Intelligent data acquisition and cloud services for apple orchard

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Abstract: An intelligent data acquisition and service system for apple orchard was developed for acquiring apple tree growth information in time and managing orchard production remotely. The data of fruit tree growth environment were collected by Portable Digital Assistant (PDA) through the ZigBee Wireless Sensors Network (WSN) deployed in the apple orchard. The collected data were packaged and uploaded following the transportation protocol through the web service interface provided by the orchard server. After that the orchard data were parsed and stored using distributed mechanism. Finally, the data could be processed, analyzed and visualized by the cloud orchard server, and the orchard production decisions based on WebGIS technology could be made as well. Hence the users could access the services provided by the network platform via remote mobile or fixed terminals. The system operation test showed that the whole process was stable and reliable, during which intelligent data collection, storage, and cloud data processing and publishing services were achieved.

Keywords: orchard, PDA, WSN, WebGIS, distributed storage, web service

DOI: 10.3965/j.ijabe.20140702.018

Citation: Guo X, Zheng L H, Li M Z, Zhang Y. Intelligent data acquisition and cloud services for apple orchard. Int J Agric & Biol Eng, 2014; 7(2): 146－153.

1 Introduction

Information technology supporting modern agriculture has been significantly enhanced with the rapid development of information technologies such as computer technology, network technology, communication technology, and information security technology. However, most of Chinese orchards are still under traditional management which is labor-intensive and relatively low-tech. The factors such as small plant density, mismanagement of fertigation, low pest prevention level, unreasonable pruning, etc., could cause the decline of the fruit quality. To improve the fruit trees nutrition status and yield, it is necessary to fertigate properly according to the site-specific demand and different growth stages. So it is very important for orchard farming to collect the data of apple tree growth status and environment accurately and timely to assess how much fertilizer and irrigation should be added to each tree. Currently, in China and abroad, WSN based on ZigBee has been widely used to monitor and collect the environment information of plant growth[1,2]. Its advantages are low price, strong capability of data processing and high efficiency[3]. Hence orchard production decisions based on WebGIS could be made[4,5]. Today, WebGIS technology has been widely used in Geographic information, decision support, orchard management, etc.[6,7]. However, the studies combined WebGIS with cloud computing just begin. With cloud computing technology, customers no longer need to install and run the applications in their terminals. Cloud server provides the services demanded by customers, and at the same time customers only need to connect their devices to the Internet. In this study, WSN and cloud

Received date: 2014-01-05 **Accepted date:** 2014-04-11

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computing technologies are introduced to achieve orchard data collecting and processing efficiently and accurately. Furthermore, the system provides effective production decisions for orchard owners.

PDA is the portable smart device which is rapidly developing[8]. It has the built-in operating system with powerful data management and data process capabilities. In this study, a movable data acquisition system was developed using WSN technology for apple orchard based on PDA. Through the embedded application running on PDA, data collecting map could be downloaded from the server; the WSN could be managed and orchard data could be collected; then the collected data could be uploaded to the server through the Web service interface in real-time. Meanwhile, the functions running on the server were developed as well, which could conduct data receiving, data parsing, data storing, data processing and data visualizing. The data services could be accessed using remote mobile terminals or fixed terminals. Accordingly, data storing, data processing and data visualization could be carried out on the cloud. Also the fertigation decisions provided by cloud computing through WebGIS could be used to achieve orchard production efficiently.

2 System design scheme

2.1 System architecture

The WSN based on ZigBee was established to collect the environmental data for assessing growth status of each apple tree. A customized PDA was integrated to monitor the WSN working and collect the data including soil moisture, soil conductivity, soil temperature, air temperature and humidity. A RFID (Radio Frequency Identification) tag was mounted on each tree and it could be read by the PDA so that each collected datum could be linked with the corresponding tree as one record. The collected data were then packaged and delivered to the server via GPRS (General Packet Radio Service) through the Web service interface which the orchard server deployed. The system architecture is shown in Figure 1.

