# D3.8 – Report on Traceability Demonstration System

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



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PU	Public	Х
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## 1. Introduction

This document outlines the progress of the traceability system design and implementation for WP3 on optimised traceability system, relating to the deliverable of:

D3.8: Report on traceability demonstration system (M36)

The associated milestone is:

MS7: Optimised and complete integrated traceability system (M36)

The RFID integrated traceability system described in D3.5 and D3.6 has implemented the software integration techniques such as ZeroMQ communication, JSON data format, and state machine. This report focuses on the traceability demonstration system.

The RFID system design, database design, RFID system connection with database, software integration technologies which have been implemented are discussed. The RFID system collects useful information and share the information with other modules in the line. In addition to RFID system, a camera is integrated to the system to assist the information traceability. Implemented functions are tested in laboratory, and on-line test with other modules depends on the progress of the individual modules, which will be carried out in the next step.

Further details on hardware system, database design, software integration, and functions of the traceability application are provided in the following sections.

## 2. Hardware System

Based on the regulations and requirements, this section gives key hardware designs and implementations of the traceability system: system architecture design, hardware modules, antenna placing in production line, and camera for barcode information tracing.

#### 2.1 Hardware System Architecture

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.







Figure 1 Hardware System

## 2.2 Hardware Modules

List of hardware:

- (1) PC with traceability software
- (2) Fixed RFID reader
- (3) Handheld RFID reader
- (4) RFID antennas
- (5) RFID applicator
- (6) Barcode and QR code reader (camera)
- (7) Network infrastructure and devices, such as WiFi router

In the hardware modules, the RFID label applicator and the barcode reader are new devices, which are as shown in Figure 2 and Figure 3



Figure 2 RFID Applicator



Figure 3 Barcode and QR Code Reader



#### 2.3 RFID Label Placing

As shown in Figure 4, 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 4 Antenna Placing

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

#### 2.4 Camera for Barcode and QR Code Tracing

Since the source goods batch, packaging job, and output containers all have their barcode, either obtained from previous trading partners or generated by the system, the barcode can be used to trace the information with a camera. In the hardware modules, the camera is a new integrated one.

The model of the camera is DFK 23UP1300 colour video CMOS sensor, resolution 1280x1024 (1.3MP), speed up to 95 frames per second. Model of Lens is DF6HA-1B. The camera is connected to computer with a USB cable.

The software module for camera video capture and barcode reading is developed and embedded to the traceability system. The barcode reading module supports 14 commonly used barcode format and QR code. A video capturing thread is running in background to detect barcode. The records in database linked to the detected barcode will be displayed in the search & query interface. The logic of the barcode reading and query is as shown in Figure 5.





Figure 5 Logic of Barcode Information Traceability

## 3. Process Modelling and Database Design

The main task of the RFID traceability system is to information of interest and provide interface to share and query the information. The data structure of the information to collect links to the operation process. This section illustrates the process modelling and data structure design.

#### **3.1 Process Modelling**

The EU's General Food Law entered into force in 2002 and makes traceability compulsory for all food and feed businesses [1]. The traceability needs to cover "one step backward and one step forward" in the food chain, which is also called "one-up-one-down system".

The packer needs to collect data from previous and next trading partners, and also shares data with previous and next trading partners. The modelling of the food packaging process is as shown in Figure 6. The process can be briefly described with three steps:

- (1) The source material from supplier is registered and then put in input containers, and all information is recorded and linked with RFIDs on input containers.
- (2) In packaging line, source material is put into small packages, and then put into output containers. The RFID of small packages are linked with both input containers and output containers in the database.
- (3) Output contains are set to be logistical units. Information of delivery and retailer market information are recorded.

Therefore, with the RFID and some unique IDs generated with the system, the source material information, product information, and logistic and market information are all



linked together. The data structure of the database is designed according to this relationship.



Figure 6 Food Packaging Process

#### 3.2 Database Design

The data table structure is designed according to the process in section 3.1, and the database tables are listed as follows. The underling items are the foreign keys of the tables, which are linked to other tables.

