

Applying RFID Technology in Tracking and Tracing of Pallets in Supply Chain Management*

Ming-Wei Huang and Chua-Huang Huang
Department of Information Engineering and Computer Science
Feng Chia University
Taichung, Taiwan 40724
{williamhuang, chh}@rfdilab.iecs.fcu.edu.tw

摘要

本論文採用 EPCglobal 所提出的架構實現棧板管理。決策者需要知道商品在供應鏈中的各種狀況，也就是商品在供應鏈中的能見度，而商品在供應鏈中大部分都會使用棧板當作承載工具之後運送到各個地點，所以想要了解商品在供應鏈中的各種狀況，則必須先追蹤及溯源棧板在供應鏈中的運送動向。本篇論文將會利用無線射頻辨識技術結合棧板的管理作業實現棧板在供應鏈中之追蹤及溯源的功能。EPCglobal 組織提出了一個利用無線射頻辨識技術的架構，並制定了許多此架構的規範，目的是使之能夠達到全球運籌。本篇論文將會採用 EPCglobal 所提出的架構，主要會使用 EPCglobal 所制定的 EPC 資訊服務 (EPCIS) 以及發現服務規範，應用在棧板的管理作業上。本論文會舉一些記錄在供應鏈上棧板作業之 EPCIS 事件範例。我們可以利用紀錄的 EPCIS 事件實現棧板的追蹤及溯源。本篇論文將設計並實作一個系統，利用已經被紀錄的 EPCIS 事件，呈現出棧板在供應鏈中所經過的各個地點以及執行過的各種作業，這些棧板資訊將可提供給決策者作為往後棧板管理的策略參考。

關鍵詞：棧板管理作業、追蹤及溯源、無線射頻辨識、EPCGLOBAL、EPC 資訊服務、發現服務

ABSTRACT

This paper utilizes the EPCglobal architecture framework to implement pallet management. Decision makers need to know every status of products in supply chain management, i.e., the visibility of products in the supply chain. The products always use the pallets as the carrying tools transported to various locations. If we want to understand the status of the products in the supply chain, first, we have to track and trace the pallets' transporting rout in the supply chain. This paper would use the Radio Frequency Identification (RFID) technology with the management operations of the pallets achieving the function of tracking and tracing. EPCglobal proposes the architecture framework of the

RFID technology, and they want to achieve the global logistics for the purpose of globalization and standardization. We use EPC Information Services (EPCIS) and Discovery Service (DS) specifications proposed by EPCglobal, and apply them for the management operations of the pallets in the supply chain management. This paper would give some examples for recording EPCIS events of pallet operations in the supply chain. We use these EPCIS events to achieve tracking and tracing of the pallets. This paper would use the EPCIS events for designing and implementing a system, and show all operations in various locations of the pallets. The pallet information can be provided to the manager for the strategy of the pallet management.

Keywords: Pallet management operation, tracking and tracing, Radio Frequency Identification, EPCglobal, EPC Information Services, Discovery Service

I. INTRODUCTION

Nowadays, RFID technology is applied in a supply chain widely. Decision maker can get information of the products by using RFID technology. The information includes location, time, and operation of the products, i.e., the visibility of the products in the supply chain. To make more efficient transport strategy, a decision maker needs this information to know any status of products in a supply chain. Hence, a decision maker has to obtain this information; then, he/she can achieve tracking and tracing of products. In a supply chain, products always transport to any location by pallets. So if we want to tracking and tracing products, we can focus on tracking and tracing pallets. In management of pallets, an important issue is the management of empty pallets. When a pallet unloads its products, the empty pallet has to return to the owner. This activity will influence the efficiency of pallet management [1]. This paper will use RFID technology to record the situation of pallets, to enhance efficiency of pallet management, and to achieve tracking and tracing of pallets.