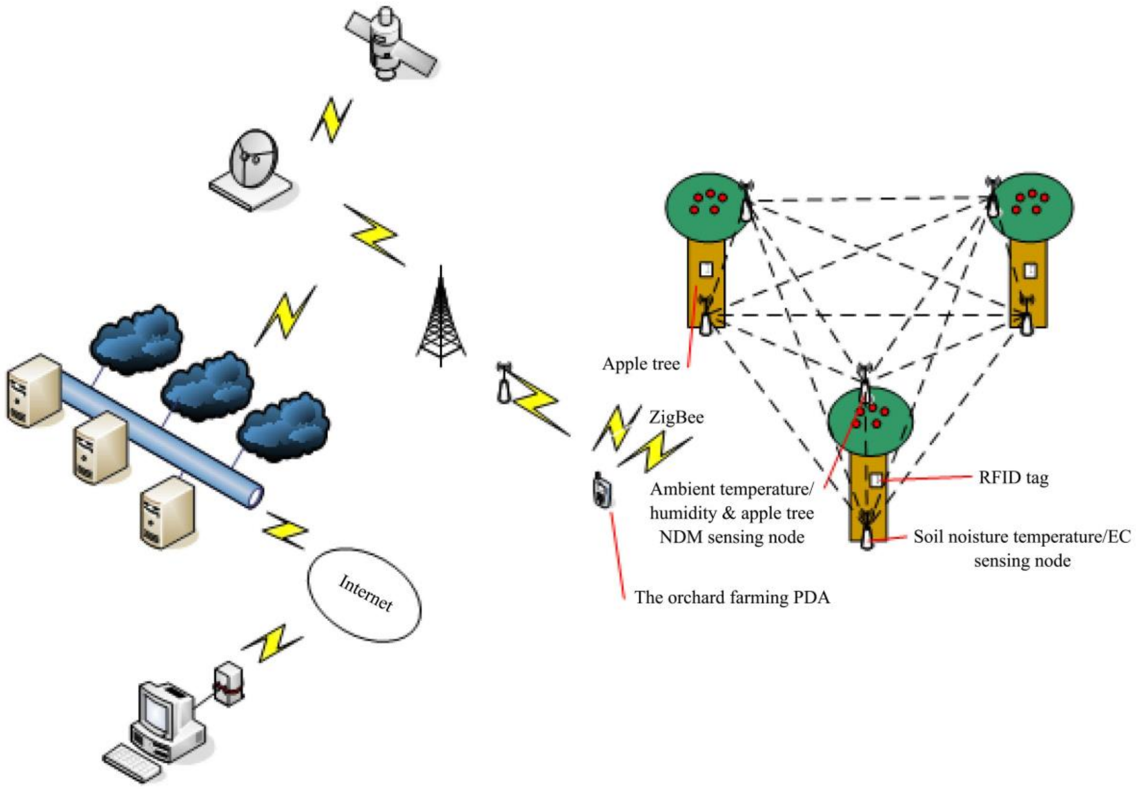


Figure 1 System architecture

2.2 Development of the orchard WSN

The WSN was composed of a plurality of sensing nodes deployed around each target tree in orchard. Each sensing node connected four sensors together: soil moisture sensor, soil temperature sensor, soil electrical conductivity sensor, and environmental temperature and humidity sensor. These nodes were used as the router communicated with the coordinator by Ad-Hoc network, and the coordinator was connected to the processor of the PDA via RS232. The coordinator was responsible for managing the WSN and collecting data from nodes dynamically according to the commands inputted by user through the PDA. The sensing nodes would turn off automatically when there was no data to collect[9,10].

2.3 Working principle of the orchard PDA

The working principle of the orchard PDA is shown in Figure 2[11]. The PDA was integrated with ZigBee coordinator module, GPS (Global Position System) OEM (Original Equipment Manufacturer) module and GPRS module. The orchard property data were collected through WSN which was managed by ZigBee coordinator. The geographic data of each target tree were acquired through GPS OEM module. GPRS module was responsible for sending orchard property data and geographic data to the orchard server and downloading data from the server.