- [Supplier]: <u>Supplier ID</u>/Location/Type/Contract period/Contact info/additional information...
- [Goods\_batch]: Goods\_Batch ID/<u>Supplier ID</u>/Content(e.g. grape)/ Quantity(volume)/ Arrived Time/Temperature Req./Humidity Req./Processed Before/Comments.....
- [Internal\_container]: Internal\_Container\_ID/RFID ID/Type/InUse/Invalid
- [Internal\_container\_fill]: Internal\_Container\_Fill
   ID/<u>Internal Container ID</u>/ <u>Goods Batch ID</u>/Operator/Packaging Before/filled
   Time/empty Time
- [Plant\_warehouse]: Warehouse ID/Location/Capacity/Remaining Capacity/ ...
- [Plant\_storage]: Plant\_Storage ID/<u>Internal Container Fill ID</u>/Time enter/ Time leave
- [Food\_packaging\_job]: Packaging ID/ Small\_Package\_ID/ Product Name/Production line ID/Start Time/ Content Type/ <u>Internal container Fill ID</u>/Best -before Date/Operator/<u>Process1 ID/ Process ... ID/Process N ID</u>/Finished Time/ *External\_Container\_Fill\_ID*/...
- [Small\_package]: Small\_Package\_ID/RFID ID/Registered Time/Type/...

PicknPack



- [Process\_N]: <u>Process\_NID</u>/Time/Operator/weight (or other information)
- [External\_container]: Container ID/RFID ID/Container
   Type/Dimensions/capacity/InUse/Invalid
- [External\_container\_fill]: External\_Container\_Fill\_ID/Container ID/Content/Fill Time/Empty Time/ <u>Delivery ID</u>
- [Delivery]: Delivery ID/Vehicle ID/Operator/Departure Time/Arrive
   Time/ Production Plant ID/Supermarket warehouse ID/Delivery Before
- [Super\_market\_warehouse]: Supermarket\_Warehouse ID/ Location/ Capacity/ Remaining/....
- [Supermarket\_warehouse\_storage]: Supermarket\_Warehouse\_Storage
   ID/ External Container Fill ID/ Time enter/ Time leave/ Supermarket\_Warehouse ID
- [Selling]: Selling ID/ External Container Fill ID/ Start Time/ End Time
- [External\_container\_return]: Return ID/<u>External Container Fill ID</u>/Send Time/Receive Time/Send Supermarket ID/Receive Plant ID
- [Supermarket]: Supermarket ID/ Location/ Other Information
- [Production\_plant]: Production\_Plant ID/ Location/ Other Information

The database is implemented with Microsoft SQL server. A software user interface is developed with Microsoft Visual C# 2010. The software application provides interface for users to manually input information in the database, collects RFID tags from RFID reader, and saves the data in database. It also provides interface for users to query product information from the database. The traceability software is illustrated in section 4.

## 4. Software Development and Software Integration

The traceability application is the intermediary between users, devices, and the database system. It provides user interfaces, data acquisition interfaces, and interface for data interaction with peer modules. This section briefly introduces the traceability application.

#### 4.1 Traceability Application Development

#### 4.1.1 Functionality

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.

#### 4.1.2 Flow Chart

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 Flow Chart of the RFID Traceability Application

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.

#### **4.2 Software Integration**

The traceability system is not a separate module. It needs to listen to the line controller and speaks to the peer modules for data communication. All devices need to follow the same protocols and standards for interoperable interaction. The standards to follow are Life Cycle State Machine (LCSM), ZeroMQ communication [2-4], Javascript Object Notation (JSON) [5, 6] data format, and spotlight protocol [7].

