users can create new suppliers, plants, production lines, and product information by manual inputs in the 'Management Windows'.

5.2.3 New Material Registration

Before subdivision and packing, the incoming new material needs to be registered manually by the users to create records for the incoming goods batch.

As shown in Figure 15, the 'New Goods Registration' interface can be called out by clicking the 'New Material' button in the main interface. The information to input is: supplier information, weight and quality information, logistic unit information of the batch, and other optional information. The records for incoming goods batch can be created by clicking the 'Update' button when all necessary information is provided.

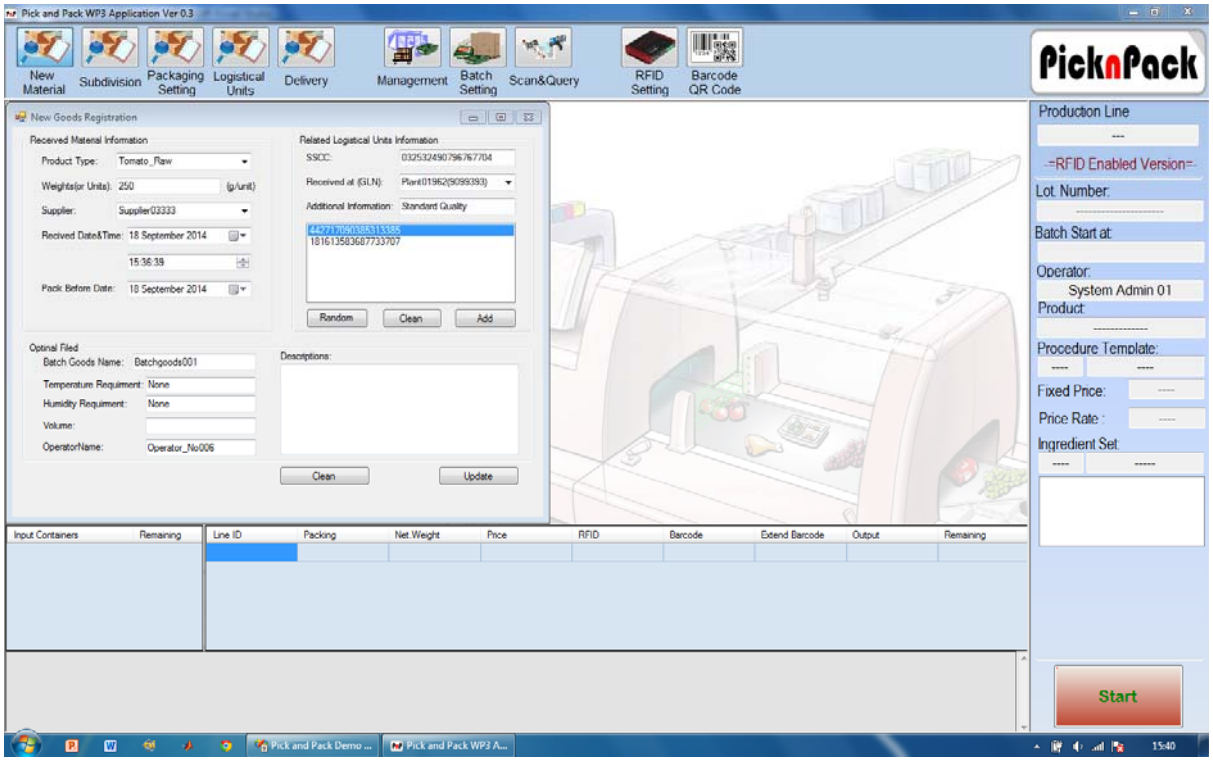


Figure 15 New Material Registration Interface

5.2.4 Subdivision

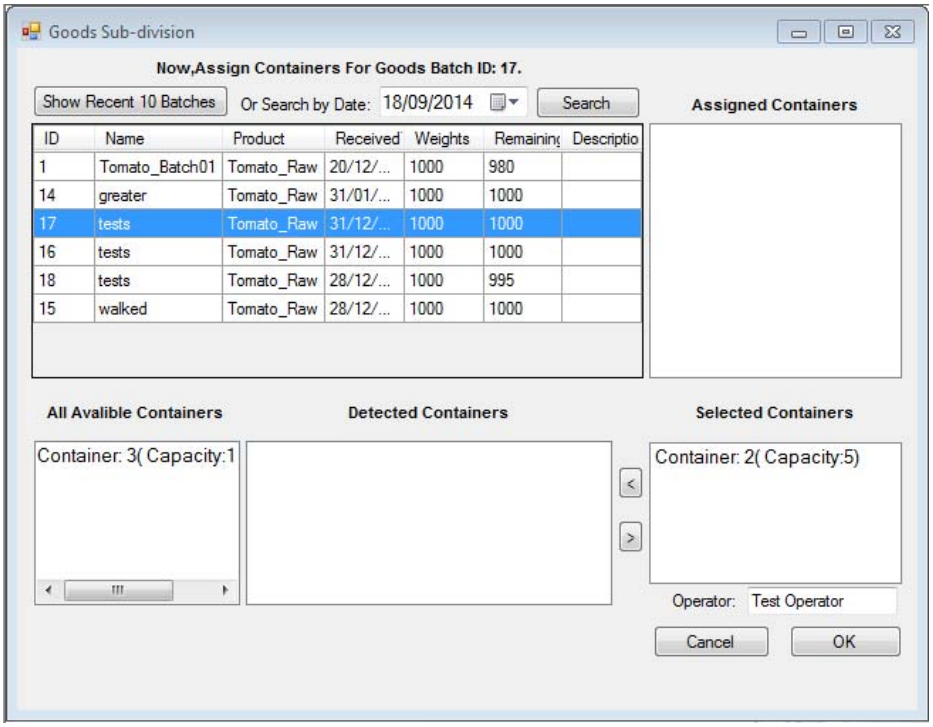


Figure 16 Subdivision Interface

The source material needs to be put into containers before it is used for packing. This activity is referred to as 'Subdivision'. The subdivision interface as shown in Figure 16 can be called out by clicking the 'Subdivision' button in the main interface.