RFID technology includes readers, tags and backend system mainly. The reader can scan a lot of tags automatically in a time. As a result, more and

* This work was supported in part by National Science Foundation, Taiwan, under grant NSC 102-2218-E-035-006.

more companies apply RFID technology to enhance the efficiency of product management. However, if companies have their own RFID systems, they cannot communicate with each other. To solve this problem, the international organization, EPCglobal, draws up a series of specifications for RFID technology [2]. In this paper, we use the EPCIS and DS specification mainly [3] [4]. EPCIS can record EPCIS events of pallet operations, and DS can do tracking and tracing of pallets, that we can know the status of pallets in a supply chain clearly.

The paper is organized as the followings. In Section II, we give a brief of EPC Information Services and Discovery Service. The methods of publishing and querying of DS are explained in Section III. The pallet transport model is presented in Section IV. Then, we show how to track and trace pallets in Section V. The system architecture and user interface are include in Section VI. Conclusion and future work are given in the final Section.

II. EPC INFORMATION SERVICES AND DISCOVERY SERVICE

To communicate with different systems, EPCglobal proposes EPCglobal architecture framework and draws up a series of specifications for RFID technology. It defines the electronic product code (EPC) used in tags, and the reader can scan the EPCs from tags. Then, capture applications (CA) can store EPCIS events which included EPC and some business information in EPCIS. In this section, we mainly use the EPCIS and DS specification to record the pallet operations and to track and trace pallets.

A. EPC Information Services

EPCIS includes an EPC repository and three interfaces. EPC repository likes a database, and it is used to store EPCIS events. EPCIS supports three interfaces which are EPCIS capture interface, EPCIS query control interface, and EPCIS query callback interface. EPCIS capture interface is used by CA, and CA can use this interface to store EPCIS events in EPCIS. EPCIS query control interface is used to query EPCIS events by users immediately, and users can make query conditions by themselves. Moreover, users can query EPCIS events periodically by using EPCIS callback interface. Users can make query conditions and assign stored location previously by using EPCIS callback interface, and then EPCIS will send EPCIS events according to users' setting. By using an EPC repository and three interfaces, the EPCIS can share its EPCIS events to other users; also, users can obtain the information from every EPCIS.

B. Discovery Service

When a pallet passes through many locations in a supply chain, the EPCIS will store the EPCIS events of this pallet in various locations. If we want to know

where the pallet passes through and store what EPCIS events, we should know the EPCIS URL's of every location, i.e., the tracking and tracing of the pallet. For this purpose, DS is needed to do the job. DS is difficultly designed and it is needed to consider the security of information, because the data will be great amount and the information is sensitive for business. According to these problems, so far the DS specification is not released, and it only has functional requirements.

III. PUBLISH AND QUERY WITH DISCOVERY SERVICE

To achieve tracking and tracing by the EPC, each place has to build the EPCIS in the supply chain. Then, the owner of the EPCIS has to publish some data to the DS when a pallet reaches his place. In Fabian's paper, the owner has to publish the data including EPC, EPCIS URL, and time primarily in his proposed DS architecture [5]. In Fig. 1, when a pallet arriving owner's place, he has to publish the data such as EPC, EPCIS URL, time, etc., to the DS. Then, the DS can use this data to do tracking and tracing of pallet. As shown in Fig. 2.