#### 4.2.1 Finite State Machine

To integrate with the line, a finite state machine is designed. The design of the FSM [8] is based on its events and activities of the traceability application. For the traceability system of current version, it is separated into five states: Configure, Ready/Waiting, Running, Pause, and Interrupt:

- Configure: the system initiates and configures hardware devices, such as ZMQ connection, RFID reader initiation and configuration, packaging setting, job batch setting, input/output container registration, etc.
- Ready/Waiting: waiting when hardware devices and settings are ready
- Running: working
- Pause: stopped because of container empty, needs user to restart
- Interrupt: stopped because container removed, auto-start when container is found

The events in traceability system can be classified into four types:

- Device and setting state event
- Line command event
- User UI command event (start, pause, stop)
- RFID detected container event (full, empty, lost, or found)

The states transfer of the state machine is triggered by these events. In the state machine, the states are set with transitions "e[g]/a", where

- e=event
- [g] = guard condition
- a=action



Diagram of the state machine is as shown in Figure 8.



Figure 8 FSM of the Traceability System

The events are monitored by Window UI, and TCP socket from RFID reader, and ZMQ message from the line. In the Microsoft Visual C# environment, since the application has already been complicated, the handling of multi-thread communication is important for the performance of the traceability application.

#### 4.2.2 ZMQ Interfaces for Inter-module Communication

The ZMQ based message interface for inter-module communication is as shown in Figure 8.



Figure 9 ZMQ Interface for Data Request

As shown in Figure 9, the traceability application connects to a TCP ports as a ZMQ DEALER, and modules requesting data are also connect to a ZMQ ROUTER. The modules send ZMQ message in JSON to the traceability application. The traceability application receives the message, parses the JSON message, executes the request, wrap the data in JSON, and then reply the message to the requester. On the other hand, the traceability system can also request data from the other modules in the line. The line controller works as a ZMQ Client.

In the data interface, the ZMQ ROUTER plays a very important role. It forwards module X's request to the traceability application and the forwards traceability application's reply back





to module X. It also forwards traceability applications data request to module X and forward back module X's reply back. In addition, it forwards traceability application's broadcasting information to all connected modules. Figure 10 illustrates the inter-module communication between traceability application and other modules.



Figure 10 Data Flow of the Traceability System

#### 4.2.3 Zyre Interfaces for Inter-module Communication

In addition to ZMQ interface, the Zyre interface is also implemented and tested, which will be integrated into the traceability application. Zyre is an open and standard way to connect applications without the cost of complicated technologies. A cheap, simple, universal messaging system that spoke the most widely used, and best understood protocol: plain old HTTP [9].



Figure 11 Topology of Zyre Connection



Different from ZMQ connection, the Zyre connection is more convenient to use. The main functions of Zyre are whisper and shout. Whisper is used for a node to talk to a specific node in the network, and shout is for a node to broadcast messages to all nodes in a group. The topology of the devices in Zyre connection is as shown in Figure 11.

The Zyre in Microsoft Visual C# is learned from work package 2 by visiting on 17 September 2015. The dynamic link library (DLL) file wrapping the functions [10] are used in our applications. This will be integrated to traceability application for inter-module communication with the modules in the packaging line. The testing of Zyre can be found in section 5.2.

## 5. Work Up to Date

This section summarise the functions implemented so far, including the software development and integration, and provides some test results.

#### **5.1 Functions Implemented**

The main functions implemented so far are summarised as follows:

- RFID hardware in place
- Traceability application
- Handheld RFID query application
- Database connection of both traceability application and handheld reader query application
- Inter-module communication interface with ZeroMQ
- JSON message generation and parsing for inter-module communication

The traceability application and handheld RFID reader application can fulfil the tasks of information traceability. The ZeroMQ interface can receive messages from line and other modules and also send messages to other modules for data exchange. JSON wrapper can generate JSON message which can be understood by other modules, and JSON parser can understand messages from other modules.

#### 5.2 Test and Results

This section gives some selected test results of the traceability application development and integration technologies.

Figure 12 gives the main interface of the traceability application. Top left are the buttons to launch the interface of all functions of the software, such as new material registration, subdivision, packaging setting, logistic units setting, delivery, management, batch setting, scan&Query, RFID reader setting, and camera setting. On the bottom are events messages





and communication messages. In the middle are Barcode and QR code generated for packaging products. On the right is the packaging process information.