Before the subdivision, the incoming goods batch should be selected. Users can query the last 10 incoming goods batches by clicking the 'Show Recent 10 Batches' button, or searching goods batches by date.

When users have selected a goods batch from the searched results, a list of valid containers is showing up in 'Detected Container Section'. The list shows containers detected in subdivision location only and it is updated in real-time. Users can pick up a container from the list and click 'OK' button to confirm the 'Subdivision'.

5.2.5 Packaging

(1) Batch/Lot Setting

Before packaging record can be started, users need to configure the job setting which can be found in the 'Batch/Lot Setting' window as shown in Figure 17.

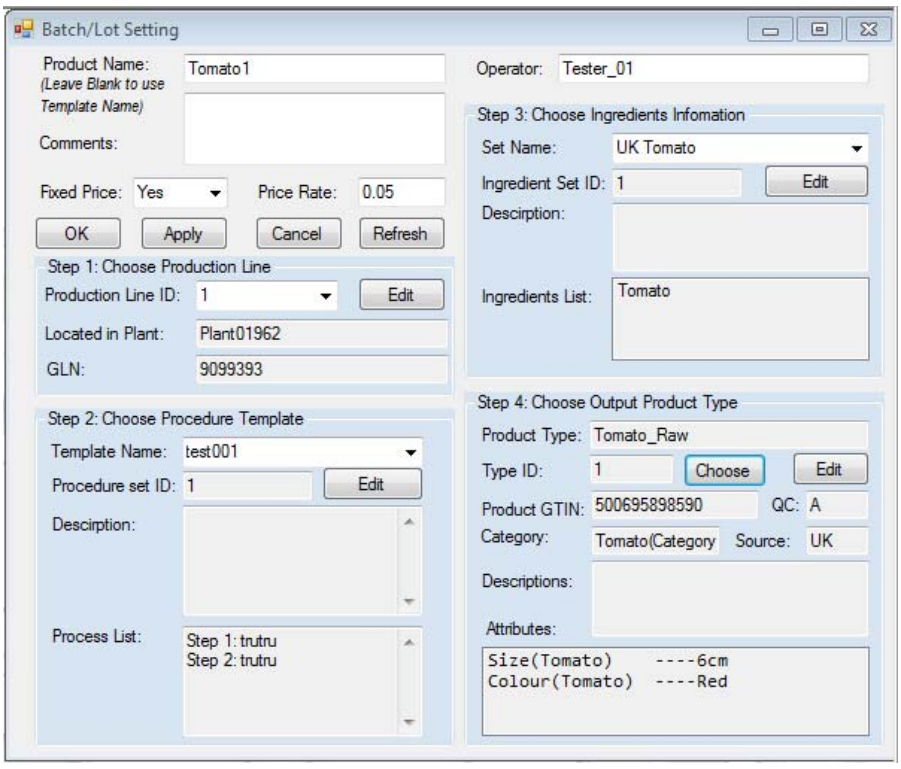


Figure 17 Batch/Lot Setting Interface

Four kinds of information are required in the batch setting: name of product, production line information, procedure set, categories of ingredients, and output product type and its GTIN number.

The production line is then ready for recording the packaging activities when users click 'OK' button to confirm the provided information. The main window is also updated as shown in Figure 18.

