Regional purchase orders dissemination and shipments aggregation of agricultural products with interworking EPC network and EDI system

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Abstract—This paper proposes an Electronic Product Code (EPC) based supply chain visibility system framework which interworks with Electronic Data Interchange (EDI) system which manages its orders and inventory with non-EPC stock keeping units (SKU) and their quantity. The feature of the framework is the cascadable packing/shipping management, which enables regional dissemination of purchase order and shipment aggregation. The feature is enabled by an EPC event interpreter which demands minimal modification to EDI systems. We implemented the framework in an agricultural products commerce system in which the inventory is distributed in multiple farmers and collectors. We confirmed the functionality and performance of the framework through one-months pilot commerce operation with over 150 transactions. We found 54% of the orders involve multiple products and 27% of orders exceeds the shipment free threshold. It was revealed that the regional order dissemination and shipment aggregation function is attractive both to farmers and consumers because we can provide various assortment of regional agricultural products in one commerce site. In addition, we can reduce the shipment cost and shipment labors of farmers by regionally aggregating shipments.

keywords: EPCIS, EDI, Supply Chain

I. INTRODUCTION

Electronic Data Interchange (EDI) stands for a sets of stan-
dardized business vocabularies, definitions of business docu-
ments and workflows and communication protocols to execute
business transactions with computers among enterprises. EDI
standards, such as ebXML [1], allow enterprises to register
their merchandises, company profile and implementation detail
of their local EDI system to a registry. A buyer company
can, thus, find a proper business counterpart and do business
transactions with single EDI system. Supply chain visibility
system such as barcode and RFID provides the function of
capturing the physical locations and dispositions of inventory
and purchased items. The interworking with the EDI system is
essential and indispensable for a supply chain visibility system
[2].

EPC architecture is a set of standards on ID data structure,
data capturing method and application interfaces to form an
item level supply chain visibility system [3]. In an item
level supply chain visibility system, each product item is
individually handled in the information system. In this way,
supply chain participants and consumers can track and trace
the information on each product item while in existing supply
chain visibility systems, the atomic data is a stock keeping unit
(SKU), its quantity and its location. Although EPC architecture
originally presumes RFID as its data capturing method, it
can employ GS1 standard conformal barcodes as a capturing
method. In EPC architecture, any ID is eventually represented
by “pure identity EPC” in the information system although
the ID may be binary encoded in an RFID tag or may be text
encoded in a barcode. A pure identity EPC comprises of an
Internet Assigned Numbers Authority (IANA) registered name
space, an ID scheme and an ID number to form a universal
resource identifier (URI). Pure identity EPC has well defined
relationship with corresponding GS1 element string [5], [4].

Interworking between an EDI system and an EPC-
architecture-based information system (EPC network here-
after) shall be done through EPCIS query interface, since it is
the sole interface for query applications from and to any EPC
network. Since the data in EPC network are the collection of
events, each of which comprises of event time, related EPCs,
business step and business location.

The combination of EPC network and EDI can enable
unprecedented business operations because of the automatic
purchase order dissemination and the accurate and distributed
inventory management. Motivating from an agricultural trace-
ability experiment with a melon farm [6], we are developing
an integrated EPC network and EDI system which enables re-
gional purchase order dissemination and shipment aggregation.
We have a regional collector of agricultural products who oper-
ates the EDI system. The regional collector can have inventory
in its warehouse and also it can delegate a portion of inventory
to each farmers or to contracted collectors. The comparison of the proposal and the existing commerce systems, electronic mall (e-Mall) and amazon, is shown in Fig.1. E-mall systems usually provides a showcase in Internet and payment options, while the shipment and delivery is the responsibility of sellers. In amazon, every inventory is collected into large modern warehouses so that the delivery to buyer is extremely fast when there is sufficient inventory in the warehouse. In case of lack of inventory, however, the replenishment process is not always swift. While in the proposal, since the inventory is distributed over regional sellers and a purchase order can be automatically distributed, we can achieve regional shipment aggregation and mutual compensation of inventories among sellers. We believe this is particularly effective for fresh foods commerce with a group of relatively small farmers and processed food companies.

To achieve the business operation, a cascadable representation of purchase order dissemination and shipment management is needed. The mechanism to adjust inventory in EDI system in accordance with the captured events in EPC network is also needed because physical shipments and storing are captured by EPC network.

