Enterprise-Oriented IoT Name Service for Agriculture Product Supply Chain Management

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***Abstract* - Internet of Things (IoT) technologies have great potential in protecting safety and quality of agriculture products. Convenient and efficient identification and name service (NS) are the basis of such IoT technologies. An enterprise-oriented name service for the application of the IoT for agriculture products, iotNS, is proposed in this work. The iotNS reduces the complexity of the object name service (ONS) and improves the access efficiency. An IoT application for agriculture products based on the iotNS is developed and deployed in actual scenarios.**

***Index Terms* - Name service; IoT; Agriculture Products; Food safety**

I. INTRODUCTION

Food safety issue is drawing global attention in recent years. Agriculture products are greatly suffering safety issues. Both the academic and industrial communities are interested in how to provide reliable and credible information of agriculture products. Internet of things (IoT), which is firstly proposed in 1999[1] [2], can be used to manage the information of agriculture products quickly and conveniently, and has great potentials for food safety applications of agriculture products [3] [4].

Agriculture products have the following attributes [5]:

1) Short production-consumption circle: because of the seasonality and expiration date of agriculture products, the storage and processing of sensor data and object events need to be reasonably optimized.
2) Non-standardization: differing from the industrial products with the standardized producing process, agriculture products require better management in tracing the data of a certain batch, even a specific product during the entire life-circle.
3) Audit for quality control: It is not cost-effective to conduct a thorough quality inspection before consuming the agriculture products, so the related production information, for example agriculture events, is to be audited for further inspection.
4) Complexity in production chain: Since the supply chain of agriculture products is long, the effects of processing may appear quit late. As a result, data recording throughout the whole supply chain is necessary to meet the needs of prompting inquiries.

Applying the IoT technology to the management system of agriculture products makes it more convenient for the supervisors, the consumers and the food providers to trace the changes in property and state of agriculture products [6].

In order to apply the IoT technologies to the information management of agriculture products, object identification and name service need to be settled first. Identification based on GS1 system is the most popular method nowadays. Currently, most identification methods of agriculture products based on GS1 standard adopt the identification scheme established by EPCglobal ([7]-[9]), which uses the radio frequency identification (RFID) as the data carrier. However, the prices of agriculture products, especially raw agriculture products such as vegetables and fruits, are too low. The enterprises cannot afford the cost of RFID tags and RFID readers. Barcode, a low cost data carrier, is compatible with the infrastructure in the supply chain enterprises such as the supermarkets.

The identification key applied to agriculture products in this work is a combination of GS1 Identification Keys [10]. The item identifier is made up of Global Trade Item Number (GTIN) and batch or lot number. Global Location Number (GLN) is adopted as location identifier and Serial Shipping Container Code (SSCC) is adopted as package identifier. The advantage of this combination method is that it is compatible with the existing bar code infrastructure and can manage data on batch level or item level.

The agriculture products identification needs to accomplish the name service to Electronic Product Code Information Services (EPCIS), which is the interface of the network database, via the Object Name Service (ONS). The ONS realizes the interpretation from Identification Keys to Fully Qualified Domain name (FQDN) by the Application Unique String (AUS), and conducts the domain name service (DNS). The address data in the form of Uniform Resource Locator (URL) are stored in the Resource Records (RR) of the type of Naming Authority Pointer (NAPTR) in the DNS server. The address data are provided to the ONS client to accomplish the name service of the corresponding EPCIS. The scheme based on ONS is actually conducting the object name service of Object Class (OC) level via the DNS technology [20].

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There are some issues when using the ONS method in the agriculture products identification directly:

1) It is not practical for the agriculture production enterprises to register and maintain the name service data of each kind of agriculture product. Such enterprises may not have the automatic information system to join the ONS.
2) Due to the seasonality and expiration date of agriculture products, the name service data of OC level leave a large amount of useless name service recordings in the ONS.
3) The NAPTR RR impairs the performance of the DNS server. The name service data of OC level increases the cache overhead.

