

# Information Service System Of Agriculture IoT

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Internet of Things (IoT) was faced with some difficulties which contained mass data management, various standards of object identification, data fusion of multiple sources, business data management and information service providing. In China, some safety monitoring systems of agricultural product always adopt centralized system architecture in which the data is stored concentratively. These systems could not be connected with or accessed by each other. This paper proposed an information system of agriculture Internet of Things based on distributed architecture. A distributed information service system based on IoT-Information Service, Object Naming Service, Discovery Service is designed to provide public information service including of capturing, standardizing, managing and querying of massive business data of agriculture production. A coding scheme for agricultural product, business location and logistic unit is provided for data identification. A business event model of agriculture IoT is presented for business data management. The whole system realizes the tracking and tracing of agricultural products, and quality monitoring of agriculture production. The implementation of this information service system is introduced.

**Key words:** Agriculture IoT, Object Naming Service, Information Discovery

**Informacijski servisni sustav za poljoprivredni IoT.** Internet stvari suočen je s poteškoćama poput upravljanja s velikom količinom podataka, različitim standardima identifikacije objekata, fuzije podataka iz više izvora, upravljanja poslovnim podacima i pružanje informacijskih usluga. Sigurnosno nadgledanje poljoprivrednih proizvoda u Kini uvijek podliježe centraliziranoj arhitekturi gdje su podatci koncentrirani na jednom mjestu. Takvi sustavi ne mogu biti povezani jedni s drugim te jedan drugome ne mogu pristupiti. U ovome radu predložen je informacijski sustav za poljoprivredni internet stvari temeljen na distribuiranoj arhitekturi. Distribuirani informacijski servisni sustav baziran na IoT (Internet stvari), sustav za imenovanje objekata i sustav za otkrivanje omogućuju javni informacijski servis uključujući prikupljanje, standardizaciju, upravljanje i ispitivanje velikih količina podataka o poljoprivrednim proizvodima. Prikazana je shema kodiranja za poljoprivredne proizvode, poslovne lokacije i logističke jedinice za identifikaciju podataka. Poslovni model događaja za poljoprivredni IoT je prezentiran za upravljanje poslovnim podacima. Cjelokupni sustav omogućuje praćenje poljoprivrednih proizvoda te nadgledanje njihove kvalitete. Rad također daje uvid u implementaciju informacijskog servisnog sustava.

**Ključne riječi:** poljoprivredni IoT, sustav za imenovanje objekata, informacijsko otkriće

## 1 INTRODUCTION

The concept of Internet of Things (IoT) was first introduced by Professor Ashton in the Auto-ID center of MIT while he was making a research on RFID [1]. The Internet of Things is an emerging technology which intends to get all the real world items connected to the network. Internet of Things involves many heterogeneous technologies, including of RFID (radio frequency identification), wireless sensor, video image, laser scanners and other information sensing devices.

Nowadays, agriculture informatization has become a core and effective technology to realize agricultural modernization. The purpose of agriculture informatization is to

acquire and integrate digital information in every aspect of agriculture production to ensure the quality and safety of agricultural products. By using IoT-related technologies, the efficiency and safety of agricultural production should be obviously improved. Among these technologies, RFID and wireless sensor network (WSN) are the most mature and practical technologies. Wireless sensors and WSN can be deployed in the farmland, greenhouse, cold storage and refrigerator cars to monitor the environment and transfer various data to the management system in real time. The IoT management system can capture all the logistics events for tracking and tracing. In addition, video surveillance, GIS and other information sensing technology are

also widely used for monitoring production process. The information system of agriculture IoT is responsible for coordinating multiple types of perceptual data on production process. With control of massive information, the system provides multiple services, including of tracking, tracing, quality monitoring and logistics management.

Some tracking and tracing system of agricultural product in China always adopt centralized system architecture in which the data is stored concentratively. In this mode, data and resources are centralized in one data center which makes it easy to manage and update. But centralized system is very hard to adapt to the rapid increasing of data size and functional categories. At the same time, these centralized systems are closed-loop systems which makes them hard to communicate and exchange data with each other. This paper proposed a distributed framework of information service system which is based on agriculture IoT to solve this problem.

The rest of the paper is structured as follows. Section 2 presents related literature reviews about the studies of IoT data management and information service. Section 3 describes the framework of public information service system for agriculture IoT and gives a detailed description of system architecture based on Object Naming Service (ONS). We provide in details about coding methods of object identification, data capturing and storage in Section 4. Business event model of agriculture IoT is provided in Section 5. In Section 6, the project implementation of agriculture IoT is introduced. Finally, a conclusion about the agricultural production management system based on IoT is drawn and suggestions for future work are made.

## 2 LITERATURE REVIEW

RFID and WSN are the most commonly used technologies in IoT system. Evan Welbourne and Leilani Battle 2009 tried to build the Internet of Things using RFID and developed a suite of applications for users to understand and manage the system [2]. Wang Zhengxia 2010 proposed a modern logistics monitoring platform based on the Internet of Things [3]. Jingran Luo proposed a remote health care system based on the Internet of Things using WSN [4]. Junyan Ma proposed a design which connects agriculture to the IoT [5]. However, how to integrate these perception technologies such as sensor, GPS and video into one system and handle multivariate data is still a big problem to researchers.

In practical application, IoT technology has been used in a variety of information service systems. There are mainly two kinds of applications. Firstly, IoT perception technologies are very suitable for integrated information management of products, equipments and goods [6,7]. The other kinds of applications are logistics management systems [8,9]. The comprehensive utilization of automatic

identification, environmental monitoring and GPS accurate positioning revolutionized the traditional logistics management.