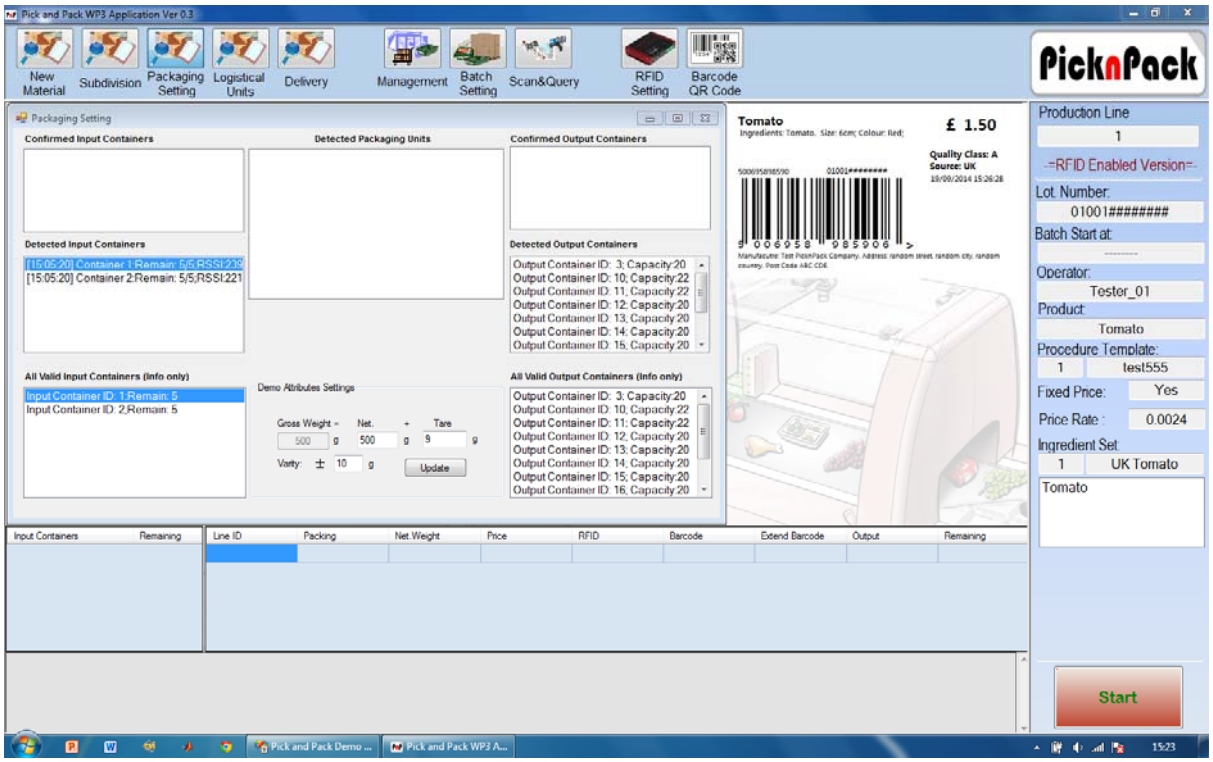


Figure 18 Updated Main Interface after Batch/Lot Setting

(2) Packaging Setting

The 'Packaging Setting' window is used to observe the RFID modules and display them in real-time. The interface can be called out by clicking 'Packaging Setting' button in the main interface.

When the packaging recording is started, the application will select all detected input containers as the 'source' and a container with the greatest RSSI listed in the output containers as the output container. The process is as shown in Figure 19.

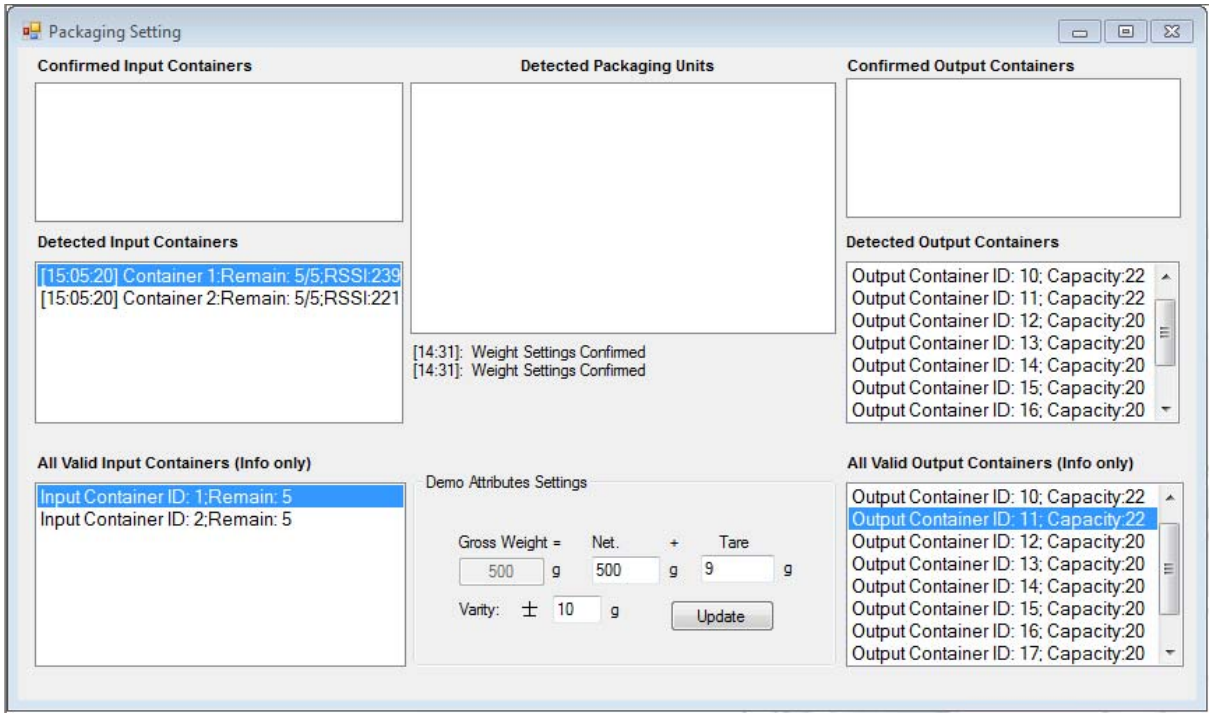


Figure 19 Input and Out Containers are Automatically Selected by the System

(3) Packaging Recording

The function of detecting and recording a product package relies on the RFID module. Each package should be assigned a RFID tag, and the RFID detection needs to follow the rules as below:

- The tag is new with no record in the database
- The tag is detected in the location of 'Package'
- The packaging job is running
- The input containers and output containers are both confirmed

If the above rules are matching, a package is confirmed and a record is created in the database. The display in the interface is also updated as shown in Figure 20. Packaging will be stopped if the rules are not matching. An example of packaging stop due to lacking of input container is as shown in Figure 21.

