Mobilising RFID Data for Greenhouse Crops Tracking Using Web Service Framework

Abhijit Sen and Asad Khan

***Abstract*—Mobile Devices such as netbooks, laptops, and smart phones have become vital tools for workers to access corporate data remotely. Web services technology enables these mobile devices to integrate seamlessly with other distributed functionalities through well-defined interfaces. This paper explores how crops tracking data for greenhouse crops tracking system (GCTS), collected using RFID (Radio Frequency Identification) hardware and associated software, can be delivered to mobile devices such as iPhone, Android, and Windows mobile phones using Web services technology. These devices provide browser capabilities to support HTML 5-based websites providing mobile users with richer web application and improved usability. The design and implementation of GCTS prototype system are discussed in the paper. The result shows that plant tracking data can easily be delivered to mobile devices with different hardware platform and operating system using Web services technology.**

***Index Terms*—DBMS, RFID, supply chain, tags.**

I. Introduction

The RFID (Radio Frequency Identification) technology is gaining widespread deployment in industries such as asset tracking, supply chain management, patient tracking, inventory management etc. The interactive map [1] shows the deployment of RFID technologies in different parts of the world. RFID technology is also gaining wide spread usage in agriculture to accurately track the progress of crops growing process. In the Netherlands [2], plant growers are using an RFID-based solution to improve plant health and production. The Hawaii Department of Agriculture has launched a pilot of RFID tracking [3] designed to help farmers, distributors and retailers track their produce through the supply chain, and to allow for traceability in the case of contamination. A Dutch systems provider for greenhouse botanical growers has implemented a plant ordering system for commercial greenhouses using RFID technology [4]. Researchers are determining the feasibility of using various types of RFIDs with nursery plants [5]. RFID technology is used to digitally monitor food products as they moved through the supply chain [6].

The GCTS project is envisioned as a proof of concept for use at the greenhouse at Kwantlen School of Horticulture in Langley, British Columbia, Canada to demonstrate that crop information could be collected, digitally stored and monitored as it moved through the supply chain.

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II. Objective

The objective of the GCTS system is to allow growers to track the progress at item-level of growing process of crops (such as rows of tomatoes). Fitting each row with a RFID tag, growers will be able to monitor progress of plants in every row in the greenhouse. Similarly, harvest boxes when affixed with RFID tags will enable one to track the crop to market, recording environmental parameters such as temperature fluctuations. In addition such RFID equipped system will provide traceability information such as date of harvest, distance traveled (food miles), and farm of origin.

III. Equipments Used

For the purposes of prototyping this project, RFID tags and readers from Identech Solutions [7] are used. This equipment may not be used in a real implementation due to their relatively high cost and non-disposable nature of the tags. However, the equipment used is adequate for a proof-of-concept prototype.

The equipment used is as follows:

- Identec Solutions RFID tags [6], model i-D2, type PL/NA (non-disposable, read/write/rewrite capability) with supplied manufacturer drivers (3 tags for testing purposes)
- Identec Solutions i-Card 3 with 1/4 Wave Antenna (PCMCIA-based interface) (one reader)
- Laptop with PCMCIA card interface, running Windows XP SP3
- ZigBee CC2530 ZigBee Development Kit
- (Texas Instruments)

IV. Specifications of RFID-Based GCTS

The primary requirement of the GCTS is to provide the capability to automatically track the movements of all greenhouse plants and containers equipped with an RFID tag and monitor their status from central and remote locations as they travel to, from, and around the greenhouse.

The GCTS is designed to detect an RFID-equipped plant when the plant container reaches a sufficiently close proximity of an RFID detector. The placement of several such detectors at different sections of the greenhouse would allow tracking of each plant and containers, and update the plant's location status accordingly, without the need for human intervention.

For Kwantlen's greenhouse application pilot project, a central database of plants is designed to record, monitor and

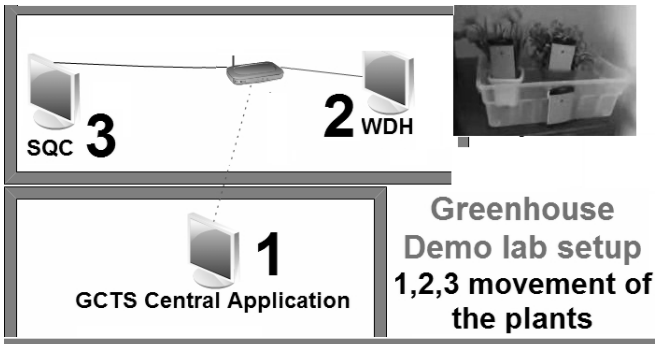
track plants. RFID tags in read only mode is used.