In distributed IoT system, all data services are based on Internet which makes discovery services model indispensable and important. EPCglobal proposed an architecture framework and provided a feasible solution based on Internet to provide instant data sharing between trade partners in the supply chain [10]. But the whole system depends on the use of RFID tag and EPC code standards [11]. Many researchers have given their improvement solution to this framework which makes it more practical and efficient [12,13]. But agriculture IoT has its unique features so that until this moment there is still more work to do to realize the information service of agriculture IoT.

To solve the above problems, this paper proposed a distributed information service system of agriculture IoT which can capture, store, manage and utilize multivariate and enormous perceptual data. It provides object name service and information discovery service to meet the needs of information query of the users. Also, an implementation of the agriculture IoT architecture presented is conducted.

## 3 PUBLIC SERVICE SYSTEM OF AGRICULTURE IOT

As mentioned above, most public information service platforms which have been built in China are centralized systems. The standards of data identification, storage and services are non-uniform. Meanwhile, the communication and data exchange are hard to conduct between closed-loop systems. In agriculture IoT, a public service system compatible with multiple types of perception technologies, agriculture products and supply chain enterprises is needed. For this reason, a distributed information service system of agriculture IoT is proposed in this paper.

### 3.1 Architecture of Public Information Service System of Agriculture IoT

The proposed architecture of public information service system for agriculture IoT is shown in figure 1. The whole system is designed to satisfy the requirements of three kinds of users which are end consumers, supervision department and supply chain enterprises. With the help of information services, government regulators can perform quality monitoring of product and information tracing of supply chain, consumers can verify product authenticity and examine the production process of the product they bought. Supply chain enterprises can communicate and exchange data with trading partners to improve the supply chain management.

The system can be divided into two parts. The first part is information center of agriculture IoT. Basic data

such as enterprise information, product category information and person information are centralizedly stored and managed in this center. With the help of perception and business data, information center can perform production quality monitoring to help enterprises prevent from accident. A web-based information service platform is provided for system users to query and view the information of agriculture production. The second part is an information discovery and service system which is designed for capturing, standardizing, managing, rapidly locating and conveniently querying of all agriculture production data. This system consists of IoT-IS (Internet of Things Information Service) module, ONS (Object Naming Service) module and DS (Discovery Service) module. As mentioned above, traditional central system cannot adapt to the characteristics of IoT data. Therefore, our system adopts a distributed architecture for information storage and information services.

In distributed storage, the business data are stored in the IoT-IS servers all over the Internet. Each IoT-IS server is corresponding to a perception subsystem or an enterprise. It is mainly responsible for capturing data from subsystems and providing different kinds of information to users through web service. All perception and business data in agriculture IoT are abstracted into different kinds of IoT events and stored in IoT-IS in predefined format. This unified storage standard makes different kinds of product information can be queried by the same set of service interfaces.

Every product in agriculture IoT is identified by a tracing code. All information services are based on this code. When information service system gets a tracing code of a product, the first step it takes is to address which IoT-IS server(s) is storing the related information. The ONS module and the DS module are responsible for this problem. ONS (Object Naming Service) is a central lookup service whose functionality is mapping a product code to an IoT resource address. In implementation, ONS consists of code resolver and DNS. Code resolver parses an object code and outputs a domain name which can be processed by DNS and mapped to a set of resource records. DNS runs as a distributed database which stores the mappings of domain names to IoT resources in a tree structure. Besides, in the agriculture IoT, multiple coding schemes are used to identify products. For this reason, the ONS is designed to be able to detect the type of the object code automatically and then parse the code following the predefined decoding rule of the specific code type.

From production to sale, an agricultural product may travel through several supply chain links so that the business data would be spread all over the supply chain. Multiple IoT-IS servers may contain event data about a single product. But ONS can only point the query to one data

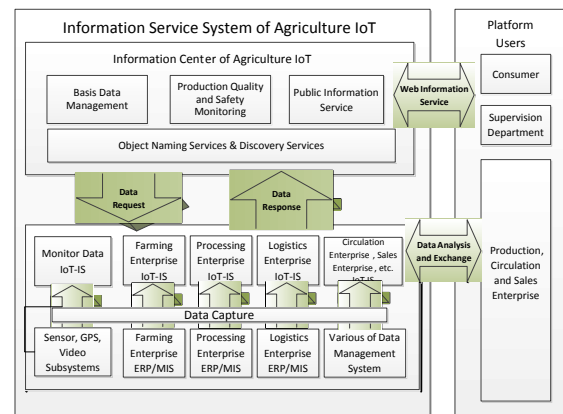


Fig. 1. Distributed information service system of agriculture IoT

resource address. Therefore, a more accurate addressing service is required to record the data transferring through supply chain which is the functionality of Discovery Service (DS). DS provides the mapping between an object ID and the address list of IoT IS servers. When a manufacturer publishes a new batch of products, IoT-IS will register the products information in its DS server. As the products are transferring along the supply chain, related enterprises will publish product basic event data to the local DS servers who will update the event data to the manufacturer’s DS server. In this way, the user can instantly access all the data about a specific object stored in IoT from any location in Internet.