[2] provides a high level functional overview for EDI and EPC network interworking but no technical implementation is presented. [7] proposes an integration of ebXML based EDI and EPC network. In the integrated system proposed, the EPC events associated with a purchased order are returned to EDI system as order response messages. However, it is not clear from the literature how to handle the delay between a purchase order issue and the determination of EPCs of shipment particularly when we have a third-party logistics company between the buyer and seller companies. Since an EDI system receives EPCs, the EDI system needs to be revised such that it can process received EPCs and can place EPC queries, if needed. In other implementations and guidelines [8], Advanced Shipment Notification (ASN) are claimed to be extensively used to notify EPC events to EDI system. However, implementation details, such as how to select EPC events associated to the purchase order from an EDI counterpart and how the EDI handles the notified EPCs for further processing, are not described. The application of supply chain visibility system with unique IDs of objects in conjunction with EDI is still an early stage of application.

This paper proposes an Electronic Product Code (EPC) based supply chain visibility system framework, which interworks with existing EDI systems with minimal modifications. We have developed a commerce system of agricultural products in Fukuroi-shi, Shizuoka-ken, Japan and operate the system for over two-months. In Section II, we describe the fundamental design of the system. In section III, we describe the developed agricultural commerce system and the outcome of the pilot commerce.

II. INTERWORKING FUNCTION DESIGN

A. Identifiers definition

1) SKU and item reference: Although we need a unique ID of each agricultural product item in EPC network, it is impracticable to mandate each farmer to obtain an EPC manager number. A regional collector, thus, acquires an EPC manager number and allocate item references to contracted farmers and collectors. If a contracted farmer would like to have its own manager number for the autonomy of operation, it is perfectly valid in the system as long as the numbering scheme conforms. Although we learn that a successful EDI platform of electronic parts, Rosettanet, use GTIN as its SKU [9], we presume non-EPC SKU may continue to be used in EDI system because of the following reasons.

- There are established numbering scheme to classify agricultural products (such as SEICA Catalog ID[10]).
- For mutual compensation of inventory purpose, a group of farmers may wish to provide their crops under single SKU.

We employ the fresh food standard code (seisen-hyojun-code) developed by Japan government as the SKU in our EDI system. The 13 digits code has the structure depicted in Fig.2. We establish SKU master database which relates the SKUs with the crop item references as shown in Fig.3. In the figure, two EPC item references with different manager numbers share single SKU, which means that the two farmers mutually compensate their inventories.
2) Location ID: Every business location in the system is described with serialized global location number (SGLN). We allocate a location reference of SGLN to each contracted farmer. "extension" field of a SGNL can be defined by the farmer. We request each farmer to register their business location information (name of the location, mailing address and geographical longitude and latitude information) to a location master database. Example of a location ID is shown in Fig.4. Since a location reference belongs to a farmer or a collector, it can be used as an elemental identification of the farmer.

3) Shipping containers and returnable assets: One of the benefit of regional shipping aggregation is to enable regional sharing and circulation of shipping containers and returnable assets. We assign serialized shipping container code (SSCC) and global returnable asset identifier (GRAI) to containers. Farmers can check out containers from container yard of the collector with their elemental ID (location reference, please refer Subsection II-A2).

4) EPCIS event definitions: In fresh food commerce, we sometimes prefer to use item reference and its quantity. Suppose we have a number of tomatoes in an inventory shelf. There is a purchase order of 20 tomatoes. We pick 20 tomatoes and put them into a bag and put a SGTIN tag on the bag. If we allow this operation, the SGTIN shall accompany its quantity for later verification. Although it is technically possible to register the quantity in a master data, from which we obtain data associated with each item, it is simpler to generate a quantity event with object and aggregation events. In Appendix Table I, a list of typical EPCIS event and the vocabulary definitions in our implementation are provided.

B. Message processings in the interworking function

In the process of designing the system, we found PetriNet [12] is a convenient tool to determine the requirements for the interworking function between EDI system and EPC network. We define two PetriNets, one is for EDI purchase order propagation, referred to as forward Petrinet, which starts from the root purchase order and ends at the branch purchase order. A forward PetriNet defines the topology of purchase order and produces a series of picking orders to contracted collectors and farmers. The other PetriNet is to track shipment aggregation, which can be start anywhere but a shipment at a contracted collector cannot be made unless all the local picking orders are completed. This is referred to as a reverse PetriNet in this paper. The reverse Petrinet use the same purchase order topology that the forward Petrinet defines. Those two PetriNet exchange information through an interworking function.

In the phase of purchase order dissemination, the interworking function need to transfer local picking orders to collectors and farmers by specifying the SKUs, their quantities and their locations (in terms of SGLN). No data interpretation is needed in this phase (Fig.5). In the figure, the dissemination is initiated by the "purchase order issued" event on the upper right. It is presumed that all the inventories associated with a purchase order are allocated before its placement. A source (a black circle in a white circle) in Fig.5 denotes the supply of inventory, which usually represents the crops from farm.