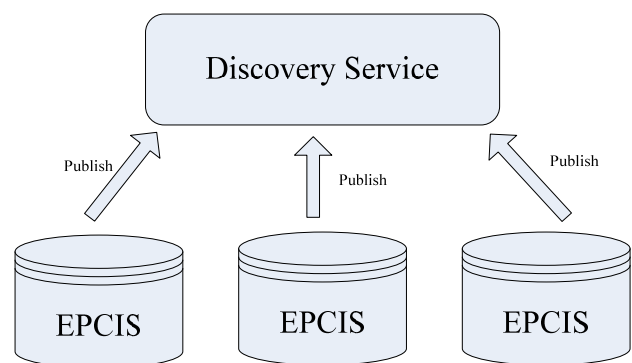


Figure 1. Publish the data to the DS

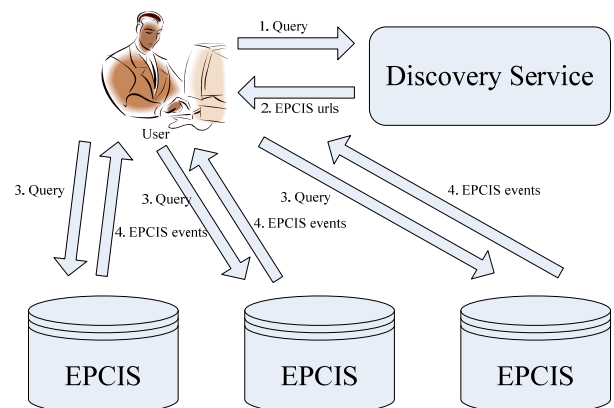


Figure 2. Steps of EPCIS query

In Step 1, user gets the EPC of the pallet, and then he can query the EPCIS URL's with the EPC by the DS. In Step 2, user can get the EPCIS URL's from the

DS's response. In Step 3 and Step 4, the user can use the EPCIS URL's to query the EPCIS events by each EPCIS [6]. Finally, user can know all information about the pallet in the supply chain. We will let all pallets follow this process, and then we can achieve tracking and tracing of pallets. Next, we should know the pallet operations in a supply chain to design what EPCIS events we should record.

IV. PALLETS TRANSPORT MODEL

When the pallets unload the products, returning the empty pallets is a problem in pallet management, i.e., reverse logistics. To return the empty pallet, there are two transport model, pooling model and exchange model.

A. Pooling model

In the pooling model, there is a logistic provider. As shown in Fig. 3. The owner of pallets is the logistic provider who is responsible for the pallet management. When other companies need pallets to load products, they have to rent pallets from the logistic provider. The loaded pallets will pass through the supply chain. At the destination side, the loaded pallets will be unloaded, and then the empty pallets have to return to the logistic provider near the end point.

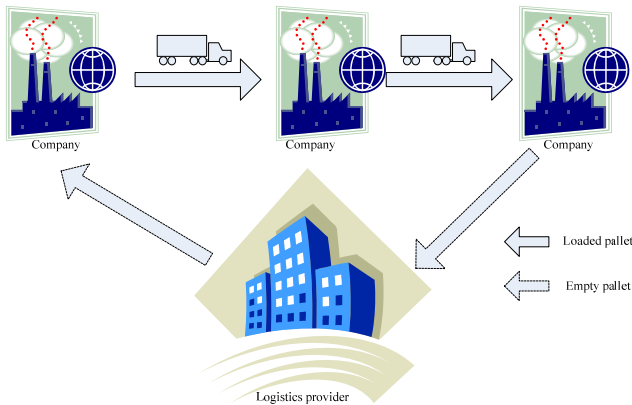


Figure 3. Pooling model

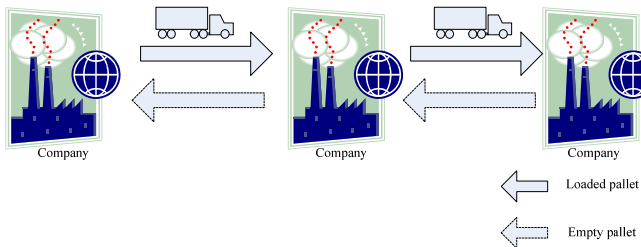


Figure 4. Exchange model

B. Exchange model

In the exchange model, there is no logistic provider. As shown in Fig. 4. In this model, all companies have their pallets. They are responsible for the pallet management. When a company transporting the

loaded pallets to the next company, the next company receives the loaded pallets. Then, the next company will unload the pallets and return the empty pallets to the conveyance transporting the loaded pallets simultaneously, or take the same quantity of empty pallets to the conveyance transporting the loaded pallets.

Nowadays, the developed countries always use the pooling model. Letting the logistic provider manages the pallets, pallet management will be more specialized and the pallet will be normalization. So the consumption of the pallets will be decreased and the number of making pallets will also be decreased. Relatively, the consumption of the environment resource will be decreased. Moreover, cost of managing pallets by companies themselves is more than by logistic provider, because they do not need to control the transport process. Exchange model is always used in small supply chain, because they have special type of pallets [7] [8].