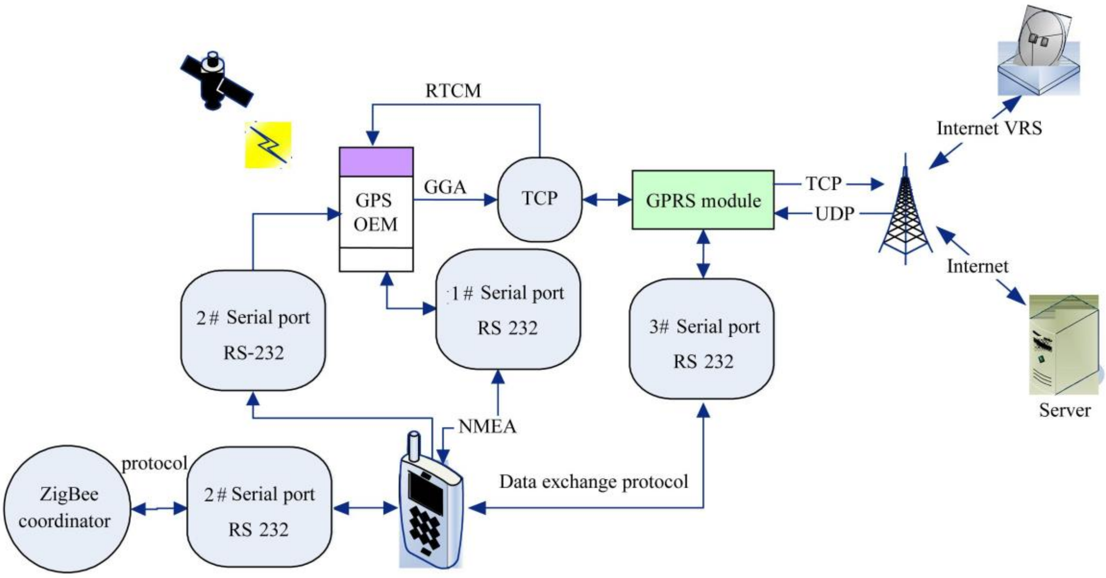


Figure 2 Working principle of the orchard PDA

3 Data transportation protocol

In order to achieve the communication between the mobile terminal and the orchard server, web service technology was used to develop the interface. Web service is a kind of communication mode based on XML (Extensive Markup Language) and it defines the standard output interface.

3.1 Format design of the returned message

When the orchard PDA exchanges data with the server, it judges the returned result of the request and then decides what to do next. The format of the returned message was designed as shown in Table 1. According to format design, "1**" represents the information tip; "2**" means succeed request; and "4**" represents failure request.

3.2 Data exchange command design

The data exchange commands were designed based on SOAP (Simple Object Access Protocol). They are used to implement data exchanging between the orchard server and PDA. The orchard server provides the orchard PDA with the Web service interfaces for data exchanging. The orchard boundary data will be downloaded to the orchard PDA and the production data collected by the orchard PDA through WSN will be sent to the server. The commands are shown in Table 2.

Table 1 Format of returned message

Format	Description
100	Unidentifiable commands
200	Login succeed
201	Succeed
400	Login failure
401	Error message after operation failure
402	Credentials of login don't exist or lapsed

Table 2 Commands of data exchanging

Command interface	Description
Login (username, password)	Login to the orchard system by sending username and password
GetTask (username)	Obtain the unique ID of the orchard PDA from the server
Getboundary (orchardid)	Obtain the boundary of orchard from the server according to the orchard ID
GetTrees (orchardid)	Obtain the information of orchard tree from the server according to orchard ID
Update Boundary (orchardid, longitude, latitude)	Send the new boundary of orchard to the server to update the database
Update Trees (orchardid, RFID, longitude, latitude, time)	Send new basic orchard data to the server to update the database, including RFID, longitude, latitude and time
Add Trees Collect (orchardid, RFID, soil Temp, soil Humidity, air Temp, air Humidity)	Send the collected data of the apple trees to the orchard server

4 Development and implementation of the embedded software

4.1 Function design of the embedded application

The embedded orchard farming application was designed as shown in Figure 3. The application was composed of GPS management, orchard boundary obtaining, map management, orchard data collecting, data uploading and data downloading. The module of orchard boundary obtaining carried out the task of adding and deleting specific boundary point. And the orchard borderlines were drawn based on these points. The module of orchard data collecting was responsible for orchard data collecting through WSN. The basic map operation was managed by the module of map management. The modules of uploading and downloading achieved data exchange between the PDA and the server.