A novel name service architecture, iotNS, is proposed in this work. The proposed name service architecture is also based on the DNS technology, but it only reserves the name service data of the enterprises in the supply chain through the DNS system. By converting the name service from object-oriented name service to enterprise-oriented name service, the improved architecture is more light-weight than the original ONS.

The rest of the paper is organized as follows: Section II presents related works; Section III details its implementation; Section IV contains experimental results of different current sub-ranges; Section V concludes the paper.

II. RELATED WORKS

There are 3 main standards of name service worldwide: the ONS defined by GS1 EPCglobal [10], the ucode Resolution Protocol (ucodeRP) name service system defined by Japan Ubiquitous ID Center based on ucode [11][12], and the Object Identifier (OID) oriented Object identifier Resolution System (ORS) defined by ITU and ISO. These object identifier name service systems are all based on or similar to the DNS technology. There are also some solutions that are not based on the DNS technology, such as the Handle name service system that supports the identifier name service of RFID.

ONS standard proposed by GS1 standard is the most popular name service standard and it can be used for the whole supply chain management, including the production, storage, transport and sales of agriculture products. The employing of GS1 Identification Keys is favorable for the supply chain enterprises, especially the super markets. GS1 offers the standard of source tracing of perishable food and vegetables, however the realization details to cooperate the GS1 keys with the IoT name service technology is still an open issue [13][14].

The ONS 1.0 standard on object name service was first proposed in 2005 to resolve the EPC numbers on the RFID tags with EPCIS server[15]. B. Fabian proposed an ONS architecture based on the DHT architecture in 2007[16] and realized an ONS system with point to point (P2P) method in 2009 in order to address the privacy issue of ONS1.0 [17]. Evdokimov proposed a multi-polar architecture MONS in order to solve the access problem of single Root of ONS 1.0 in 2008[18]. Balakrichenan proposed the F-ONS architecture in 2011[19] to address the security concerns when applied it in multiple countries and districts.

However the above name service architectures are all for the name service of EPC identification. None of them can solve the name service problem of Identification Key (for example GTIN) in agriculture products identification. In 2013 the GS1 published the ONS 2.0 standard and realized the name service of Identification Key. At the same time it introduced the Federated Model to solve the cooperating name service problem [20]. The enterprise-oriented name service in this work, iotNS, makes improvement to the ONS 2.0 according to the supply chain attributes of agriculture products.

III. SYSTEM ARCHITECTURE& IMPLEMENTATION

The architecture of Internet of Things based on iotNS is shown in Fig. 1.

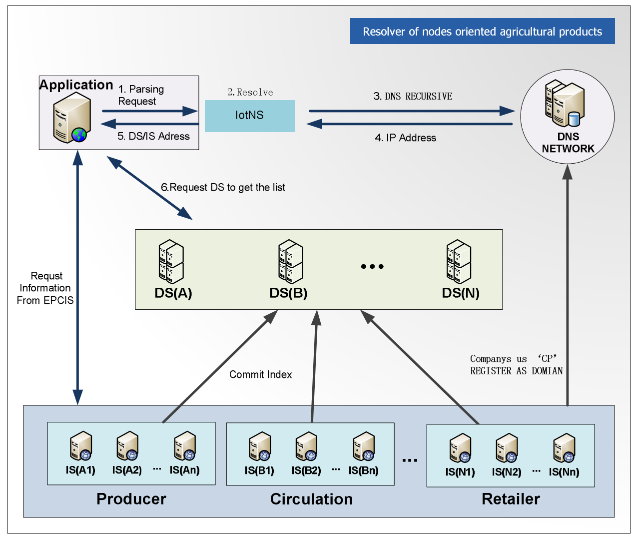

Fig. 1 Architecture of the IoT system for agriculture products

The architecture has following features:

- The iotNS is used to convert the identifier to address information. This module is a service program based on web service. It can be called by the applications that need to conduct the name service of agriculture products on PC or mobile devices. The DNS under name service recursively calls the standard DNS protocol. The iotNS can response to the directory name service requirement of IOT identification of the application programs or the EPCIS name service requirement.
- Directory Service (DS) is deployed to offer the index access of the EPCIS URI (Universal Resource Identifier) of each enterprise that the agriculture products go through. The supply chain enterprises deploy their own EPCIS and submit event index automatically to their representative DS server.
- The supply chain enterprises register and maintain their enterprise domain names through the Domain Name Registrar (DNR).