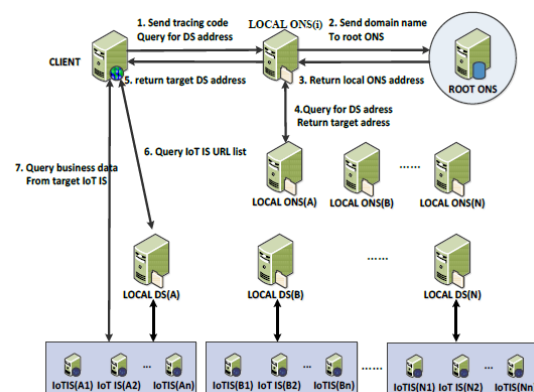


Fig. 2. System architecture based on ONS/DS Service

### 3.2 Information Discovery

Figure 2 describes a typical process of information discovery in agriculture IoT. The root ONS is the parent node

of multiple local ONS servers and its functionality is to allocate ONS queries to responsible sub (local) ONS servers. In most cases, Root ONS does not interact with end client directly. Local ONS interacts with clients directly and offers the service of mapping an object code to a DS URL address. In order to improve efficiency, local ONS server also maintains cache for information accessed from root ONS. Root ONS must be managed by a central authority and refuses to offer recursive service to minimize its load, while local ONS servers should be managed by sub organizations such as supply chain enterprises and offers recursive service for clients. DS server offers the service of mapping between tracing specific object code and a list of IOT-IS server URLs from where client can query detailed business information about the object in the next step. In our agriculture IoT architecture, DS server adopts a centralized-indexing discovery mechanism in which IoT-IS servers publish event data of the same type products in the form of a light weighted index to a centralized DS server. DS server maintains the indexes of massive event data of agriculture products and is able to find out the list of relevant IS servers for a specific object in a very short time.

As figure 2 depicts, IOT-IS server addresses are acquired by a typical query in the following steps:

Step 1: Client sends a tracing code to its local ONS (i) for querying a DS server which is in charge of this object.

Step 2: Local ONS receives the query. The code resolver of local ONS (i) will parse the tracing code to a domain name. Then it checks if there is a cache record about this product. If there is a cache hit, the local ONS (i) will directly send target DS URL extracted from cache to client and continue the process in step 3. Otherwise, local ONS (i) will send the domain name translated by the code to the DNS tree network (from the root ONS to the sub local ONS in charge) and get the resource records mapping to the domain name iteratively. The URL address of DS server (A) which is in charge of the object is extracted from the set of resource records.

Step 3: Local ONS Server (i) sends the URL of DS server (A) to the client.

Step 4: Client then sends product tracing code to DS server (A) for querying the related IoT-IS addresses in the supply chain of the product.

Step 5: DS server (A) searches the tracing code in the local databases and returns the record list of related IoT IS URLs to Client.

Step 6: The records which are returned from DS server consist of IoT-IS URL, company information, event type and event time. Client can then access corresponding IoT-IS server according to demands to get more detailed information about the object in question.

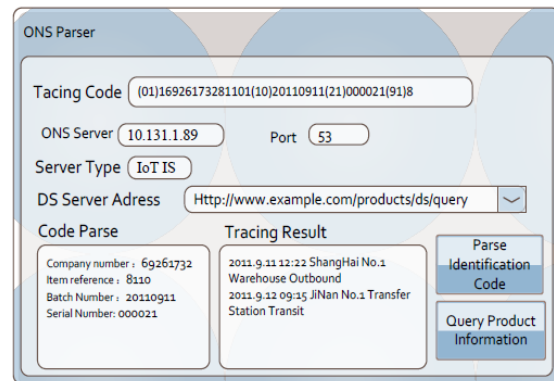


Fig. 3. Client GUI Demo of ONS Parser

Figure 3 is a demo client-side GUI used by client to execute a query. When user queries product information, Server IP of local ONS, port of ONS Server must be configured and the tracing code of product should be input. If the user is interested in the information contained in the object code itself, the program can parse the tracing code and display code information which includes company number, item reference, serial number and batch number in code parse column. The key function of the program is to invoke the interfaces of ONS, DS and IS to get the tracing result of the product code in question. Firstly, it must upload tracing code and service type as parameters to the local ONS. Following the steps in figure 2, the local ONS server replies to the client with a DS server address. Then, the program calls the web service interface provided by DS server and gets a sequence of IS addresses. Finally, it queries product tracking information from these IoT-IS servers and output the results.

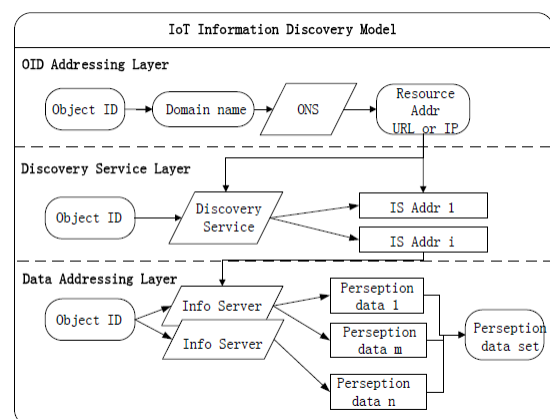


Fig. 4. IoT Addressing Model

Figure 4 gives the information addressing model of the IoT. The mappings from object IDs to the static data source are stored in ONS. Detail static information of objects are stored in the manufacturer’s IoT-IS. Event data captured by tag readers and sensors are stored in IoT-IS servers which are independently maintained by different enterprises along the supply chain. DS server maintains event indexes published from authorized IoT-IS.