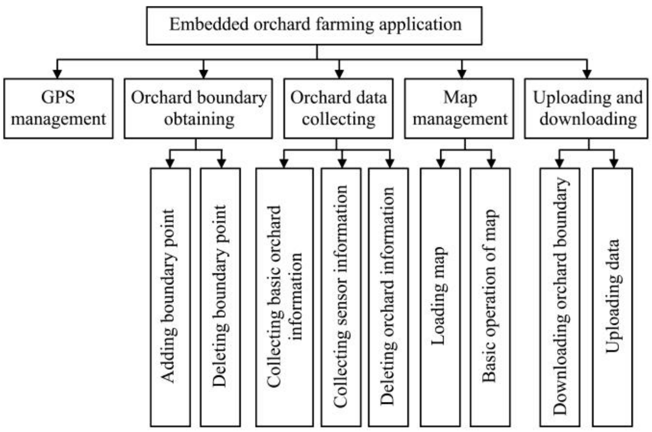


Figure 3 Embedded orchard farming application

4.2 Implementation of main functions

The main process flow chart is shown in Figure 4. After the user logging into the orchard server successfully, the map will be loaded and the sampling map can be downloaded, in which the target orchard boundary is drawn and geographical location of each target apple tree is marked. By selecting the specific apple tree in the map or reading its mounted RFID tag, its data can be collected by WSN deployed around it. The collected data for each tree are accordingly saved as one record in PDA and can be indexed using its RFID number. Then the data can be packaged and uploaded to the server via GPRS.

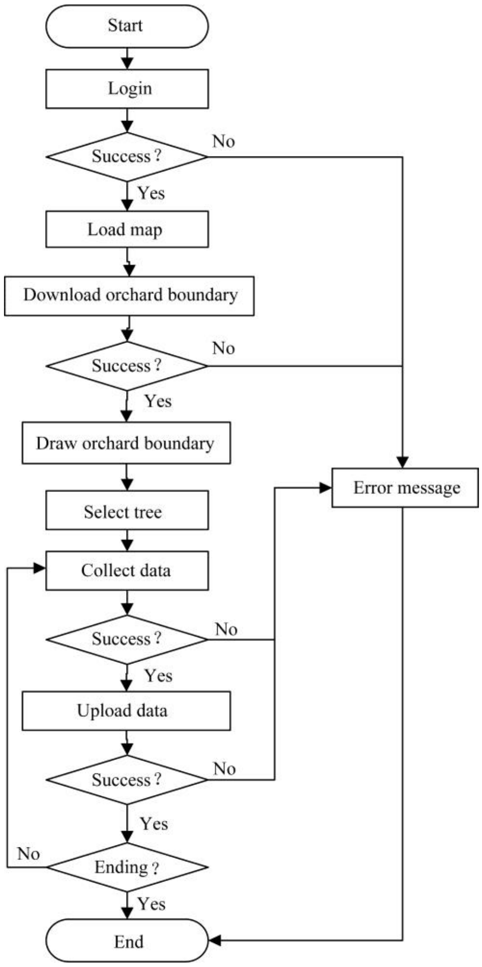


Figure 4 Flow chart of data collection

The module of orchard boundary is shown in Figure 5. When a new orchard boundary point needs to be added, the application will check whether the user has logged into the server or not. After the login succeed message being returned, the corresponding button can be clicked and the new GPS data can be acquired and added as a new boundary point. The application will redraw the orchard borderline accordingly. Then the PDA will upload the boundary data to the server and the database will be updated.