Figure 12 Main Interface of Traceability Application



Figure 13 Traceability Application in Operation



When the traceability system is running, the available input container and output container are detected, and the small packages pass the packaging are is recorded. Therefore, the RFID on small packages are linked to input containers and output containers, which are also linked to source material information, and logistic and retailer information. The system in operation is as shown in Figure 13.

Figure 14 gives the Search & Query page, where user can search the required information with RFID, Barcode, and category of objects such as new material, input container, small package, output container, logistic units, etc. User can also click RFID tags detected on the bottom to query the information linked to it. In addition, user can launch the camera to query the information with Barcode and QR Code, as shown in Figure 15. All related information in data base can be displayed on the user interface.

Pick and Pack WP3 Application Ver 0.3			_ 0 ×
New Subdivision Packaging Logistical Do	Eivery Management Setting Scan&Query RFD Barcot	a N De	PicknPack
Search Information			Production Line
Number/ID/Code:	Small Package Tag		1
RFID Tags/Barcodes     Object Name	Search Finished, 24 Re	cords are displaying.	-=RFID Enabled Version=
REID	RFID Tag ID: E2001063100801251290935F	Barcode Number: 01001	Lot Number
E2001063100801291710632D	Source Information	Production Information	01001########
E20010631008012917006794 E2001063100801290740CD28	Batch Name: Red Grape (ID: 20)	Product Name: Red Grape(LotNumber: 0100100005) -	Ratch Start at
E2001063100801291030AD41	Suppler: Suppler03333 GLN: 3405353	Package Time: 15/09/2015 18:03:29	Daton Stan at
E2001063100801290720CD26 E2001063100801281130048E	Received Time: 15/09/2015 15:53:28	Lot. Number: 0100100005	Operator
E200106310080128146081EC	Product Name(Source): Hed Grape	Country Tarter 01	Tester 01
E2001063100801281140A4C0	Catacore Name: Grane		Product
E2001065100801261120A4BE	SSCC number (Source): 291836985399762949	Product GTIN: 500942368206	Grape1509
E20010631008012817605ECA	Containers (Input): Internal Container 8 (Fill ID: 9)	Production Line: 1 Plant: Plant01962	Procedure Template
E20010631008012820903D07		Plant GLN: 9099393	1 test555
E20010631008012821003D08		Fixed Price: Yes Price Rate: 1.9900	Fixed Drive: Yes
E2001063100801270700D0D0 E2001063100801271030AD39	OutGoine/Delivery Information	Net Weight (# Applicable): 509 g	Fixed Flice. 103
E2001063100801271050AD3B	Logistics Lints SSCC 521445433670784618(0.±UntID: 5)	Price(if Applicable): 1.9900	Price Rate : 1.99
E20010631008012820803D06 E2001063100801251270935D	Dispatch Location: Plant01962	Extended Barcode Number (If Applicable): 00199	Ingredient Set
E20010631008012513009360	Dispatch   equation GLN: 0000000	Containers (Output): External Container ID:19	2 Grape Red
E2001063100801250970B583 E2001063100801251290935E	Normal Terry 15/00/2015 10:10/02		Grape
E20010631008012516306BE9 -	Dispatch Time: 15/03/2015 18:18:05		Giupo
Unique ID: Module ID:	Destination: Customer9910		
20150328153425186 PnP_DAQ - Request	Destination Location GLN: 8736134		
Object Type F	RSSI RFID	Time	
			Start
L			
🍘 🖻 🔍 🔟 🔺 🚾 🔿	Con PickNPack (Running M Pick and Pack WP3 A	EN	🔺 add 📴 🌓 🍡 18:26