#### 4 DATA MANAGEMENT OF AGRICULTURE IOT

In agricultural production processes, large amounts of business data will be generated at all times. Meanwhile, a lot of production environment data need to be monitored and stored. So data management is a vital link of agriculture IoT. The new architecture of IoT provides a suitable management mechanism for agricultural related data collection, transmission, storage and information service interfaces.

##### 4.1 Identification Code of Agricultural Product

Tracking and tracing of agricultural product are two important and significant functions of agriculture IoT. Each product and business location must be marked with a unique identification code at every stage of agricultural production process. The identification code is also the foundation of business management and various information services.

Radio frequency identification (RFID) is a very mature technology for non-contact automatic identification and product tracking. In breeding production, every livestock is attached with an electronic ear tag of RFID. When performing operations like feeding, vaccination and immune inspection, workers can read multiple tags without contacting livestock and record business information efficiently.

Coding scheme is a key foundation for identification. The corresponding code scheme is described in table 1. There are mainly four kinds of identification code in agriculture IoT which include RFID, single item tracing code, logistics unit tracing code and business location code.

In circulation, agricultural products are usually identified by item tracing code with a linear barcode or two-dimension barcode based on GS1-128 standard. This tracing code consists of two parts which are single item tracing code and logistics unit tracing code. A single tracing item in circulation will be identified by a 29 digits tracing code. The first 14 digits of item code is GTIN code [14]. The 15-22 digits of item code are the batch number of the product. The 23-28 digits of item code are the serial number of the product. The 29th digit of item code stands for the length of company prefix in GTIN code. The above code (Code Example 1 in Figure 5) is an example of single item tracing code. The first 14 digits “06920152484035” is GTIN

Table 1. Code Schema In Agriculture IoT

Livestock Identification Code (15 digits)			
Single Item Tracing Code (29 digits)			
(01) X XXXXXXXXXXXXXXX X (10) XXXXXXXX (91) X			
1-14 digits	15-22 digits	23-28 digits	29 digit
GTIN Code	Batch Number	Serial Number	Length Digit
Logistics Unit Tracing Code (19 digits)			
(00) X XXXXXXXXXXXXXXXXXX X (91) X			
1 digit	2-17 digits		18 digit
Extension Digit	Company Prefix	Serial Reference	Check Digit
			Length Digit
Business Location Code (15 digits)			
(414) XXXXXXXX XXXX X (91) X			
1-13digit		14 digit	15 digit
Company Prefix	Location Reference	Check Digit	Length Digit



Fig. 5. Identification Code Examples of Agriculture IoT

code which consists of indicator digit (“0”), company number (“692015248”), item reference (“403”) and check digit (“5”). “20120605” is the batch number of the product and “000235” is the serial number. The last digit “9” stands for the length of company prefix.

When agricultural products are stored or transported, they will be put into a logistics unit such as pallets, shelves or containers which will be identified by logistics unit tracing code. This 19 digits code is an extension of SSCC standards [15]. The code example 2 in figure 5 is an example of logistics unit tracing code. The first digit “0” is extension digit. The following code “69479426” is company prefix. “23456789” is serial reference. The 13th digit “4” is check digit. The last digit “8” defines the length of company prefix.

The business location code is used to identify differ-

ent kinds of physical locations or legal entities which is used to represent a farmland, an enterprise, a warehouse, etc [16]. The code example 3 in figure 5 is an example of business location code. The first 9 digits "000012345" is the company prefix. The following code "678" is the location reference. "4" is the check digit and "9" is the length of company prefix.

In practical application, it is inconvenient and sometimes impossible to attach the agriculture product with a long linear barcode label. In recent years, two-dimension barcode labels has become popular and practical. As example 5 shown, a long barcode can be converted into a square two-dimension code label.

Sensor, video and GPS data are important monitoring and tracking data for agriculture IoT system. But the data is not useful until it is associated with corresponding business event. For sensor data, all records are identified by the combination of sensor's ID and data captured time. For video data, every surveillance video data is identified by video camera's ID and associated with related monitor scene. Both surveillance video of real time and historical video clips of special business events can be queried from IoT-IS. GPS data is identified by the license's ID of bound vehicle and specific event. In this way, all environmental and geographical monitor data are associated with related business record and greatly enrich the business-related information.

## 4.2 Data Capture and Storage

The information system of agriculture IoT supports two kinds of data storage which are centralized data center and distributed data centers. In centralized storage, all business data are stored in the database center of information platform. In the other hand, in distributed storage, business data is stored in the IoT-IS of subsystems and managed by information system. For centralized mode, it is easy for support platform to provide data backup and protection. As mentioned above, in agriculture IoT, the amount of data is enormous. A huge number of storage devices are needed to support this mode so that the performance and reliability of system are hard to guarantee. Thus distributed storage of IoT-IS server is a good way to solve these problems. In our architecture, both of the storage modes are used. Basic information of enterprises and agricultural production are centralizedly stored in the database center of information platform and most business data are distributedly stored in subsystems.

To provide information services accurately and timely, IoT-IS of each subsystem needs to perform data capture at set intervals. For business data, subsystems will package the information into a XML file which follows a predefined format. IoT-IS analyzes the file in the same rule and store

the data in IoT-IS database. Meanwhile, subsystems can also call the interface of web service which is provided by IoT-IS and upload business information as parameters. For monitoring data such as sensor, video and GPS data, there are two kinds of data needed to be captured which are real-time data and historical data. Real-time data is mostly used for monitoring and warning. It can be acquired directly by calling the interface of monitor subsystem. The IoT-IS will provide services for user to check real time monitor data.