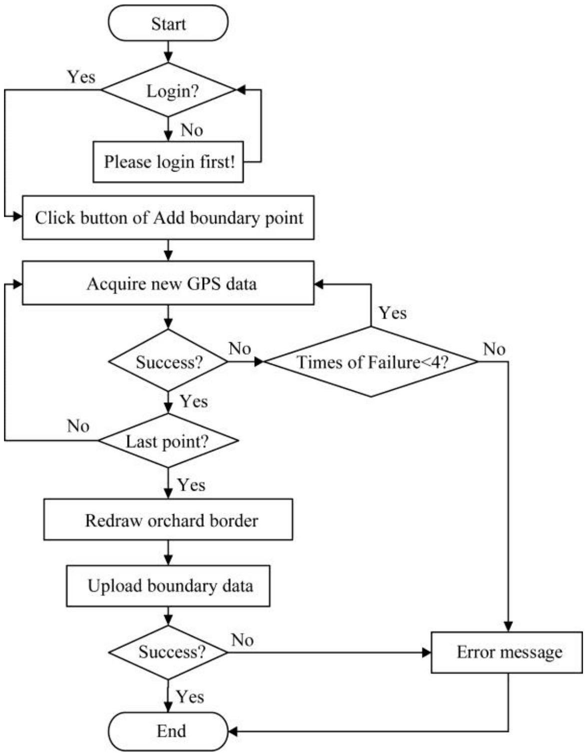


Figure 5 Orchard boundary drawing module

The module of orchard data collecting is shown in Figure 6. When the data of a tree needs to be collected,

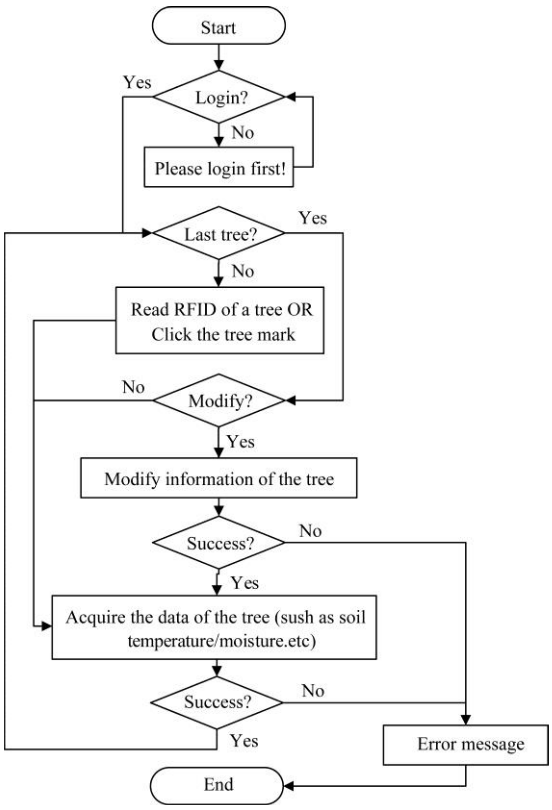
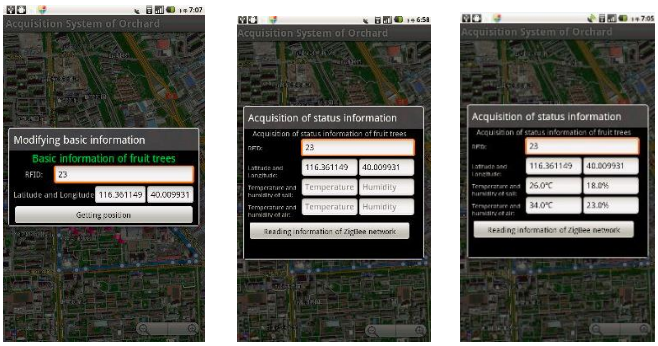


Figure 6 Orchard data collecting module

the PDA will select the data linked to that specific tree's RFID from the acquired WSN data and then saved as one record. The data can be collected and updated repeatedly. The operation interfaces of orchard data collecting module are shown in Figure 7. And as shown in Figures 7b and 7c, WSN data could be acquired by clicking the button of Reading ZigBee network.