Figure 14 Query Interface



New Material         Subdivision         Packaging Setting         Logistical Units           ✓ Search Information         Number/ID/Code:         000307765514	Delivery Management Batch Scan&Query RFID Setting - Search	Barcode QR Code	Production Line
AFID Tags/Barcodes     Object Name IntermatContainer: B	Search Finisht           RFID Teg ID:         E20010031000012500400402           Source Information         Butch Name:         Red Grape (ID: 20)           Suppler:         Source Information           Brochward Time:         11/073/07313 16:53/28           Product Name(Source)         Red Grape (ID: 20)           GTN:         Sold2382056           Category Name:         Grape (ID: 20)           SSCC number (Source)         29183589359762469           Centaines (Input):         Internal Container 2 (HI ID: 8)	Harcords are displaying.           Barcode Number:         00007795014           Product Name:         Red Grape[LotNumber: 0100100004)           Product Name:         15/09/2015 17:40:31           Lot. Number:         0100100004           Operator:         Texter:           Product GTIN:         5009/2015 17:40:31           Lot. Number:         0100100004           Operator:         Texter:           Product GTIN:         5009/20258206           Preduction Line:         1           Part:         1009333           Fixed Rice:         Ym           Prode Rate:         0.2000	-=RFID Enabled Version= Lot. Number. Batch Start at: Operator. System Admin 01 Product Procedure Template.
Barcode & QRcode Device Barcode Type: CODE_128 Code: 000307769514	OutLong Develop to level of the state         1           Image: Socie StateStateStateStateStateStateStateSta	Prooff Applicable): Extended Barcode Number (# Applicable): Containers (Output): Extended Container ID: Time Time	Price Rate : Ingredient Set

Figure 15 Barcode Decoding with USB Camera

The traceability system can share the information in database. That means other modules can request data from RFID traceability system as shown in Figure 16. Figure 17 shows the interface that other module receives data requested from the traceability application.

P ZMQ Worker	
ZMQ PPP_Worker	
Messages(Received and sent):         ZM0 message [234340] Heartbeat received Line is alive.         ZM0 message [234342] Sending heartbeat         ZM0 message [234343] Sending heartbeat         ZM0 message [234343] Sending heartbeat         ZM0 message [234344] Heartbeatreceived Line is alive.         ZM0 message [234344] Heartbeatreceived Line is alive.         ZM0 message [234347] Heartbeatreceived Line is alive.         ZM0 message [234347] Heartbeatreceived Line is alive.         ZM0 message [234343] Sending heartbeat         ZM0 message [234343] Sending heartbeat         ZM0 message [2343436] Sending heartbeat         ZM0 message [234350] Sending heartbeat         ZM0 message [234351] Reply from: PnP_RFID; "messageType"."Data_Request"."msgFrom"."PnP_DAO"."msgTime"."26/04/2015         234350". Neessaghef". RequestType"."REID."."Filo:"."moduleName"."Tomato26Sep         [/1019] "SupplerName"."Container"."IntermeContainerID"."6""productInfomation"."BoCO:"104689981846061452"."Intermet"."E00695898590"."neteorypAme"."InsoCC:"104689981846061452"."Intermet"."E00695988590"."neteorypAme"."InsoCC:"104689981846061452"."IntermetType"."The Container"."Tomato_Reade ::"0.SOC:"1	Control IPAddr 192.168.0.100 Port 5556 Start Stop Data & Command Data Request Module PnP_RFID • Key RFID • Value E200106310080127070 Send

Figure 16 Other Module Request Information from Traceability Application



ZMQ PPP Worker	
ZMQ PPPVVorker         ZMQ message [2346:15].Sending heartbeat         ZMQ message [2346:15].Yeantbeat received. Line is alive.         ZMG message [2346:16].Sending heartbeat         ZMG message [2346:17].Received Request from: PnP_RFID:         ("message Type": "DataBequest", "moduleName", "PnP_RFID:         ("message [2346:18].Sending heartbeat         ZMG message [2346:18].Sending heartbeat         ZMG message [2346:18].Sending heartbeat         ZMG message [2346:21].Sending heartbeat         ZMG message [2346:22].Sending heartbeat         ZMG message [2346:23].Sending heartbeat         ZMG message [2346:24].Sending heartbeat         ZMG message [2346:25].Sending heartbeat         ZMG message [234	Control IPAddr 192.168.0.100 Port 5556 Start Stop Data & Command Data Request Module PnP_RFID • Key RFID • Value E200106310080127070 Send

Figure 17 Other Module Receives Data Request from Traceability Application

The communication between traceability system and the other modules are through ZMQ as shown in Figure 9. The ZMQ router receives messages and then forwards these messages to the object clients. Figure 18 shows how message is received and sent between traceability application (PnP\_RFID) and another module (PnP\_DAQ).