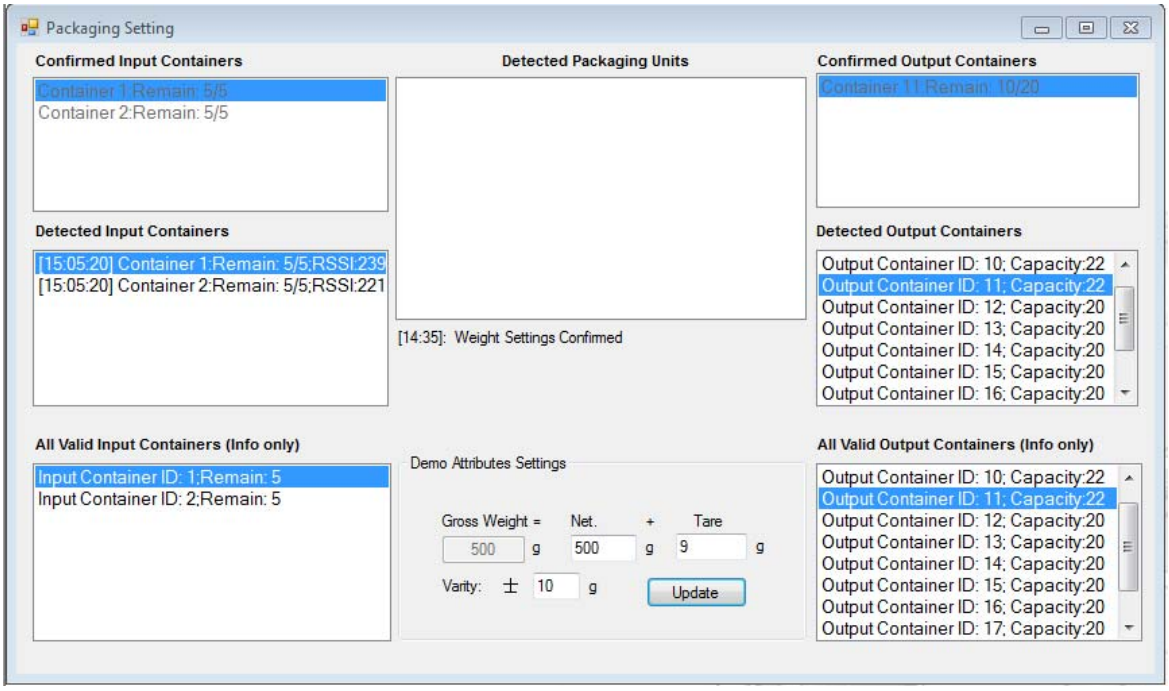


Figure 20 Packaging Recording Interface

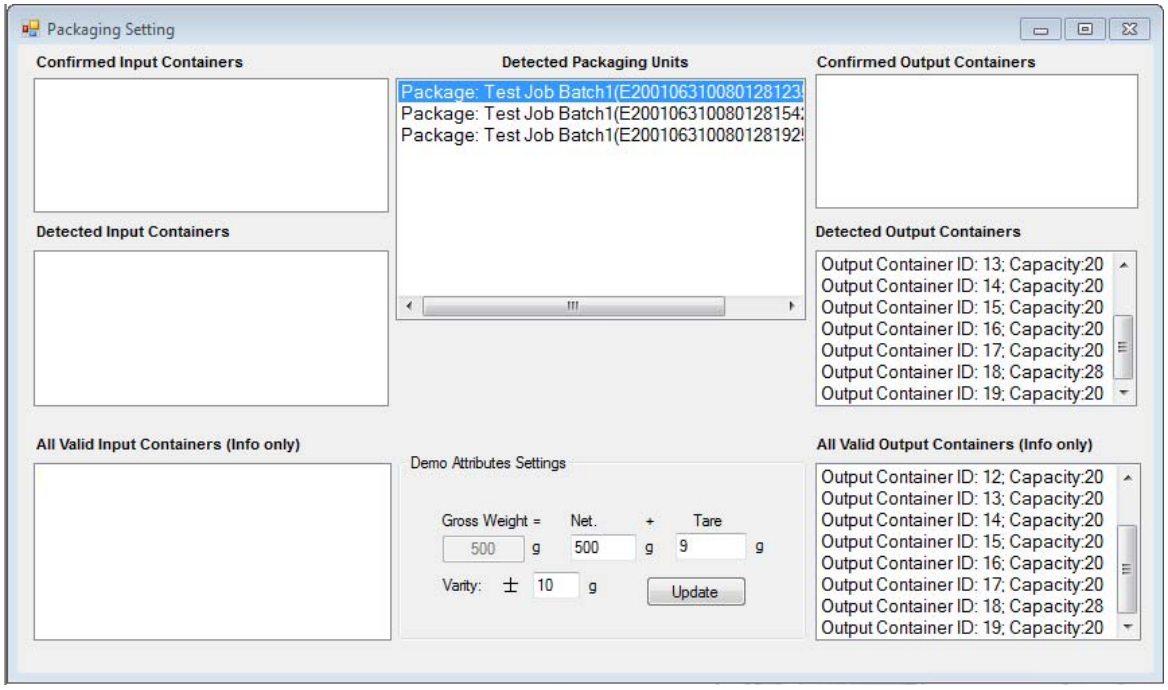


Figure 21 Packaging is Stopped

5.2.6 Logistical Unit

The function of logistic unit is to package the external containers into a logistic unit for delivery. Users can select the valid output containers in the list.