a. Modify data b. Data collection interface c. Data collection

Figure 7 Operation interfaces of orchard data collecting module

5 Orchard data cloud service system

5.1 System design

Currently, WebGIS becomes an advanced technology and has been widely used in the field of geographic information processing. The orchard data cloud service system running on the server was developed based on WebGIS to fulfil remote farming management. The system is composed of eight main modules as shown in Figure 8. Data management module provides two web service interfaces, one of them is used to receive the collected orchard data which are uploaded by the orchard PDA, and another is used for publishing the orchard boundary data to the orchard PDA. WebGIS module provides the functions of data analysis, data visualization, thematic mapping and fertigation decision making. Hence the nutrition environment or growth status of each tree in the orchard can be visualized spatially and veritably, and fertigation decision can be made after data analyzing. Meanwhile, customers can use the system only by logging in it since WebGIS uses the globalization mode of B/S (Browse/Server), and the thematic maps of orchard properties could be drawn by WebGIS module through cloud, and it provided visualized and effective guidance to customers. In addition, the module of Traceability management provides trace function of retrieving production record data of each apple tree.

The system achieved remote data collection, production management, data visualization and decision making support. It made it easier for the users to access the production data of each apple tree in their orchard timely and precisely, so that they can observe and access the growth status of trees and then make appropriate fertigation decisions.

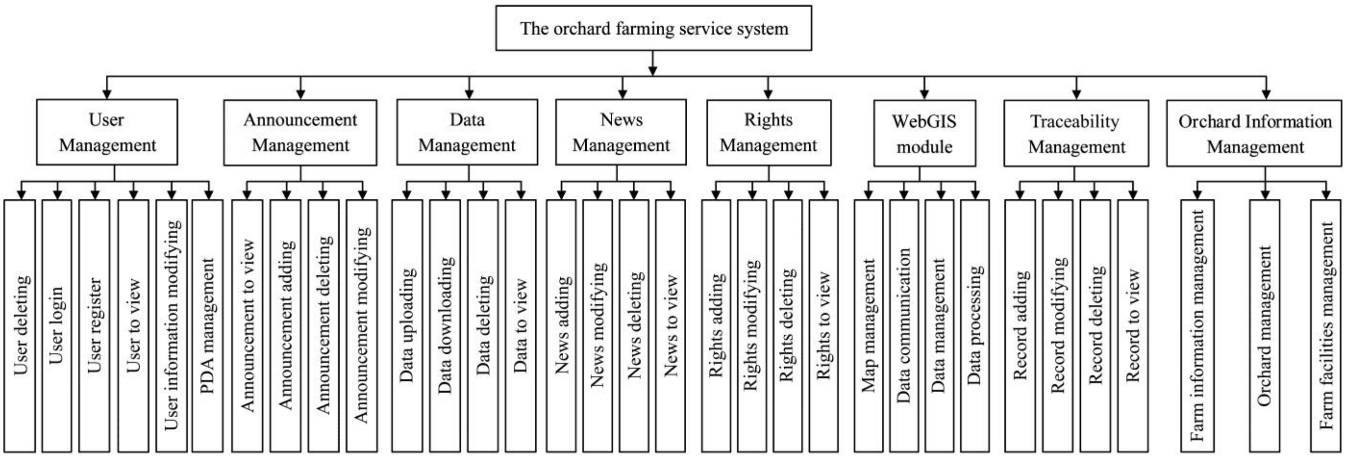


Figure 8 Orchard farming service system

5.2 Data exchange between heterogeneous platforms

The orchard data coming from heterogeneous platforms will be shared on the orchard server using web service technology. The working principle of web service in the system is shown in Figure 9.