The structure of the identifier in the architecture above is shown as follows:

01 GTIN 10 LOT 91 R

where GTIN is a 14-bit number of object, LOT is a 1-bit~20-bit number and character with undefined length of batch or serial number, R is an 1-bit number indicating the length of the enterprise identifier in GTIN.

For example, the identifier of Chinese cabbage of an agriculture products enterprise is defined as:

(01)02320206010107 (10) 201304240 (91) 9

The work flow of the name service procedure is shown in Fig. 2.

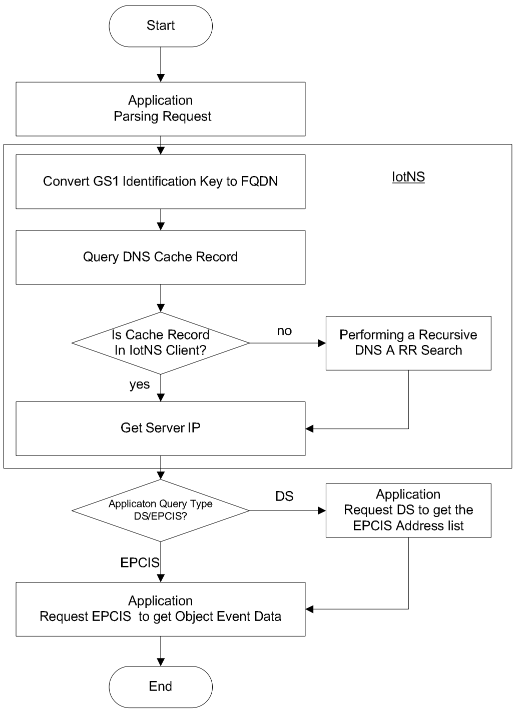

Fig. 2 Work flow of the name service procedure.

A name service procedure of the identifier of agriculture products is taken as an illustration.

1. The application program calls the iotNS service and initiates the name service request based on DS service for the identifier 0102320206010107102013042409 19.

2. The iotNS converts the identifier to FQDN (the domain name of TNSROOT.CN is provided by the China network information center (CNIC)). The procedure of the conversion is shown in Fig. 3.

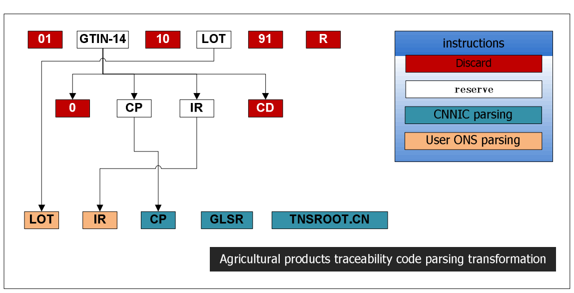

Fig. 3 Conversion of the identifier to FQDN

- When the GTIN-14 is disintegrated, the first bit of package identifier and the last checking bit are removed. Then the first R bits are taken as CP, the rest bits are taken as IR.
- After the conversion, the identifier is transformed into the following format:

201304240.010.DS.GLSR. 232020601.TNSROOT.CN

3. The iotNS conducts the recursive DNS on the FQDN - DS.GLSR.232020601.TNSROOT.C

4. The iotNS acquires the IP address of the DS server that can offer the inquiring service to the identifier.

218.90.181.232

5. The iotNS combines the IP address and the URL acquired from the DS server. Then the iotNS returns the assembled service interface back to the application program.

http://218.90.181.232:8071/getObjectRecord.aspx?GLSR=

6. The application program visits the service interface acquired in STEP 5 and gets the EPCIS server list of the object identifier by visiting the following address:

http://218.90.181.232:8071/getObjectRecord.aspx?GLSR=01 02320206010107102013042409 19

The result is shown as:

[{"issrv_addr":"
http://218.90.181.232:8072/getObjectNameFull.asp
x?GLSR=","issrv_name":"is_YJK","evt_count":"1
6","warning_count":"0","first_evt_time":"2013-4-2
4 08:00:30","last_gln":"414232020601001591
9","last_evt_time":"2013-4-24 09:40:08"}]

The result indicates that the information of the agriculture products is stored in one server. The access interface is 218.90.181.232:8072. The server name is is_YJK. The application program can inquire the event information of the agriculture products after receiving the EPCIS address.