## 5 IOT EVENT MANAGEMENT

### 5.1 Business Data Management

As mentioned above, there are a huge number of different kinds of business events needed to be stored during agriculture production. Different subsystem has different storage formats and mechanisms even for the same kind of business data. Meanwhile, at most of time, IoT-IS server synchronizes with subsystems with web service. Large diverse types of business event data will make the interfaces of web service very complex, hard to maintain and lack of expansibility. So it is necessary to simplify and unify the representation of business data.

#### 5.1.1 Basis Records of Agriculture IoT

Basis records are the foundation business data of the whole system. All basis records are centralizedly stored in the information center of agriculture IoT system and managed by system manager. Basis records include enterprise, person, business location, product type, logistic unit tracing code, event type, business step type, sensor device records, video device records and GPS device records.

Every enterprise of agricultural products on supply chain should upload and maintain these basic information to public service platform of IoT (if they are willing to join agriculture IoT). Event type and business step type are defined by system. Event type decides how many kinds of event are needed to be monitored and tracked, and business step defines the types of business event.

All monitor devices including Sensor, GPS and video need to be registered in data center before put into use. Device type, purpose, GLN, Contacts and data interface of monitor devices are recorded for future use.

#### 5.1.2 Event Model of Agriculture IoT

As mentioned, all business data of agriculture IoT are distributed and stored in IoT-IS servers which are deployed in different links of agriculture production. How to unify and standardize business data is a key problem. So we classify business data into five kinds of events which are specified in figure 6.

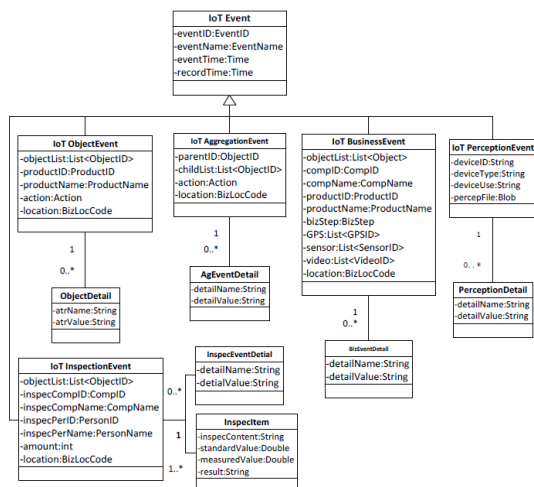


Fig. 6. Business Event Model of Agricultural IoT

a) IoT Event

IoT Event is a generic base class for all the event types in this model. It includes four attributes which are eventID, eventName, eventTime and recordTime. EventID and eventName are defined as basis records by system manager and stored in data center.

b) Object Event

Object Event (<objectList , productID, product Name , action, location, objectDetail >) captures any business data about the generation of new products such as a new batch of fruit with a batch code, a new born livestock with a livestock identification code, a new packaged fruit with a single item tracing code, etc. Meanwhile, it also records the destruction of products such as dead livestock dispose, out of date fruit or meat dispose, etc. The meaning of fields in this event are explained as follow:

**objectList:** objectList in IoT object event is a list of identification code of the event related objects. It can be a list of batch code, livestock identification code, or single item tracing code.

**productID & productName:** ProductID and name of event related product which is stored in data center as basis record.

**action:** There are three options for action field which decide the action of the object event. If the event is a record of generating a new product, the event action is “ADD”. If the event is a record of destruction of a product, the event action is “DELETE”. If the event is a simple query of the product, the event action is “QUERY”.

**location:** Location field stores the location where the event happened. All business location records are stored in data center and uploaded by enterprise as basis records.

**objectDetail:** ObjectDetail can be used to store some extended information of events. This field makes IoT object event scalable.

5.1.3 Aggregation Event

Aggregation event of IoT describes events that have been physically aggregated or disaggregated. During the agriculture production process, products often need to be packed into a bigger container for the convenience of transportation, storage or sale. In most of these processes, products are identified by the logistic unit tracing code of the container. For tracking the production process, we define the aggregation event (<parentID , childList , action, location, AgEventDetail>) to record the binding and unbinding relationships between products and logistic units. Also, the relationship between processed meat and livestock, fruit and vegetable products between batch information, packaged products and repackaged products are also stored as the aggregation event.

The meaning of fields in this event are explained as follow:

**parentID:** Parent ID identifies the “container” in an aggregation event. It can be a logistic unit tracing code, livestock identification code or a batch code.

**childList:** Child list is an ID list of objects which are aggregated or disaggregated to the “container”. In most of situations, the ID is single item tracing code.

**action:** There are two options (AGGREGATION, DISAGGREGATION) for action field which decides the action of the aggregation event.

**location:** Location field stores business location code where the event happened.

**AgEventDetail:** AgEventDetail can be used to store extended information.

5.1.4 Business Event

This event describes all the business events involved in agriculture production process. Business event not only records the business information of an event, but also stores all the monitoring related data such as GPS, sensor and video. Business event should be marked with < ObjectList , compID , compName, productID, productName , bizStep, location, BizEventDetail >.

The meaning of fields in this event are explained as the following:

**ObjectList:** objectList in business event is a list of identification code of the event related objects.

**compID & compName:** CompID and compName of event related enterprise is stored in data center as basis records.

**productID & productName:** ProductID and product-Name of event related product is stored in data center as basis records.

**bizStep:** BizStep indicates the business step of the event. It can be “Breeding”, “Planting”, “Processing”, “Storage”, “Transportation” or “Sale”.