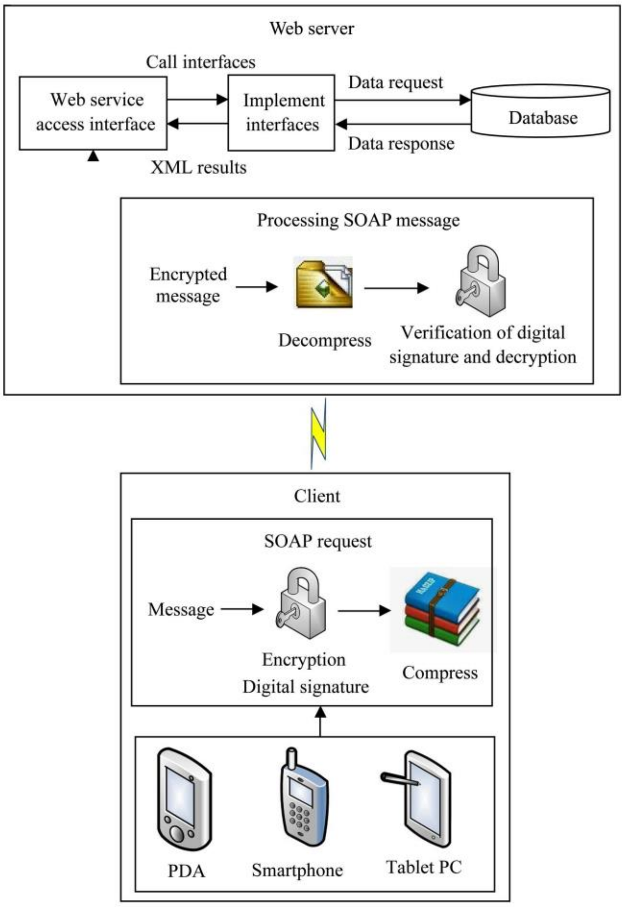


Figure 9 Working principle of web service

WSDL (Web Services Description Language) was used to fulfill web services of the orchard data. The orchard PDAs running on different OS (Operating System) platforms can access WSDL via the specific URL (Uniform Resource Locator) to get the standard output interface and then call the corresponding service functions. Although the implementation of the interface has been changed, the client does not necessarily need to know[12]. Hence it achieves the purpose of data sharing between heterogeneous platforms.

When working, the client sends a SOAP request to the server to access WSDL, the server processes the request and generates the SOAP response message to that client. The web service technology ensures the concealment, integrity and non-repudiation in the information exchange procedure via the digital signatures and encryption techniques[13,14]. Hence the security of the orchard data transmission is guaranteed.

5.3 Distributed storage of orchard data

After receiving the orchard data from the PDA, the server parses the data according to the transportation protocol and then stores the orchard data using HDFS (Hadoop Distributed File System). The architecture of HDFS is master/slave mode and all the servers interact via TCP protocol[15]. HDFS has high reliability and good scalability and it stores the data on all nodes in the

Hadoop cluster by streaming data access pattern. HDFS can provide high-throughput data access and it is suitable for storing large data sets[16]. The structure of HDFS used in this system is shown in Figure 10.

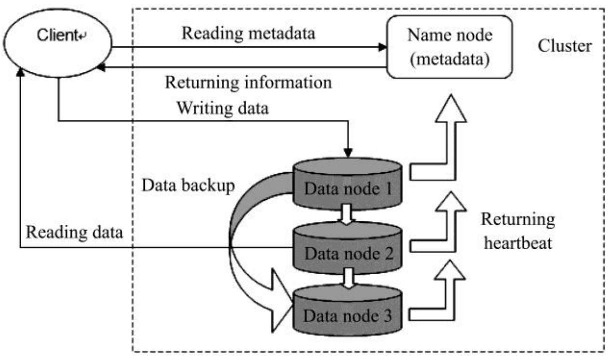


Figure 10 Structure of HDFS

5.4 Data processing and cloud service

Besides of web service interfaces and data storage, as the orchard service cloud node, the server can provide the remote terminals data querying, data analyzing, data visualizing and fertigation decision-making. The orchard map will be loaded and displayed on the website when the user logs in without installing any other GIS component. It provided an easier and more convenient way for the users to view the actual spatial distribution of orchard production data. The MapXtreme was installed as the WebGIS component on the server side, and it brought rich map operation functions to achieve map management such as basic interoperate mapping and interpolation algorithms execution. The system fulfilled providing orchard data visualizing, data analyzing and fertigation decision making through WebGIS module from the cloud. Its main webpage of WebGIS module developed in this system is shown in Figure 11.