V. Overview of GCTS Design

The following sections describe the generic model of the greenhouse used in the prototype and specify the design of the software.

A. Generic Green House Model Architecture

Fig. 1 presents the diagram of a generic greenhouse architecture showing the movement of plants at different location. The GCTS Central Application Computer (such as one in area 1) and Station computers (in area 2, and 3)are equipped with RFID readers which track the movement of the plants as they travel from one section of the greenhouse to another. The tracking related data is stored by GCTS Central Application computer in a MS SQL database.



Number of rows: 6

	Station Name	Plant Name	Date and Time Detection	Detection Description	Tag ID
▸	WDH	YARROW	Apr 06, 2011 10:39:00	954	100061954
	WDH	Multiple Plants (2)	Apr 06, 2011 10:39:00	955	100061955
	WDH	COREOPSIS	Apr 06, 2011 10:39:00	953	100061953
	SQC	COREOPSIS	Apr 06, 2011 10:44:00	953	100061953
	SQC	YARROW	Apr 06, 2011 10:44:00	954	100061954
	SQC	Multiple Plants (2)	Apr 06, 2011 10:44:00	955	100061955

Fig. 1. A Generic Green House Setup.

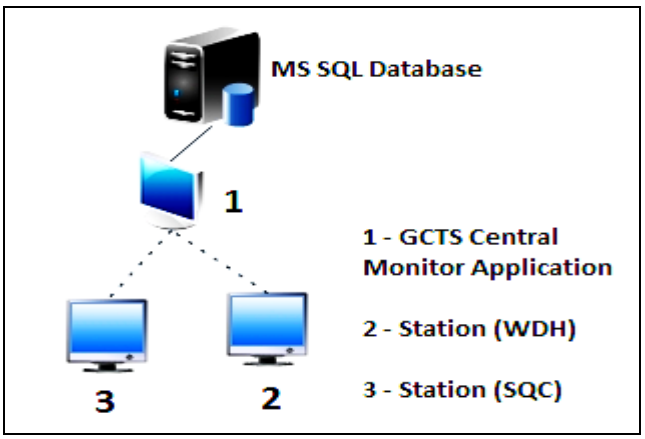


Fig. 2. Application Connectivity diagram.

Under the proposed GTCS, the following hardware components and systems are used:

- Individual (passive, read-only) RFID tags attached to plants. Each RFID tag has a unique serial number which is used to detect it and distinguish it from tags on other plants.
- RFID scanners attached to each station computer and GCTS Central Monitor Application Computer.
- GCTS Central Monitor Application Computer system connects to individual RFID scanners, as well as manages the central database that tracks the current locations of RFID-tagged plants.

B. Software Architecture

Each of the components in the Fig. 2 would require its own set of software. The database server would use a DBMS to store and manage GCTS data. The GCTS central monitor application needs to be able to collect data from RFID scanners and store it in the central database. The station will be able to detect the plant and container passing by and communicates these information and ZigBee sensor data to GCTS central monitor application.

1) Database Server

The database server used for this project is Microsoft SQL Server 2008, integrated with MS Visual Studio and the C# environment.

2) GCTS Central Monitor

The GCTS central monitor application checks the messages coming from the stations. The permitted messages are stored in the MS SQL database and plants tracking messages are displayed real-time (RFID Tags detections) on the screen.

The GCTS central monitor application are also used to retrieve stored information according to user defined search criteria from the database and to add GCTS permissions, user accounts, plants, RFID readers/tags, and stations information in the database.

This system also runs central administrative interfaces which can be used by employees to work with RFID data. The GCTS Central Monitor Application software shown in Fig. 3 supports the following features:

- Associate RFID tags with plants and containers
- Read data from RFID scanner
- Update database records with RFID scanner supplied data
- Displays real-time plant tracking information in the GCTS Central Monitor application
- Communicates with Stations
- Performs variety of administrative tasks, such as management of user accounts
- Displays various status messages
- Configure tags
- Set power level messages