**location:** Location field stores business location code where the event happened.

**GPS:** List of GPS device IDs which are related to the event. All GPS devices are registered in data center as basis records. Detailed GPS data is stored in the database of the same IoT-IS server. Server system can get event GPS data according to the event time and GPS ID list.

**Sensor:** List of sensor device IDs which are related to the event.

**Video:** List of video device IDs which are related to the event.

**BizEventDetail:** BizEventDetail can be used to store extended information.

### 5.1.5 Inspection Event

Inspection event of IoT records all the inspection and quarantine business events in agriculture production process. The meaning of fields in this event are explained as the following:

**objectList:** ObjectList in business event is a list of identification code of inspected objects.

**inspecCompID & inspecCompName:** ID and name of enterprise which is responsible for inspection and quarantine.

**inspecPerID & inspecPerName:** ID and name of the person who is responsible for inspection and quarantine.

**amount:** The amount of objects which are selected to be inspected.

**location:** Location field stores business location code where the event happened.

**InspecItem:** InspecItem represents detail inspection item. It consists of inspection context, standard value, measured value and result. System will monitor inspection results to send warning.

**InspecEventDetail:** InspecEventDetail can be used to store extended information of inspection event.

### 5.1.6 Perception Event

Perception event of IoT records all perception data which are generated by various devices such as sensor, GPS and video. All perception data are stored in a form of data file and directly captured by server. IoT-IS server

will extract perception data from the data file and store them into database for future query. The perception data are closely related to business event. The detail sensor, video, GPS data structure is shown below.

#### Sensor Data Structure:

**Sensor\_Data(SensorID, Time, Event\_Type, Position, Data)**

**SensorID:** The sensor ID is registered in the data center.

**Time:** Time information of this sensor data record. It can be a time point or a period of time.

**Event\_Type:** The related event type of this record.

**Position:** The business location code which identifies where this sensor is set up.

**Data:** The corresponding records identified by sensor ID and time such as temperature, humidity and gas concentration.

#### Video Data Structure:

**Video\_Data(Video\_ID, Time, Event\_Type, Position, SVideo\_URL, Hvideo\_Rec)**

**Video\_ID:** The device ID of this video camera which is registered in the data center.

**SVideo\_URL:** The URL which can be accessed and provide real time surveillance video.

**Hvideo\_Rec:** Historical video clip which records the whole process of the event.

#### GPS Data Structure:

**GPS\_Data(GPS\_ID, Time, Event\_Type, GPS\_Route)**

**GPS\_ID:** The device ID of this GPS which is registered in the data center.

**GPS\_Route:** A sequence of GPS coordinate points which described the path of transportation. The GPS data can be painted in a digital map and showed detail geographic information.

## 5.2 Information Service of Agricultural IoT

Information service of IoT is a data bridge between subsystems and IoT system. It is responsible for synchronizing data with subsystems and providing data query service. IoT-IS servers are distributedly deployed in the subsystems or enterprises over the internet. IoT-IS server performs data synchronization with enterprises by web service.

Web service is language independent technology to support interoperable machine to machine interaction over the internet. IoT-IS server publishes the interface of web services in a specific machine readable language which is



called Web Services Description Language (WSDL). Sub-systems or enterprises can interact with the web service and get the WSDL file which can be used to automatically generate the client side code in Java or .Net. Then enterprises can conveniently package data into an Extensible Markup Language (XML) file by predefined format in WSDL file and call specific interface to upload data using SOAP message. In the same way, application system can query data from IoT-IS server through web service.

The following definition is an interface for uploading an object event to IoT-IS server. The interface is defined strictly according to the definition of object event. Client can call this service interface and upload object event data in XML format to IoT-IS server. The return value is an integer which can tell the client if this data is uploaded successfully. Afterwards, the server will analyze the XML packet and collects data of the object event which can be stored or used to provide service. The XML schema is defined in WSDL file and it describes the format of the XML package. The XML file is an example of uploading a new product event.

**Service Interface:**

Int objectEventUpload (String eventID, String eventName, Date eventTime, List<String> objectList, String productID, String productName, String action, String location, List<ObjectDetail> objectDetails)

**Return Value:**0 for success, -1 for fail

**XML Schema:**

```
<xs:schema xmlns:xs="http://www.w3.org/2001/XMLSchema" >
  <xs:element name="objectEventUpload">
    <xs:complexType name="objectEventUpload">
      <xs:sequence>
        <xs:element name="eventID" type="xs:string"/>
        <xs:element name="eventName" type="xs:string"/>
        <xs:element name="eventTime" type="xs:dateTime"/>
        <xs:element maxOccurs="unbounded" minOccurs="1" name="objectList" type="xs:string"/>
        <xs:element name="productID" type="xs:string"/>
        <xs:element name="productName" type="xs:string"/>
        <xs:element name="action" type="xs:string"/>
        <xs:element name="location" type="xs:string"/>
        <xs:element maxOccurs="unbounded" minOccurs="0" name="objectDetails">
          <xs:complexType name="objectDetail">
            <xs:sequence>
              <xs:element name="atrName" type="xs:string"/>
              <xs:element name="atrValue" type="xs:string"/>
            </xs:sequence>
          </xs:complexType>
        </xs:element>
      </xs:sequence>
    </xs:complexType>
  </xs:element>
</xs:schema>
```

**XML:**

```
<objectEventUpload>
  <eventID>21001</eventID>
  <eventName>new product event</eventName>
  <eventTime>2012-05-21 13:51:07</eventTime>
  <objectList>0106919764950017101112120121000001919</objectList>
  <objectList>0106919764955053101112080321000000919</objectList>
  <productID>DH001</productID>
  <productName>YANTAI APPLE</productName>
  <action>ADD</action>
  <location>00001234567849</location>
</objectEventUpload>
```

The web service definition below is an interface for querying an object event record by single item tracing code. After the client calls this interface and uploads the tracing code of the product as parameter, the IoT-IS server will return an ObjectEventQueryResult structure as shown below. ObjectEventQueryResult can tell the client if this query is successful and how many records are found. The resultBody part is a list of result records. Each record is encapsulated in a structure called ObjectEventInfo which contains all the information of a fruit processing event. At the same time, ObjectEventInfo structure contains a list of ObjectDetail sturcture which consists of detailed information of each processed product.