As shown in Figure 22, the detected contains and those available are listed in the 'Logistic Unit' window, and the list is updated in real-time. Users can select one or more containers from the 'Available Containers' section or 'Detected Containers' section. The selected containers can be registered as a logistic unit by clicking the 'Register' button.

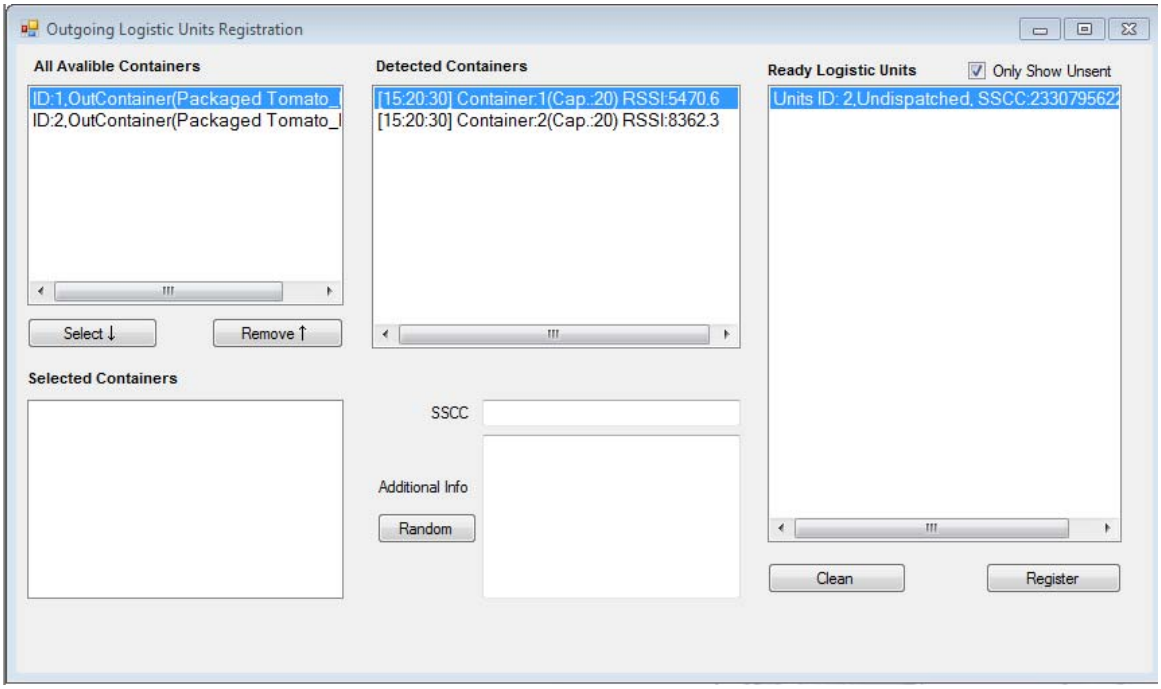


Figure 22 Logistic Unit Interface

5.2.7 Delivery

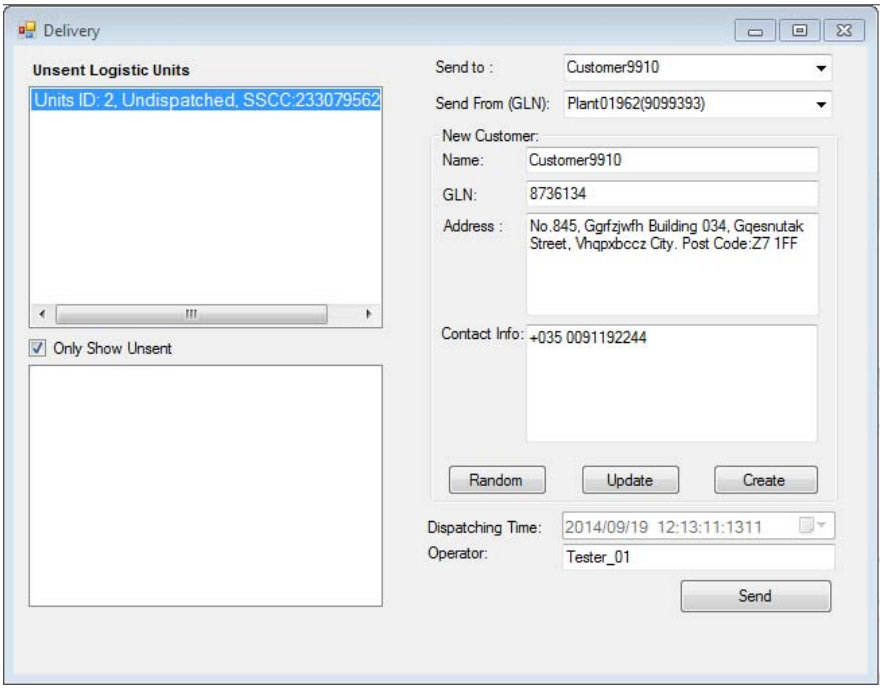


Figure 23 Delivery Interface

The prepared logistic units are then displayed in the 'Delivery' window as shown in Figure 23. In order to create a record of logistic unit dispatching, a valid customer and sending place must be selected. Then, a record in the database is created by clicking 'Send' button if all necessary information is provided.