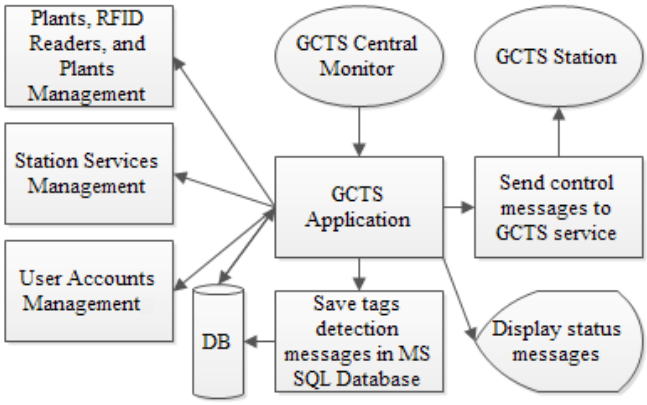


Fig. 3. GCTS Central Monitor Application architecture

3) Stations

The stations send messages about RFID tags detection and ZigBee device light information to the GCTS Central Monitor application. In the case, the GCTS Central Monitor application could not be reached the stations will store the messages locally in a Microsoft Access database file. The GCTS Station software shown in Fig. 4 supports the following features:

- Communicates with GCTS Central Monitor Application
- Transmits ZigBee light sensor data
- Read tags data
- If connections to the GCTS central application fails , data is saved on MS Office 2010 Access database

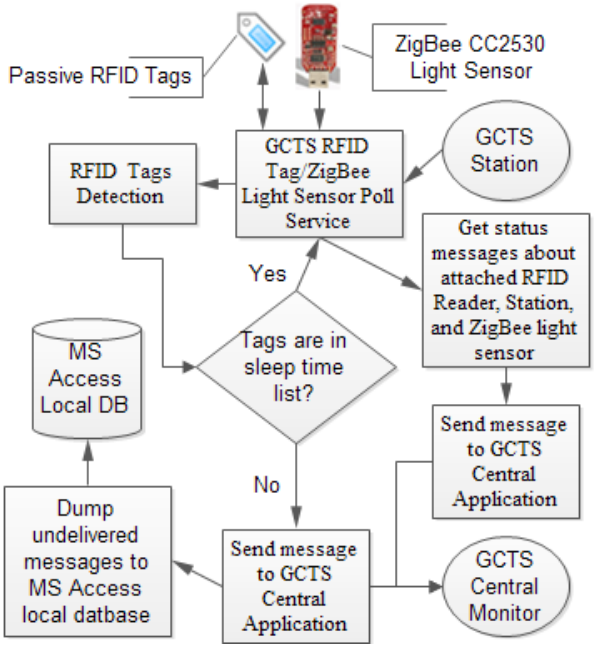


Fig. 4. GCTS Station (Service) architecture

4) Internet Information Services (IIS)

The webserver is used to display plant tracking information from the database to mobile web browser. The GCTS website retrieves the plants' location from the GCTS web service, and the GCTS web service receives information from the database.

VI. Prototype Implementations

For demonstration purposes, the current prototype is implemented using Microsoft Visual Studio Framework.

A. Database Server

All relevant GCTS data is stored in central SQL Server database. The structure of central database is shown in Figure 5.

These tables are used to store and manage stations, plants, RFID readers and tags data, create and manage user accounts, and generate error / operational status messages,

The RFIDReader table stores information about RFID scanners, including their serial numbers and descriptions.

The RFIDTag table stores information about RFID tags, including their serial numbers, descriptions, and last creation/update date.