🛃 ZMQ-Queue	_ <b>_</b> ×
ZMQ PPP_Router	
Messages(Receive/Forward)	Central
I: sending data request to:PnP_DAQ:{"messageType":"Data_Request","msgFrom"."PnP_DAQ","msgTime"."26/04/2015	
I: receiving hearbeat [23.45.17] (PnP_RFID)	Backend
I: sending heartbeat [23:45:17] (PnP_RFID) I: receiving heartbeat [23:45:17] (PnP_DAQ)	IP Addr 192.168.0.100 Port 5556
I: receiving heartbeat [23:45:17] (PnP_DAQ)	Frontend
("messageType"."Data_Request_Reply","requestType":"RFID","moduleName"."PnP_RFID","returnTime"."26/04/2015 23:51:06","objectType"."SmallPackage","sourceInformation","BatchName"."Tomato26Sep (ID:10", "sunciendAmeri"SuncientI333" suncientef10", Wir3405763", "receivedTime"."26/04/2014	IP Addr 192.168.0.100 Port 5555
(b):19. Supprentation - Openicity of the second	Start Stop
00.30.10","IoNumber"."0100100003","operatorName"."Zhaozong" "outputGTIN"."500695898590","productionLineID"."1","plantName"	Devices in Connection
"Plant01962","plantGLN":"9099393","twPrce"" 1 rue","prceR4ata""D.9000","netWeight"'500","pre:"0.5000", extendbarcode":"0005 0","registerTime":"26/09/2014 00:38:03", externalContainerID:"16","deliveryInformation",("outSSCC","376949226092311498 (OutLintID 4)","plantName","Plant01962", "dispatchGLN":"9099393", "departure Time"."26/09/2014 01:00:01","destination"."Customer9910","destinationGLN":"8736134"}}	PnP_RFID PnP_DAQ
t: sending data request to:hn/_DAQ: {"message Type""Data_Request_Reply" "requestType":"RFID" "moduleName"."PnP_RFID" "returnTime":"26/04/2015 235106 ":objectType" "SmallPackage", "sourceInformation" ("BatchName"."Tomato26Sep	
(ID:19)". SupplierName: "Supplier03333", "supplierGLN":"3405333", "received Time" "25(09/2014) 00:18:01". "productName": "Tomato_Raw, "inputGTIN":"500695898590", "categoryName": "Tomato", "InSCC":"104689981846061452", "I ncontainerType": "In_Container", InternatContainer(ID": "6"), "productInfomation", "outputTypename". "Tomato_Raw(Lot	
No.:0100100003)","inFillTime"."26/09/2014 00:30:10","lotNumber"."0100100003","operatorName":"Zhaozong","outputGTIN":"500695898590","productionLineID":"1","plantName"	
"Plant01962","plantGLN"."9099393","fxPrice"."True","priceRate"."0.5000","netWeight"."500","price"."0.5000","extendBarcode"."0005 0" "registerTime"."26/09/2014.00.38.03" "externalContainer(D"."16"), "deliveryInformation".4" outSSCC'376949226092311498	
(OutUnitDr4)", "PlantName"."Plant01962", "dispatchGLN"."9099393"," departure Time"."26/09/2014	
I: receiving heartbeat [23:45:19] (PnP_RFID)	
I: receiving heartbeat [23:45:19] (PnP_DAQ)	
t receiving heartbeat [23:45:20] (PnP_RFID)	
•	

Figure 18 ROUTER Forwarding Messages between Traceability Application and Other Modules





In addition to ZMQ, the Zyre interface is also implemented and tested. Figure 19 shows the traceability application receives JSON message in Zyre, and replies JSON message to the node talks to it. Figure 20 shows other node receives whisper message from traceability system, and Figure 21 shows all nodes in group module1 receive shouted messages from traceability system.