V. TRACKING AND TRACING OF PALLETS

We can achieve tracking and tracing of pallets with RFID technology. In other papers, such as Zhang's and Jin's research, they are using RFID technology on pallets in logistic provider with special designed information systems [8] [9]. However, their information systems are closed systems. When logistic provider ships the pallets from their places, it cannot know the status of the pallets until the pallets are returned. So we use EPCglobal architecture framework. If the partners of the supply chain build EPCglobal architecture framework, they can share their information to each other. In this section, we will introduce the EPC coding format for pallets, and specify the EPCIS events.

A. EPC coding format

EPC is stored on a tag, and the tag is attached on a pallet. We can identify pallets by EPCs. EPC format is defined in Tag Data Standards (TDS) of EPCglobal architecture framework [10]. TDS defines the formats of EPC, such as Serialized Global Trade Item Number (SGTIN) used on general products, Global Location Number with or without extension (SGLN) used on expressing the locations, Global Document Type Identifier (GDTI) is used on documents. The pallets always use Global Returnable Asset Identifier (GRAI) and Serial Shipping Container Code (SSCC). GRAI is used to express returnable asset, and a pallet can be identified by the GRAI. The format of GRAI is shown below:

`urn:epc:id:grai:CompanyPrefix.AssetType.SerialNumber`

“urn:epc:id:grai:” is the header of the GRAI. “CompanyPrefix” is the number of company making the pallet. “AssetType” is the returnable asset type of the company. “SerialNumber” is used to identify each pallet. An example of GRAI is shown below:

urn:epc:id:grai:0615566.12345.134

Also, the SSCC is used to express a group of products which are on the pallet. When a pallet loads a group of products, user has to commission an SSCC to these products. When a pallet unloads a group of products loaded on its, user has to delete the SSCC of these products. The format of SSCC is shown as below:

urn:epc:id:sscc:CompanyPrefix.SerialReference

“urn:epc:id:sscc:” is the header of SSCC. “CompanyPrefix” is used to express the number of the company commission the SSCC to the products loaded on the pallet. SSCC has no “AssetType” and uses the “SerialReference” to identify the products loaded on a pallet, because the class of products may be different. An example of SSCC format is shown as below:

urn:epc:id:sscc:0615566.1234567890

Hence, a pallet must have two tags, one for GRAI, and another one for SSCC. Using two formats of EPC in pallets, we can do access control. If logistic provider wants to know the status of his pallets at partner’s place, partner can store EPCIS events with SSCC for sharing. If partner does not want to share information of his products, he can determine whether the EPCIS events with GRAI will share or not such that he can decide what EPCIS events with GRAI will be store in his process. Then, using two formats of EPC, one can achieve some requirement of information security.

B. EPCIS events

To achieve tracking and tracing of pallets, we have to record the pallet operations. We can use the EPCIS events to record the pallet operations in EPCglobal architecture framework. An example of the EPCIS event is shown as below:

```
<ObjectEvent>
  <eventTime>2013-06-08T09:00:00.000+08:00
</eventTime>
  <recordTime>2013-06-
19:31:06.000+08:00</recordTime>
  <eventTimeZoneOffset>+08:00</eventTimeZone
Offset>
  <epcList>
    <epc>urn:epc:id:grai:0615566.12345.60</epc>
  </epcList>
  <action>ADD</action>
  <bizStep>urn:epcglobal:cbv:bizstep:shipping</biz
Step>
  <disposition>urn:epcglobal:cbv:disp:active</dispo
sition>
  <readPoint>
    <id>urn:epc:id:sgln:0614141.00001.1</id>
  </readPoint>
  <bizLocation>
    <id>urn:epc:id:sgln:0614141.00001</id>
  </bizLocation>
  <bizTransactionList/>
</ObjectEvent>
```