5.2.8 Query/Search

The query and search function can be performed by both the traceability software application and the handheld RFID reader application.

(1) Query/Search with Traceability Software Application

The 'Query/Search' function is used for the users to look up the information of a certain object. The interface of 'Query/Search' function is shown in Figure 24.

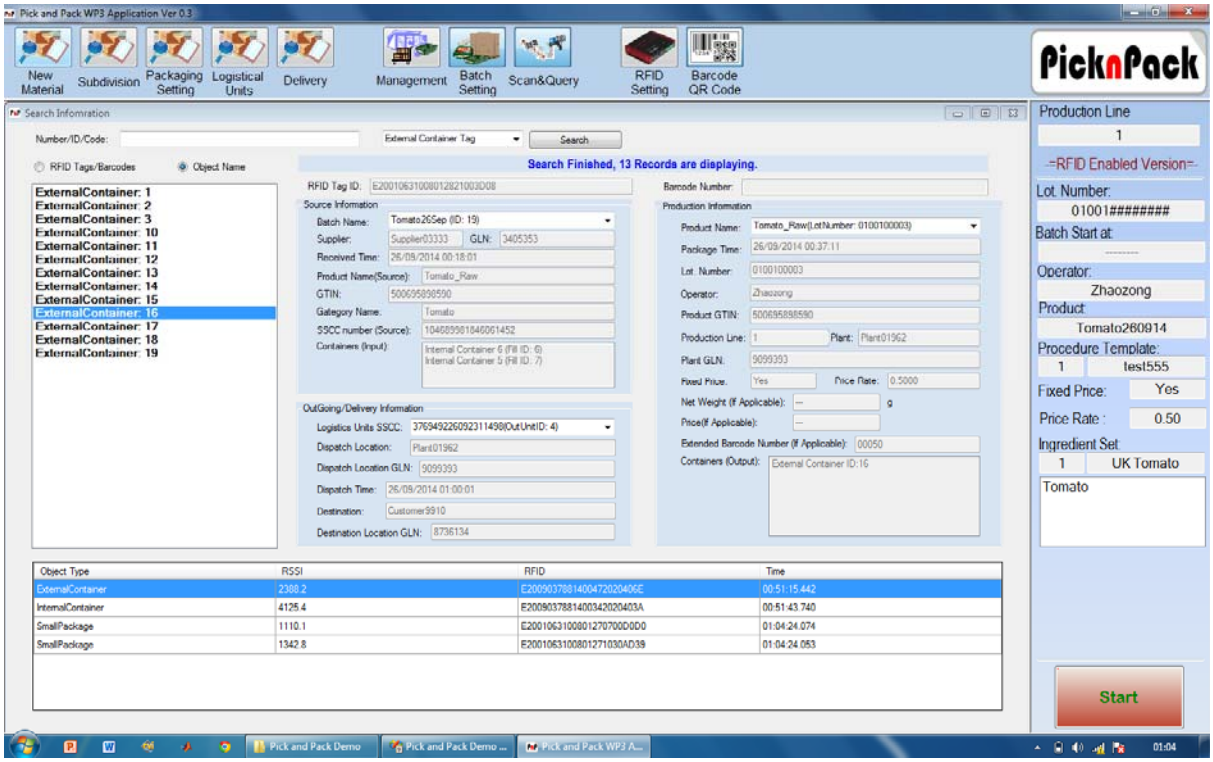


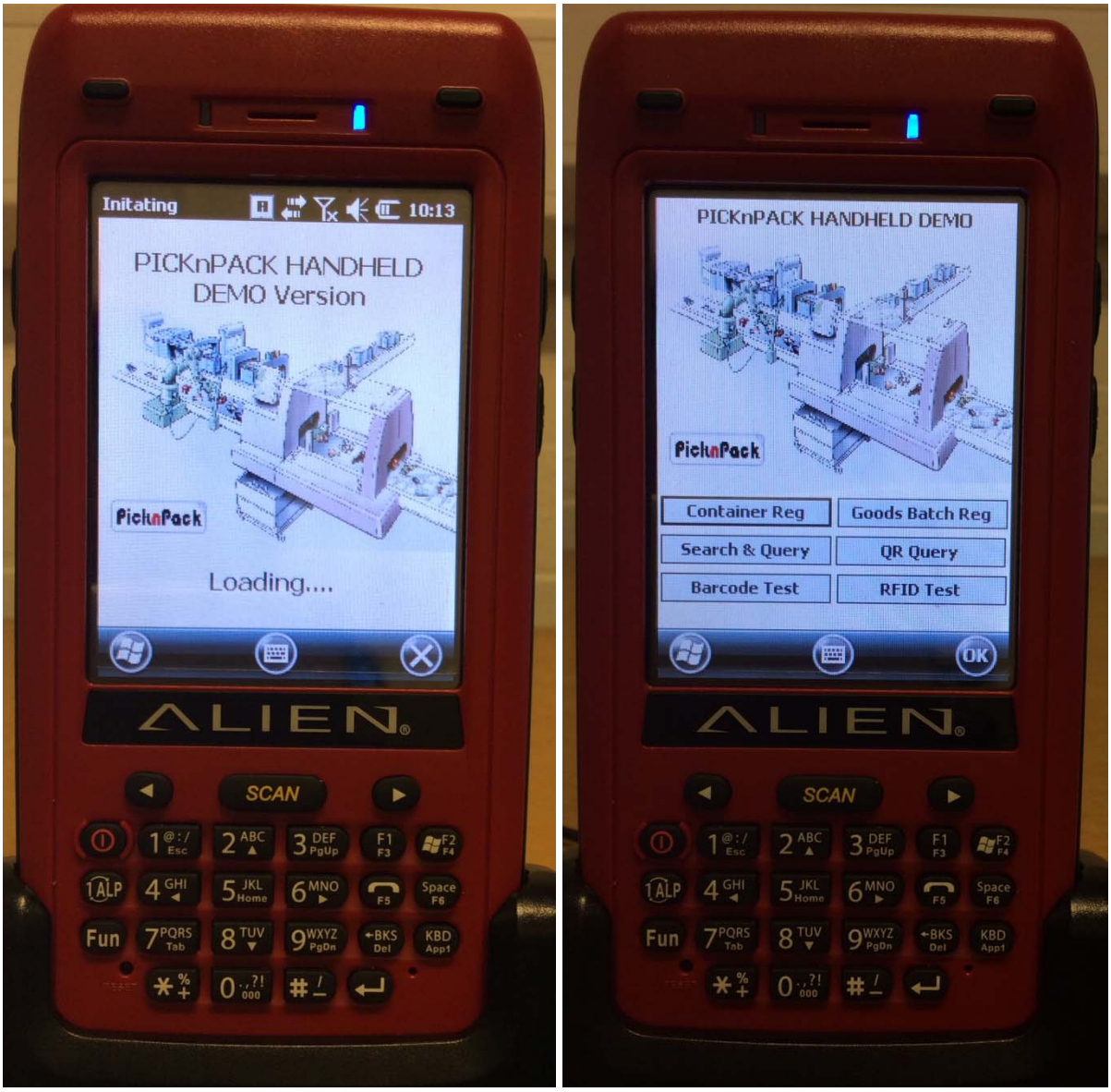
Figure 24 Query Interface

Users can input specific tag ID, Barcode, or other object ID to search the detailed information. Users can also retrieve details of objects by double