🖳 RFID Module		<b>— —</b> X
Msg[21:30:20]: whisper from node1 info: {"MessageType":"Data_Request","msgFrom":"ModuleX","msgTime":"27/0 8/201510:30:45","MessageInfo":"RequestType":"RFID","RequestValue":" E2001063100801270700D0D0"}} Msg[21:31:05]: whisper to node1 info:	Name p	mp_rfid Group module1
{"messageType":"Data_Request_Reply","requestType":"RFID","moduleN	Node:	node1
ame":"PnP_RFID","returnTime":"27/08/2015 10:30:45", "objectType": "SmallPackage","sourceInformation":{"BatchName": "Tomato26Sep ID:19)","SupplierName":"Supplier03333","supplierGLN":"3405353","rece ivedTime":"26/08/2015 00:18:01","productName": "Tomato_Raw", "inputGTIN":"500695898590","categoryName":"Tomato","InSCC":"10468	Message:	"destination":"Customer9 910","destinationGLN":"8 736134"}}
9981846061452","IncontainerType":"In_Container","InternalContainerID ":"6"},"productInfomation":{"outputTypename":"Tomato_Raw(Lot No.:0100100003)","inFillTime":"26/08/2015 00:30:10", "IotNumber": "0100100003", "operatorName":"Zhaozong","outputGTIN": "500695898590" "productionLineID":"4" "plantName":"Plant01962" "plan	Group	Whisper
tGLN": "9099393", "fixPrice": "True", "priceRate": "0.5000", "netWeight":	Massage:	
"500", price :: 0.5000", extendBarcode :: 0050", register 1me :: 25/08/ 2015 00:38:03", "externalContainerID":"16"}, "deliveryInformation": {"outSSCC":"376949226092311498(OutUnitID:4)", "plantName": "Plant01962", "dispatchGLN":"909393", "departureTime":"26/06/2015 01:00:01", "destination":"Customer9910", "destinationGLN":"8736134"}}	message:	{"messageType":"Broad casting","mdouleName": "PnP_RFID","sendTime"
Msg[21:33:41]: shout to module1 info: {"messageType":"Broadcasting","mdouleName":"PnP_RFID","sendTime":		Shout
"27/03/2015 10:49:54","msglnfo":"tagID":"000011112222333344445555", "uniqueID":"20150827104954823"}}		Stop

Figure 19 Traceability System Whisper and Shout to Other Nodes

🖳 Test Device 1		
Msg[21:30:20]: whisper to pnp_rfid info: {"MessageType":"Data_Request","msgFrom":"ModuleX","msgTime":"27/0 8/2015 10:30:45","MessageInfo":"RequestType":"RFID","RequestValue": "E2001063100801270700D0D0"}} Msg[21:31:06]: whisper from pnp rfid info:	Name n	ode1 Group module1 Start
{"messageType":"Data_Request_Reply","requestType":"RFID","moduleN	Node:	pnp rfid
ame:::"PhP_KFID","return Time:::27/08/2015 10:30:45", "objectiype": "SmallPackage", "sourceInformation":{"BatchName": "Tomato26Sep ID:19)", "SupplierName"::"Supplier03333","supplierCLN":'3405353", "rece ivedTime":"26/08/2015 00:18:01","productName": "Tomato_Raw", "inputGTIN"::500695898590","categoryName":"Tomato","InSCC"::10468	Message:	{"MessageType":"Data_ Request","msgFrom":"M oduleX","msgTime":"27/0
9981840001452 , incontainer i ype 'i in_Container', internationtainer D ":"6"}, "productinformation"; "output/Typename:"Tomato_Raw(Lot No.:0100100003)", "inFillTime":"26/08/2015 00:30:10", "lotNumber": "0100100003", "operatorName";"Zhaozong", "output/GTIN"; "500050005000 ("bestor: into: the the the terms of terms of the terms of the terms of the terms of terms		Whisper
tGLN": "90993939", "fixPrice":"True", "priceRate":"0.5000", "netWeight":	Group:	
"500", "price":"0.5000", "extendBarcode":"00050", "registerTime":"26/08/ 2015 00:38:03", "externalContainerID":"16"}, "deliveryInformation": {"outSSCC":"376949226092311498(OutUnitID:4)", "plantName": "Plant01962", "dispatchGLN":"9099393", "departureTime":"26/06/2015 01:00:011" "destination"."(ustomer0910" "destinationCLN":"87366134")}	Message:	
Msg[21:33:41]: shout from pnp_rfid/module1 info: {"messageType":"Broadcasting","mdouleName":"PnP_RFID","sendTime":		Shout
"27/03/201510:49:54","msglnfo":"taglD":"000011112222333344445555", "uniqueID":"20150827104954823"}}		Stop