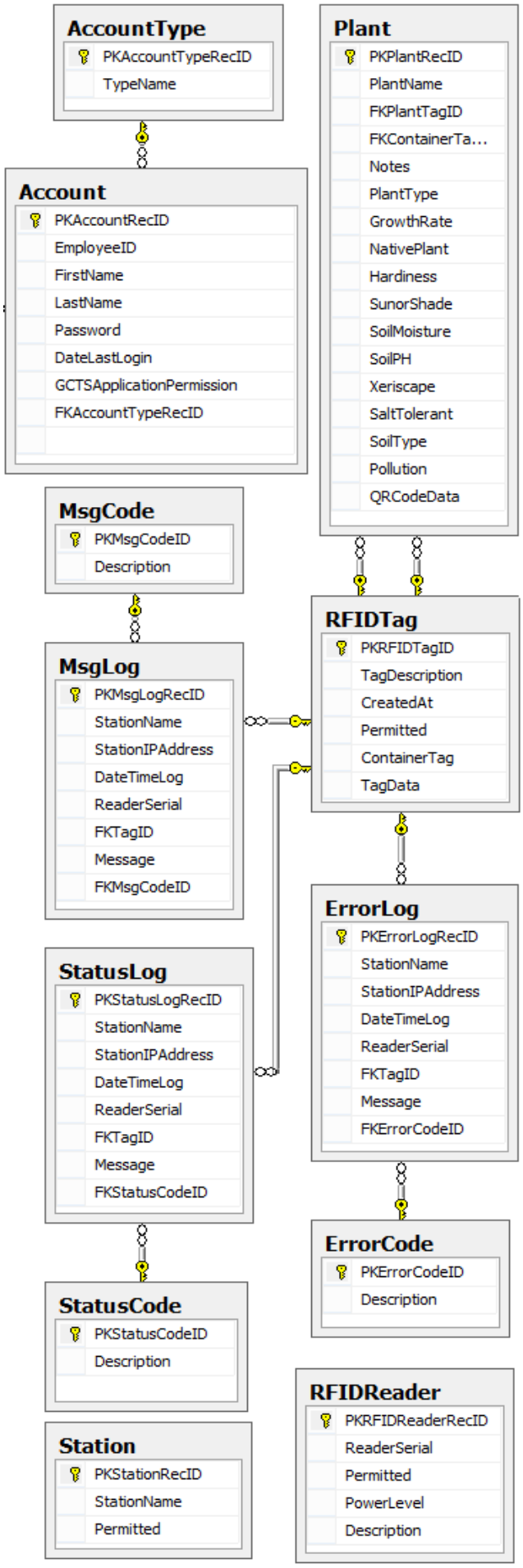


Fig. 5. Database Structure.

The Plant table is used to store information relevant for the particular plants including plant name, growth rate, and soil moisture level and soil type.

The other tables are used for user account management, logging various status messages and generating error messages.

Station table keeps basic information about each configured stations.

Account Management for users are implemented through tables Account and AccountType.

The other tables are used to process different categories of messages. The system generates three different types of messages: status messages (such as Station Alive –OK), error messages (such as cannot connect to RFID), and normal communication messages (such as Tag detected – cannot read data).

Status messages are generated using StatusCode, StatusLog tables. Error messages are generated using tables ErrorCode, ErrorLog. Normal communication messages are generated using tables MsgCode, MsgLog.

B. GCTS Central Monitor

The GCTS central monitor is written in C#, and uses driver libraries supplied by the manufacturer of the available Identec RFID tags.

The GCTS central monitor software is designed with multiple threads – main thread updates UI or terminates the application. The application processes three types of communication: Error, Signal Message, and Status. Each type has dedicated thread (total three threads)

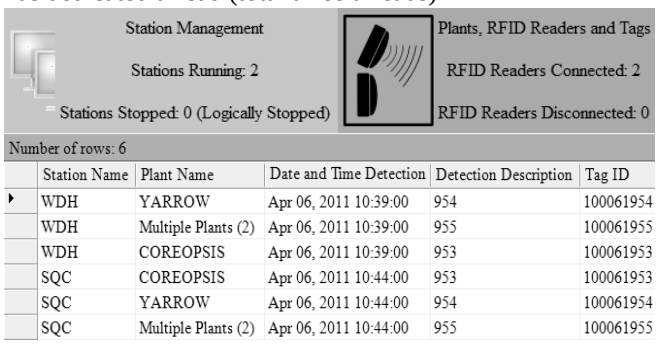


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Fig. 6. Real Time Plants Tracking.

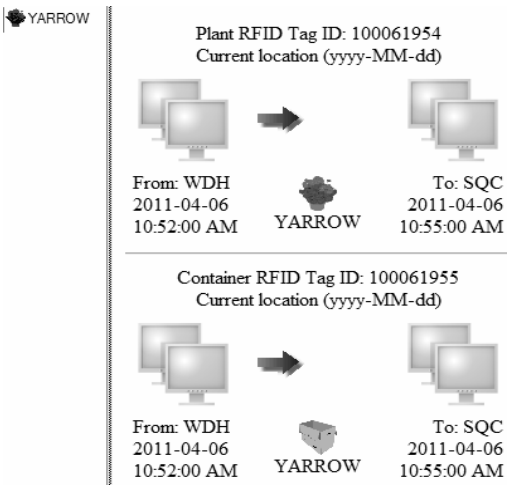

Fig. 7. Track Plant Location

The GCTS central monitor initiates the connection to the RFID scanner, as well as to the MS SQL Server database. These connections are needed before anything else can be done.

After the connection is set up, when scanner detects RFID tags, relevant data is recorded in the database as shown in Fig. 6, and Fig. 7.

C. Station

The Station code is written in C#, and uses driver libraries supplied by the manufacturer of the available Identec RFID tags, and Zigbee CC2530 SDK.

The station software is designed with multiple threads – main thread sends ZigBee light sensor data or terminates the service, second thread detects RFID tags, third thread dispatches messages to the central GCTS application.

The station also backs up data to local Microsoft Access database.