**Service Interface:**

ObjectEventQueryResult objectEventQuery (String ObjectID)

**Return Value:**

```
ObjectEventQueryResult {
  int resultState;
  int resultNumber;
  List<ObjectEventInfo> resultBody
}

ObjectEventInfo {
  String eventID;
  String eventName;
  Date eventTime;
  String objectID;
  String productID;
  String productName;
  String action;
  String location;
  List<ObjectDetail> objectDetails;
}

ObjectDetail {
  String atrName;
  String atrValue;
}
```

**6 PROJECT IMPLEMENTATION**

The information service system has been strongly supported by Chinese government. A series of demonstration project has been carried out.

As figure 7 shows, a demonstration project of agriculture IoT has been established in Shandong Province and Wuxi City, Wuxi city in China. Perception devices such as sensors, GPS, video cameras have been set to

multiple testing fields for experiments. The data center of agriculture IoT system has been set up by Wuxi Institute of Fudan University. A series of servers such as video server group, data mining server group, GIS & WSN server, basis records server are already put into use. Multiple information servers which include DS, ONS servers have been deployed in Shanghai, Jinan and Wuxi. Several IoT-IS servers are put into operation in different enterprises which include planting enterprises, wholesale enterprises and sales enterprises. Various types of perception data which include SDCAM surveillance, HDCAM smart surveillance, WSN, weather station and GPS are collected by different subsystems and uploaded to data center through Internet or GPRS network. A big demonstration center of agriculture IoT has been set up in Zhang Jiang campus of Shanghai. In this center, the whole prospect view of agriculture IoT system is displayed and many application examples are showed.

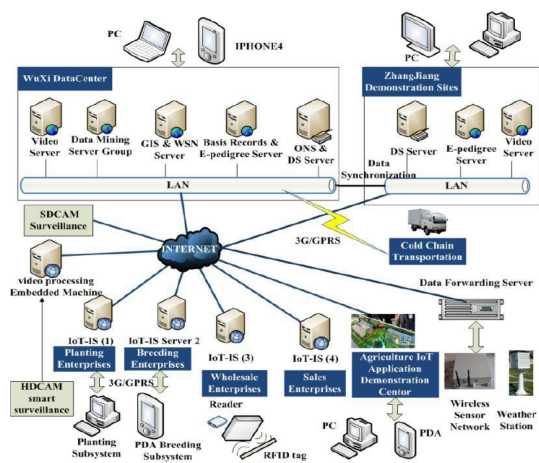


Fig. 7. Implementation of Agriculture IoT

Figure 8 shows the public information system of agriculture IoT. When user inputs the single item tracing code or the logistic unit tracing code by barcode and sends query request, the web server will follow the steps which are described in figure 2 and locate the data source of this product according to the response of the ONS and DS servers. When website server finds out which IoT-IS servers are storing the related data, it will collect all business event data of the product and display it to user. It provides the data query for planting, gathering, packaging, transportation, storage and sale. As shown, user can also check all kinds of monitoring data such as sensor, GPS and video. It provides the tracking and tracing of agriculture production.

Besides website, an iOS and android application are also developed to help convenient query for product information.

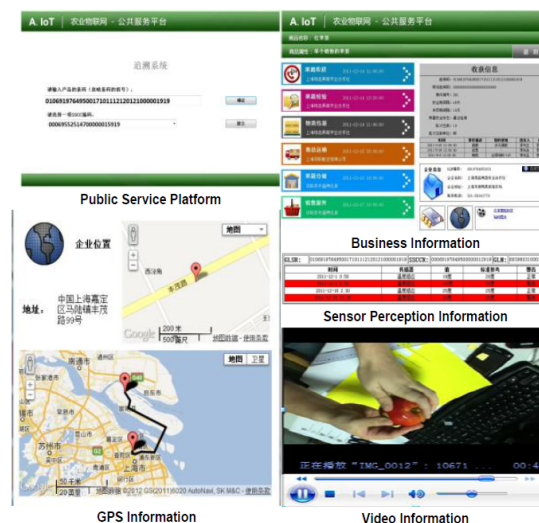


Fig. 8. Public Information Service Platform of Agriculture IoT



Fig. 9. iOS application of Agriculture IoT

With an iPhone or android device shown in figure 9, user can easily scan the two-dimension code of the product and perform information query. The tracing code of product will be sent back to server. Just like the website server, the application server will also locate the IoT-IS addresses with the help of ONS and DS services. Then it displays the product circulation information on the screen directly. User can check detailed information such as business data, enterprise data, e-pedigree data and perception data. This application is convenient, portable and solves the problem that people cannot read the two-dimension bar code directly.