Figure 20 Other Node Receive Whisper Message from Traceability System



## PicknPack

P Test Device 2	
Starting Zyre node node2 in Group module1 with model pnp_model.Name noUUID: 9865F980A47D154495111E33C0C6FA21Name noGroup: PNP module1 Callback registered.Msg[21:28:37]:75 bytes received: ENTERB092D497EA6D6148985535DF9D6FF606 pnp_rfidtop://420.98.145	ode2 Group module1
Node:	
Msg[21:28:37]:51 bytes received: JOIN B092D497EA6D6148985535DF9D6FF606 pnp_rfid PNP Message:	
Msg[21:28:37]:55 bytes received: JOIN B092D497EA6D6148985535DF9D6FF606 pnp_rfid module1	
Msg[21:28:37]:72 bytes received: ENTER C3A4A9CCF7C3EF41AA4DFF3DEBF6CF06 node1 top://130.88.116.99:49156	Whisper
Group:	
Msg[21:28:37]:48 bytes received: JOIN C3A4A9CCF7C3EF41AA4DFF3DEBF6CF06 node1 PNP Message:	
Msg[21:28:37]:52 bytes received: JOIN C3A4A9CCF7C3EF41AA4DFF3DEBF6CF06 node1 module1	
Msg[21:33:41]: shout from pnp_rfid/module1 info: {"messageType":"Broadcasting","mdouleName":"PnP_RFID","sendTime":"2 7(03/201510:49:54", "msoInfo":"tagID":"0000111122223333444455555", "unig	Shout
ueID":"20150827104954823"}}	Stop

Figure 21 Other Node Receive Shouted Message from Traceability System

In addition to the traceability application based on PC, a handheld RFID reader can be used to trace the product information. The handheld RFID reader can detect the RFID tag, query the database, and display the matching records to the user on its interface. The start page and main page is given in Figure 22, and search and query page is given in Figure 23.



Figure 22 Start Page and Main Interface of Handheld Reader Application







(1) Incoming Goods Tracking



(2) Small Package Tracking

Figure 23 Information Tracing with Handheld RFID Reader

In addition, the handheld RFID reader can also decode the QR code generated by the traceability application, which is as shown in Figure 24.



Figure 24 QR Code Decoding with Handheld Reader Application



All the above interfaces are some selected typical ones, which are cut in the test of the system.

### 5.3 Traceability System under Testing

The hardware modules and software interface under in-lab testing is as shown in Figure 25.



Figure 25 In-lab Test Bench of the RFID Traceability System

#### 6 Summary

This report summarises the design and development of the traceability system for demonstration, including (1) hardware system, (2) process modelling and database design, and (3) software development and software integration.

The functions for integration are implemented with to the required protocols and standards in the current version of the traceability application. In order to achieve interoperability, ZeroMQ and JSON are successfully implemented. Further test and optimisation will be carried out in order to interact with other modules in the next step. The future work for the traceability system is suggested as follows:

- (1) Fit the traceability system to the line for demonstration, including hardware and software
- (2) Design the data sharing application interfaces using the standards, according to the interfaces other modules provide
- (3) In line test and evaluation of performance of the traceability system
- (4) Optimise the integrated traceability system
- (5) Since ZeroMQ will be changed to Zyre, the updated functions will integrated to the traceability application.

The points listed above are the essential tasks to be achieved in the future work.



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