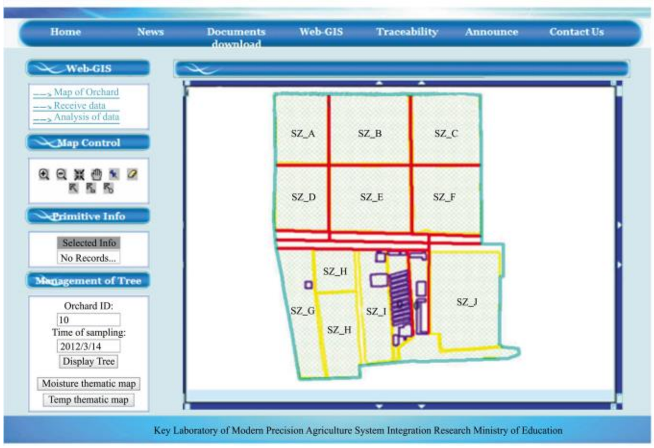


Figure 11 Webpage of WebGIS module

The MapXtreme component provides three interpolation algorithms and they can be used achieve thematic mapping for orchard data. Figure 12 showed the orchard soil moisture thematic map using IDW interpolation algorithm.

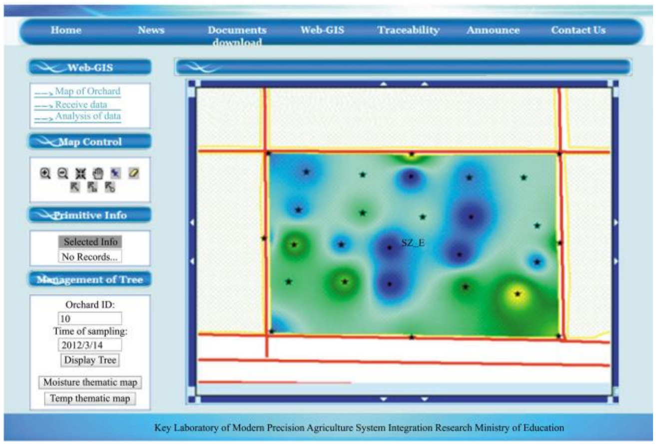


Figure 12 Thematic map of soil moisture

6 Conclusions

In this study, an orchard data transmission link from the ZigBee WSN via the orchard PDA to the orchard server was established, and data exchanging via GPRS between them was achieved following the corresponding protocols. Then the orchard production data could be collected to the cloud server and accordingly the service functions based on data processing could be realized. The level of orchard information management was improved through applying technologies of WSN, Web service, distributed storage and WebGIS in data acquisition and data services for apple orchard production. The achievement of this research was as follows:

1) Intelligent data acquisition was fulfilled through a movable WSN. The WSN was responsible for collecting the property information of the target trees in the target orchard. The PDA was used to manage the WSN, read the RFID tag mounted on each tree, acquire GPS data and achieve data exchanging with the server. It was convenient for customers to acquire the tree growth and nutrition environment information in orchard.

2) Data sharing on heterogeneous platforms was achieved through web service technology. By providing web service interfaces on the orchard server side, the orchard data could serve for different devices running on different OS platforms. XML technology helped data be

recognized by different system, and it improved data utilization rate in some extent.

3) The WebGIS service function on cloud server was developed to provide GIS for users. It was more convenient for customers since they did not have to install any GIS component in their terminals, and it reduced the difficulty of using the platform by design of thin client. Furthermore, WebGIS cloud service made it possible for users to view spatial data distribution and acquire the thematic map of target property parameters.

Acknowledgments

The financial support provided by the National High Technology Research and Development Program of China (863 Program, 2012AA101901) and Chinese National Natural Science Foundation (No. 31071330) are greatly appreciated.

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