## 7 CONCLUSION AND FUTURE WORK

In this paper, an information service system of agriculture IoT is proposed. Compared to other IoT information systems, this system can better manage and make use of the multiple-sourced, real-time and enormous data stored in distributed IoT-IS servers. Meanwhile, every agricultural product is well identified and decoded to query the information of agriculture IoT with this system. All the perception data are directly associated with business data and agricultural products which can perform management and query conveniently. The tracking and tracing of the whole agricultural production process is realized with DS server and distributed IoT-IS servers. An information discovery system which consists of ONS, DS and IoT-IS server is designed to realize capturing, standardizing, managing, rapidly locating and conveniently querying of all business data of agriculture production. A business event model of agriculture IoT is designed for unified management. In addition, for production, processing and circulation enterprises, this system can improve productivity and strengthen enterprise management. Meanwhile, consumers can use this system to query product information to verify the authenticity and quality of agriculture products.

In the future, this system will actually be further implemented to more agricultural demonstration projects of Shandong province, Wuxi and Yangling in China. The information service will be improved to support more types of products and provide more services. By taking advantage of IoT technology, the efficiency of agricultural production can get a significant improvement. With constantly improving, agriculture IoT must be able to lead agriculture production to a new era.

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## REFERENCES

- [1] Stephan Haller, Stamatis Karnouskos and Christoph Schroth, "The Internet of Things in an Enterprise Context," 1st Future Internet Symposium, FIS 2008, Lecture Notes in Computer Science, vol.5468, pp.14-28, Sept. 2009.
- [2] Welbourne E, Battle L, Cole G, Gould K, Rector K, Raymer S, Balazinska M and Borriello G, "Building the Internet of Things Using RFID: The RFID Ecosystem Experience," IEEE Internet Computing, vol 13, pp 48-55, Mar. 2009.
- [3] Wang Zhengxia and Xiao Laisheng, "Modern Logistics Monitoring Platform Based on the Internet of Things," Intelligent Computation Technology and Automation (ICICTA) 2010 International Conference, pp.726-731, May 2010.
- [4] Jingran Luo, Yulu Chen, Kai Tang, and Junwen Luo, "Remote monitoring information system and its applications based on the Internet of Things," BioMedical Information Engineering, FBIE 2009. International Conference on Future, pp.482-485, Dec. 2009.
- [5] Junyan Ma, Xingshe Zhou, Shining Li, and Zhigang Li, "Connecting Agriculture to the Internet of Things through Sensor Networks," Internet of Things (iThings/CPSCoM), 2011 International Conference on and 4th International Conference on Cyber, Physical and Social Computing, pp.184-187, Oct. 2011.
- [6] Xu XiaoLi, Zuo Yunbo, and Wu Guoxin, "Design of Intelligent Internet of Things for Equipment Maintenance," Proceedings - 4th International Conference on Intelligent Computation Technology and Automation, ICICTA 2011, vol 2, pp.509-511, 2011.
- [7] Jiahuan Wan, Xiuwan Chen, Jing Liu, and Chunhua Zhuang, "Design of network monitoring system of moving goods in the internet of things based on COMPASS," 2011 International Conference on Remote Sensing, Environment and Transportation Engineering, RSETE 2011 - Proceedings, pp. 1096-1099, June 2011.
- [8] Mao Cuiyun and Han Yuanhang, "Discussion on the Application of Internet of Things in Logistics Production Management," Proceedings of the International Conference on E-Business and E-Government, ICEE 2010, pp.3901-3903, May 2010.
- [9] Wang Zhengxia and Xiao Laisheng, "Modern Logistics Monitoring Platform Based on the Internet of Things," 2010 International Conference on Intelligent Computation Technology and Automation, ICICTA 2010, vol 2, pp. 726-731, May 2010.
- [10] EPCGlobal, "The EPCglobal Architecture Framework," EPCglobal Final Version of 1, July 2005.
- [11] EPCGlobal. "GS1 EPC Tag Data Standard Version 1.6," [http://www.gs1.org/gsm/kc/epcglobal/tds/tds\\_1\\_6-RatifiedStd-20110922.pdf](http://www.gs1.org/gsm/kc/epcglobal/tds/tds_1_6-RatifiedStd-20110922.pdf).

- [12] Gyeongtaek Lee, Jonghun Shin, Daewon Park, and Hyukchul Kwon, "Discovery Architecture for the Tracing of Products in the EPCglobal Network", Proceedings of The 5th International Conference on Embedded and Ubiquitous Computing, EUC 2008, vol 2, pp. 553-558, Dec. 2008.
- [13] Lorenz Martin, Mueller Juergen, Schapranow Matthieu-P., Zeier Alexander, and Plattner Hasso, "A Distributed EPC Discovery Service based on Peer-to-peer Technology", RFID SysTech 2011; 7th European Workshop on Smart Objects: Systems, Technologies and Applications, pp.1-7, May 2011.
- [14] GS1, "GTIN (Global Trade Item Number)," <http://www.gs1.org/barcodes/technical/idkeys/gtin>.
- [15] GS1, "SSCC (Serial Shipping Container Code)", <http://www.gs1.org/barcodes/technical/idkeys/sscc>.
- [16] GS1, "GLN (Global Location Number)", <http://www.gs1.org/barcodes/technical/idkeys/gln>.
- [17] EPCglobal, "EPCglobal Object Naming Service (ONS)," [http://www.gs1.org/gsm/kc/epcglobal/ons/ons\\_1\\_0\\_1-standard-20080529.pdf](http://www.gs1.org/gsm/kc/epcglobal/ons/ons_1_0_1-standard-20080529.pdf).



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