D. Internet Information Services (IIS)

Internet Information Services (IIS) implements Web services to gather data from MS SQL database. ASP.NET framework is used to develop web application and services for delivering plant tracking data to mobile devices and desktop computers. Three methods are developed and implemented as Web services and made available to mobile clients. These are:

- Public bool validateLoginAndUpdateLoginAtTime(string strEmpID, string strPassword) -Authenticate mobile client
- Public DataSet fetchAllPlants() - Select the plant to be tracked from list of plants recorded in the database
- Public DataSet fetchPlantLocation(string strPlantID) - Access plant information.

Mobile clients invoke these web services from their individual mobile browsers. When the ASP.NET application is launched from mobile devices, one can see a list of tags recorded in the GCTS. The information is retrieved from database, and includes the tag ID, description, creation date, and tag history. The history is different for each tag. . If at any point a tag has been updated, it will be reflected in the stored data. Web Services Framework is shown in Fig. 8.

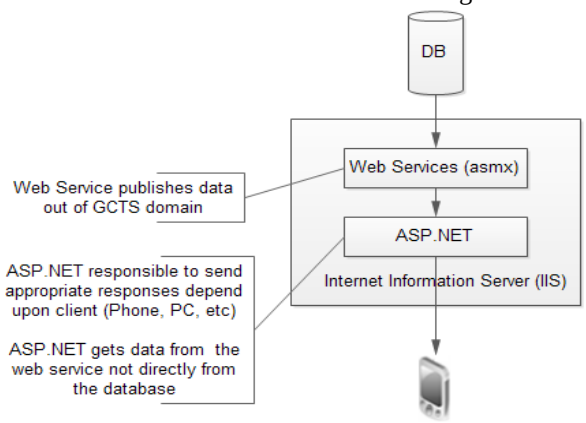

Fig. 8. Web Services Framework

Fig. 9 to Fig. 11 show screenshots of plant tracking data delivered to smartphones such as Windows Mobile, Android, and iPhone. As the plants are moved from one location to the next, their movements can be tracked by remote users equipped with variety of mobile devices.

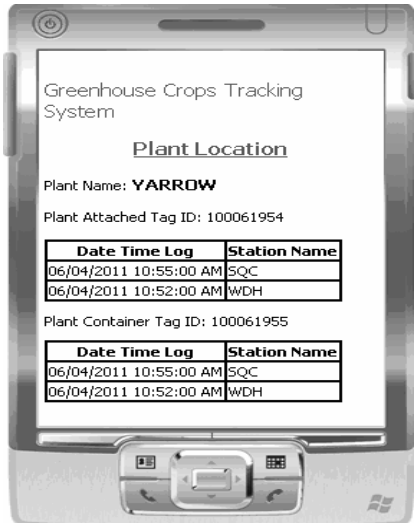

Fig. 9. Plant and container Location- (WDH -> SQC) (Windows Mobile 6 Browser)

Fig. 10. Plant and container Location - (WDH -> SQC) (iPhone Browser).

Fig. 11. Plant and container Location- (WDH -> SQC) (Android Browser)

VII. Conclusion

In this paper we have discussed the design and implementation of RFID-based Greenhouse Corps Tracking System for Horticulture industry. We have proposed Web Services framework to enable mobile users equipped with devices such as smart phones to track the movements of plants and containers as they travel to, from, and around the greenhouse. We have successfully demonstrated that mobile users equipped with Android, iPhone, and Windows Mobile phones can easily access plant tracking data through integration of Web Services with mobile Technology, and Databases.

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References

[1] RFID Deployments Worldwide. [Online]. Available: http://www.rfidjournalevents.com/map.php
[2] RFID Helps Grow and Track Potted Plants. [Online]. Available: http://www.rfidjournal.com/article/view/3497
[3] Hawaii Plans Trace-Back Program for Fresh Food. [Online]. Available: http://www.rfidjournal.com/article/view/3702
[4] The growth of the RFID-enabled greenhouse. (July 26, 2007). [Online]. Avaialble: http://www.usingrfid.com/news/read.asp?lc=k16237rx1155zm
[5] Bob Ratliff. (September 2004). Radio Chips Help Keep Tabs on Plants. [Online]. Available: http://msucares.com/pubs/highlights/summer2004/radio.pdf
[6] Rafael Ruffolo. (November 25, 2008). Manitoba tests IBM food traceability system. ITWorldCanada.com. [Online]. Available: http://www.itworldcanada.com/news/manitoba-tests-ibm-food-traceability-system/06105
[7] Identech Solutions. [Online]. Available: http://www.identecsolutions.at/

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