After picking orders are issued, each farmer and collector start picking, packing and shipping according to the picking order. There are also regular or on-demand inventory replenishments. Such physical transition of items need to be reflected in the purchase order management and inventory control in the EDI system. Since EDI system issues a picking order associated with a purchase order identification (PO, hereafter), it would be simple if the interworking function returns the PO with shipped EPCs (most likely SSCC and GRAI to which the picked items are stored) as a response message to the purchase order. When the EDI system received a PO from the interworking function with a shipped EPCs, the corresponding inventory in the EDI system are decremented. In our implementation, we choose "packing" business step to trigger the inventory adjustment. To increase the inventory in the EDI system, we use "storing" business step. When the interworking function receives a "storing" event with EPCs and the destination SGLN. The interworking function make a query to the EPC event interpreter, which is explained in the next sub-section, to obtain a list of SKUs and quantity to increment the inventory.

C. EPC event interpreter

EPC event interpreter converts a set of EPCs to corresponding set of SKUs and their quantity. If the received EPC is a SSCC or GRAI, EPC event interpreter discover the aggregation event associated with the SSCC or the GRAI to find involved EPC list. In order to lookup a SKU from an EPC, EPC event interpreter uses SKU master data explained in subsection II-A1 as shown in Fig.7. As shown in Fig.7, the trigger to EPC interpreter is from EDI system rather than an EPCIS notification message. We choose this design because EPC interpreter can be easily maintained if it is agnostic to any business logic.
III. SYSTEM DEVELOPMENT AND EVALUATION

In this section, we introduce an implementation of the proposed framework in an agricultural product commerce system and its evaluation.

A. System overview

Figure 8 shows a high level overview of the developed system. We use IBM WebSphere®Commerce as our EDI and WSM system. An open source RFID platform, FOSSTRAK[11], is used as the supply chain visibility system. Actual implementation of EPCIS requires additional functions such as a function to prevent duplicated capture and EPC list lookup from SSCC or GRAI as explained in subsection II-C. A collection of such utility functions are implemented as EPCIS adaptors[6]. The information system and master data are implemented in cloud servers. We implement the system with two farms, a processed food manufacturer, and a collector. We use barcodes in each agricultural product item and also use UHF RFID in foldable containers. Typical barcode implementation to agricultural products are shown in Fig.9. As shown in Fig.9, we use GS1-128 with AI to realize item level identification with barcode. QR code is for buyers.
of the merchandize to obtain information about the crop and to communicate with its farmer through a social network system, in our case, Facebook. For the transportation among farmers and collector, we use returnable assets (foldable boxes) with GRAI encoded RFID tag.

Figure 11 shows the typical picking order screenshot in the collector. A picker prints out the picking order and then collects specified items with the printed sheet and handy terminal. At the completion of picking, the collected items are packed into a case or a container and is shipped for further packing or to its buyer.

B. Result of one-month operation

We establish an web commerce system to sell agricultural products and processed food and have been operating the commerce service from the beginning of March 2013. Through the operation we fixed a number of bugs in the implementation and confirm our fundamental design and implementation of the interworking function between the EPC network and the EDI system is valid.
The top page of commerce site is shown in Fig.12. In March, we received 156 purchases from the web. 54% of the purchase of a combination of our merchandizes. Although our featured merchandize is melon, we continuously receive purchase orders on tea leaf, which is an award product with a purchase of melon. This is a good example of an additional-buy enabled by the assortment of local merchandizes. If a total purchase exceeds 5,000 yen (about $US 50), we provide free shipment. Below the purchase, a consumer need to cover the shipping fee 1,015 yen. We found 29% of purchase exceeds the free shipment threshold. We, in fact, asked some buyers whose purchase is below 5,000 yen if they buy a little more, we would provide free shipment, most of them bought additional product beyond the threshold.

IV. CONCLUSION

Interworking of EPC network and EDI system can achieve unprecedented accuracy, speed and granularity in supply chain, and thus enabling unprecedented business processes. The regional purchase dissemination and shipment aggregation proposed in this paper is one of such process which is realized with advanced ICT. The difficulty of the interworking function stems from the establishment of cascadable purchase order management and non-EPC based inventory control in EDI system which are driven by EPC event notifications. In this paper, we use PetriNet to analyze the requirements on the interworking function. It was found the inventory in EDI system can be controlled by monitoring storing and packing business steps in EPC network. To properly increment the inventory according to regular and on-demand fulfillment of inventory with storing event, EPC event interpreter, which works with SKU master data and EPCIS, is effective. We implement the system in an agricultural product commerce system and have been operating the site for two months. It was revealed that the regional order dissemination and shipment aggregation function is attractive both to farmers and consumers because we can provide various assortment of regional agricultural products in one commerce site. In addition, we can reduce the shipment cost and shipment labors of farmers by regionally aggregating shipments. Since the effective of the proposal has been examined for several months with limited orders, the authors continue to operate the system to clarify the limitations and further applications.

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