Here are the advantages of the proposed architecture:

1) The configuration number can be reduced

The name service data is in corresponding with the enterprise Company Prefix (CP) of the GS1 standard. The enterprises do not need to configure or maintain the products information repeatedly. As the quality of agriculture products is not easy to evaluate, more supply chain enterprises are required to take part in the application of the IoT on agriculture products to supply more complete event information. The reduction of the configuration number can improve the convenience of actual application for the supply chain enterprises and reduce the coupling of the enterprises' system and DNS system. This name service can also reduce the amount of redundant data caused by the limited-time consumption and non-standardization of agriculture products in the DNS server.

Assuming that the number of the producing enterprises taking part in the application of the IoT on agriculture products is X, and the number of types of agriculture products of each enterprise is Y, each enterprise has its respective authoritative DNS server. A supermarket is simulated to accept agriculture products from the enterprises. The procedure of the name service of object identifier is analyzed. The GS1 ONS and our ONS are both simulated to be adopted to realize the name service procedure. The comparison on the amount of records and requests number is shown in Table I. The iotNS has obvious advantage over the GS1 ONS on the amount of records and requests number.

Table I Comparison on the amount of records and requests number

	Number of records in the root server	Number of records in each enterprise's server	Number of records in the supermarket's recursive server	Requests number of the supermarket's recursive server
GS1 ONS	X	Y	X*Y	X*Y
iotNS	X	1	X	X

2) Decreased configuration complexity

The IP name service from the enterprise node to the EPCIS or DS is realized by adopting the A(IPv4)/AAAA(IPv6) record. Then the data access of the application level is accomplished through the JSON interface provided by the DS server. Although defining the IP address based on the A record has lower flexibility compared to defining the URI based on NAPTR, it is convenient for enterprises because only simple configuration on the IP address is needed in the proposed solution.

3) Reduced name service number

Because the length of company prefix (CP) in GTIN, GLN and SSCC is uncertain, the GS1 ONS system stipulates that the length of CP can be obtained by interpreting the identifier. Actually, for a particular kind of agriculture product, the length of CP is constant. So the Company Internal Information (CII) can be configured to indicate the length of CP in GTIN, GLN and SSCC when the identifier is designed. In this way, the access number to the iotNS and DNS can be reduced.

IV. Experiment & Deployment

Different from the name service of the ONS on OC level, the name service employed on agriculture products identification is an enterprise-oriented solution based on company prefix. To compare the performance of these name services with the related works, experiments are conducted. A set of DNS server is adopted and the OPS of DNS are calculated by the client using Queryperf. The list of test instruments is shown in Table II.

Table II List of test instruments

Equipment	Configuration
DNS Root Server	CPU E5620; RAM 1G; Bind9.3.6+Redhat5.4
DNS Authoritative Server	CPU E5620; RAM 1G; Bind9.3.6+Redhat5.4
DNS Local Server	CPU E5620; RAM 1G; Bind9.3.6+Redhat5.4
Client	CPU E5620; RAM 1G; Ubuntu12.04+Queryerf1.12

Experiment No.1: The number of data samples to be resolved by DNS is 100,000. The number of enterprises is 1,000 and each enterprise has 100 kinds of agriculture products. In the test procedure, the data samples of the first enterprise are visited in order, and all the other data samples of other enterprises are visited in the same way. After testing for 10 times, the calculated QPS value is shown in Fig. 4.