clicking the object IDs list on the bottom of the window detected by the RFID readers when the packing job is running.

(2) Query/Search with Handheld Reader Application

Since handheld reader is lightweight, portable, and convenient, it is very useful for information tracking in some situations where fixed readers are not available.

The application starts automatically when the handheld device is turned on as shown in Figure 25 (a). The main interface is as shown in Figure 25(2).



(1) System Booting (2) Main Interface

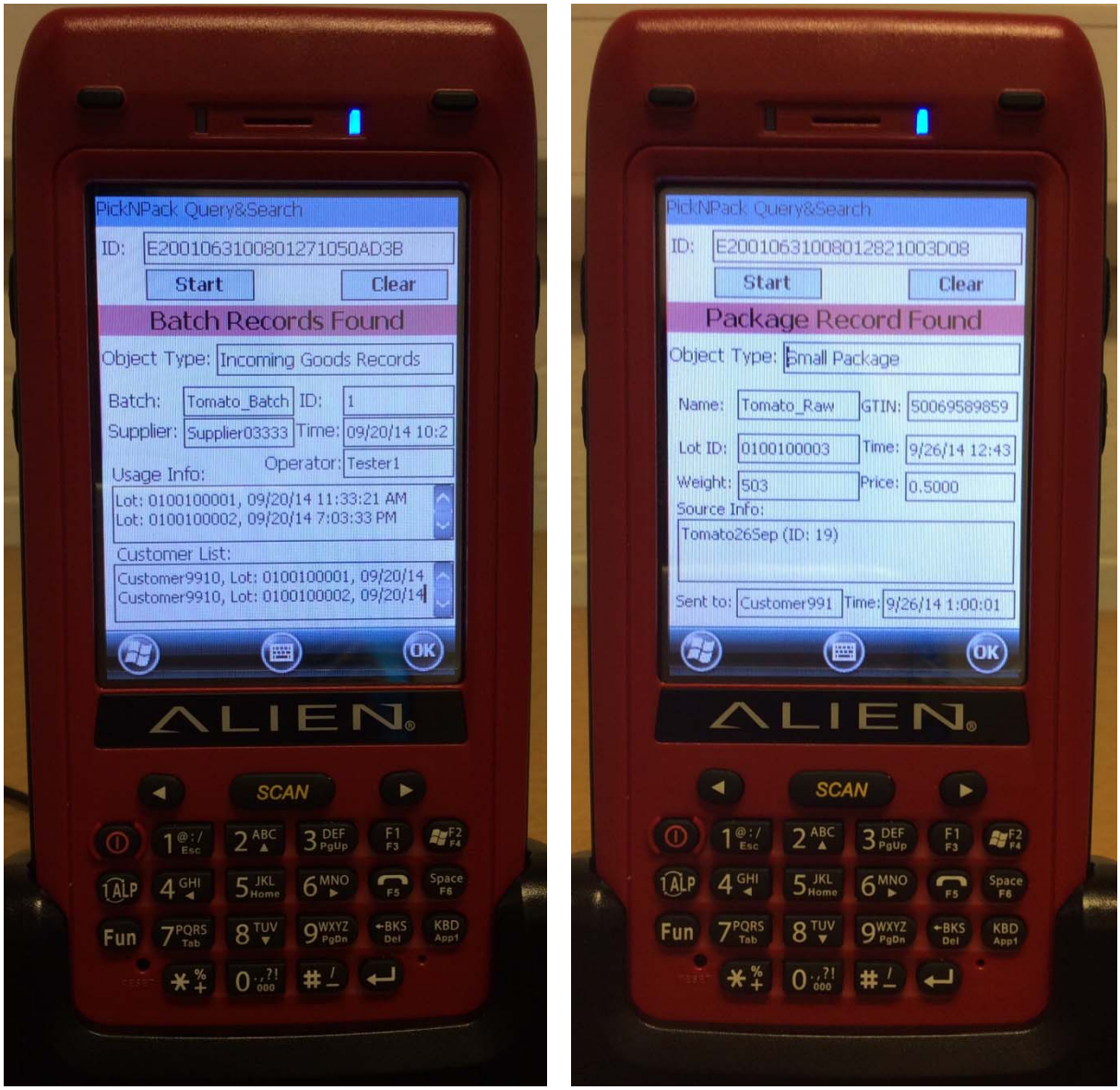
Figure 25 Start Page and Main Interface of Handheld Reader Application