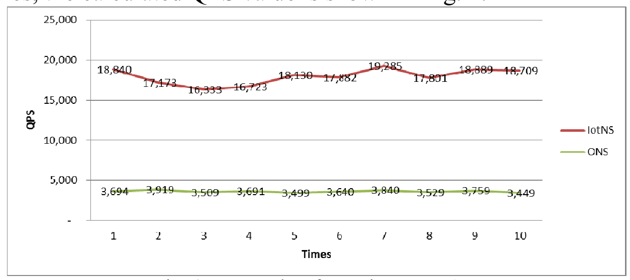

Fig. 4 Test results of experiment No.1.

Experiment No.2: Based on Experiment No.1, the number of data samples of each enterprise varies from the options of 100, 200, 300, 400 and 500. The average response time of 10 tests is recorded in Fig. 5.

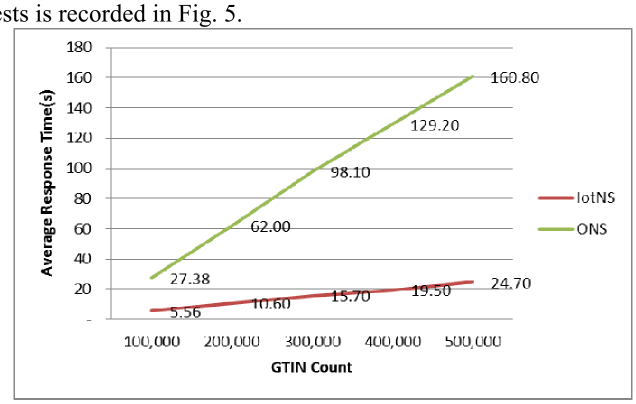

Fig. 5 Test results of experiment No.2.

In experiment No.1, a larger QPS value indicates higher performance to response to the service. In experiment No.2, a shorter responding time indicates higher performance to response to the service. The test results show that the iotNS scheme is more efficient in employing the DNS compared with the GS1 ONS scheme.

Because the iotNS interprets the identifier to the enterprise with A records, the number of requests to local recursive server is smaller than the normal GS1 ONS 2.0 scheme. For the URL data returned by ONS scheme (for example http://www.gsl.org/ons/epcis), another DNS name service is needed before the data access. So the actual response time of ONS should be longer and the workload to the DNS network is heavier.

The name service system based on the architecture above is put into practice in 5 cities of China.

At the same time, the application of the IoT on agriculture products based on the name service system is established. The main contribution of the application is resolving the source tracing problem of agriculture products. Fig. 6 shows the pictures of actual application scenarios of the iotNS system.

Fig. 6 Application scenarios.

Here is the work flow in the actual application scenario:

1. Farmers provide the information of production, packaging and shipping of the products to the EPCIS owned by agriculture enterprises.

2. During the transportation, the parameters of the transporting environment are collected by different sensors and sent to the EPCIS owned by logistics companies automatically.

3. Retailer use handheld terminal or stationary equipment for the receiving process, inventory process, and selling process, and all these information will be uploaded to the EPCIS owned by the retailer automatically.

4. Consumers scan the 2D barcode of agriculture products using mobile phone or the stationary machine at the retailer, and can be aware of the life cycle information of the products as the iotNS will interpret the serial number of the agriculture product to any of the EPCIS above.

V. CONCLUSIONS

An enterprise-oriented name service for the Internet of Things, iotNS, is proposed and implemented for the supply chain management of agriculture products. The improved name service, which is implemented based on GS1 ONS 2.0, is better to meet the requirement of seasonality and expiration date demands of agriculture products. The method also improves the deployment efficiency for agricultural companies. As accesses to the network databases of the objects are transformed to the access of directory service first, the complexity of name service using DNS technology is reduced. As a result, the iotNS is easier to be implemented as a public service for agriculture product supply chain management.

Here are some future works:

1) Although the adoption of A record does decrease the configuration difficulty, the flexibility is sacrificed compared to those using URI based EPCIS name service. We will look into this issue in future works.

2) iotNS buffering structure can be optimized according to the request characters (such as seasonality and request frequency) of different agriculture products.

3) The current name service system is of low security level and in need of more comprehensive protection. Introducing DNSSEC protocol to the system is another research topic in the future works.

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