The application provides functions to scan RFID tags and QR code for product line information tracking. By scanning the tag and QR code on the containers with the handheld reader, type and information of the object is displayed for the user.

(1) RFID Tracking with Handheld Reader

As shown in Figure 26, (1) and (2) are the results of incoming goods and small package information tracking with handheld RFID reader. When RFID tags stick on the objects are

recognised, the detail information of the object is retrieved from the database and displayed immediately. Since the handheld reader is WiFi and 3G enabled, the application can be used for remote tracking.



(1) Incoming Goods Tracking (2) Small Package Tracking

Figure 26 Information Tracking with Handheld Reader

(2) QR Code Tracking with Handheld Reader

In addition to RFID tracking, QR code is another efficient way supported by the handheld devices with a built-in camera. The product information is encoded in the QR code with the traceability software application in production line process. Then, users in the following stages can obtain the encoded information with the handheld reader conveniently. The QR code method is a flexible way for end users of products to access the product information

with some consumer electronics such as smartphones. Example of QR code information tracking is given in Figure 27.

Figure 27 QR Code Information Tracking

6 Test

The system is tested in laboratory environment in the current stage, and the implemented functions presented in the previous sections work properly. Further detailed test needs to be conducted on real food packaging production lines before integration with other modules.

The RFID hardware modules and test environment is as shown in Figure 28.

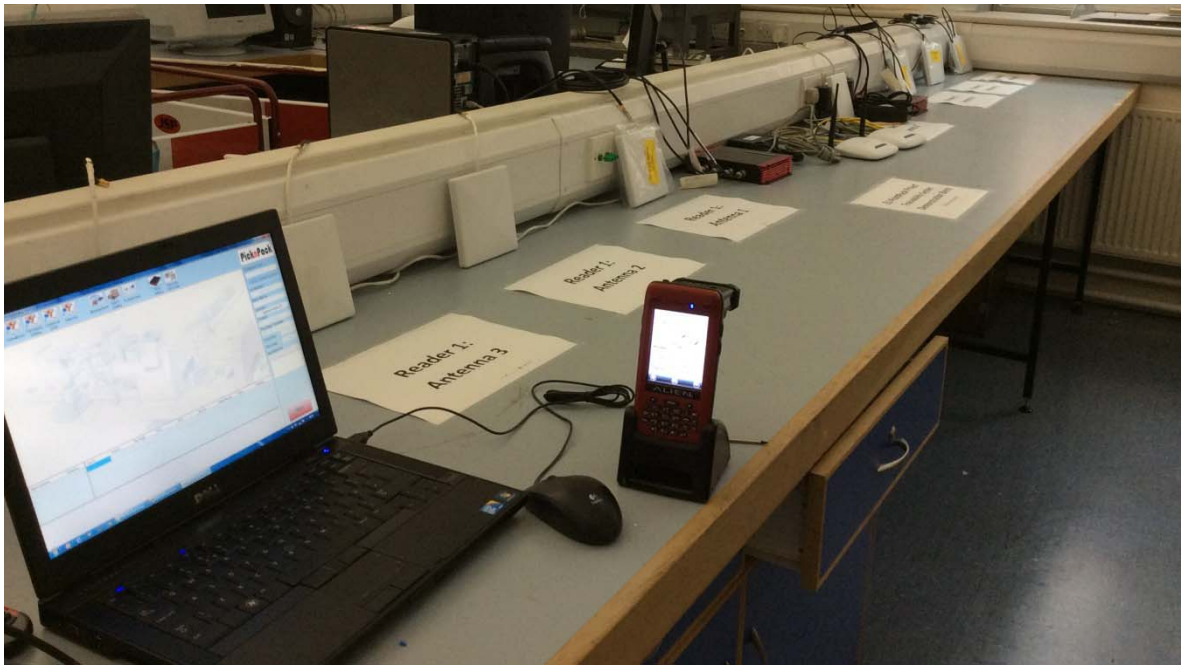


Figure 28 RFID Traceability System Test Bench

7 Summary

This document reports the major concerns in implementing the RFID system for information traceability in food packaging production line. The requirements and regulations are given in the first place, and then the hardware system architecture design and hardware module selection and implementation are illustrated accordingly. When the hardware is in place, software function and interfaces are designed and implemented according to the requirements and process model designed.

Future work will focus on the optimisation of the traceability application to better fit the production line process. The user interaction process, user interfaces, efficiency of communication and information processing will be improved to enhance the efficiency and user experience of the system.

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