This is an ObjectEvent which is a type of EPCIS events, and it is expressed using XML format.. An ObjectEvent has several fields which record the EPC’s of pallets, reader identifier indicating location, the time of reading, the business step, the location of reading, etc. The vocabularies of business step are defined in the Core Business Vocabulary Standard [11]. Then, EPCIS event can indicate the pallet operations by these fields. EPCIS event has four types, ObjectEvent, AggregationEvent, QuantityEvent and TransactionEvent. ObjectEvent is used to record general reading events, such as a pallet passes through a reader and the reader read the EPC of the pallet. AggregationEvent is used to specify the aggregation relationship between EPCs, such as the relation between a pallet and the products on the pallet. QuantityEvent is used to record the number of pallet in an inventory. TransactionEvent is used to record business activity, such as selling a product. We can set up the reader in specific point, such as the gates of pallet storage zone, conveyors, etc. By using ALE middleware to control readers, we can read the tags automatically. So we can record the EPCIS events automatically. Next, we give some patterns of EPCIS events for pallet operations. We only specify important field for these patterns. When a pallet is made, we have to assign an EPC to this pallet, and record the EPCIS event as below:

```
ObjectEvent:
  EPC: GRAI
  Action: ADD
  Business step: commissioning
```

We use ObjectEvent to record this operation. The GRAI is the EPC for the pallet. Action is ADD because the GRAI begin using on the pallet. Business step uses the “commissioning” to express the EPC be assigned to the pallet. When a pallet is shipped, we record the EPCIS events as below:

```
ObjectEvent:
  EPC: GRAIs
  Action: OBSERVE
  Business step: shipping
```

We use ObjectEvent to record this operation. We record the GRAIs of the pallets, because we want to identify the pallets. Action is OBSERVE, because the EPCIS event is a general reading event. Business step uses “shipping” to express the pallet shipping. When a pallet is broken and cannot be repaired, we record two EPCIS events as below:

```
ObjectEvent:
  EPC: GRAI
  Action: OBSERVE
  Business step: destroying

ObjectEvent:
  EPC: GRAI
  Action: DELETE
  Business step: killing
```

In this pallet operation, first we use an ObjectEvent to express the pallet being broken with business step “destroying”. Second, we use an ObjectEvent to kill the EPC of the pallet, because the pallet is broken and will never be used. Action is DELETE, because the EPC will never be used. business step uses “killing” to express that.

When a pallet loads products, we record the EPCIS events as below:

ObjectEvent:
 EPC: SSCC
 Action: ADD
 Business step: commissioning

AggregationEvent:
 parent EPC: SSCC
 children EPC: SGTIN's
 Action: ADD
 Business step: packing

In this pallet operation, first, we need to commission an SSCC to this group of products on the pallet. We use ObjectEvent to record this operation. Action is ADD because the SSCC is first use and commission to this group of products. Business step uses “commissioning” to express the SSCC is commissioned to this group of products. Second, we have to record the aggregation relationship between the SSCC and products. Hence, we use AggregationEvent to specify this aggregation relationship. To specify the aggregation relationship by AggregationEvent, there are only one parent EPC and many children EPC's. The parent EPC is SSCC expressing the group of products on the pallet. The children EPCs are SGTIN's expressing all loaded products. Action is ADD because it is a new aggregation relationship. Then, business steps use corresponding vocabulary of CBV. When a pallet unloads its products, we record two EPCIS events as below:

AggregationEvent:
 parent EPC: SSCC
 children EPC: SGTIN's
 Action: DELETE
 Business step: accepting

ObjectEvent:
 EPC: SSCC
 Action: DELETE
 Business step: killing

In this pallet operation, first we have to remove the aggregation relationship between the pallet and the products on the pallet, so we use AggregationEvent to express that. In this AggregationEvent, parent EPC is SSCC expressing this group of the products, and children EPC is SGTIN's expressing the every EPC of the products. Action is DELETE, because we want to remove the aggregation relationship. Business step uses “accepting”. In CBV, “accepting” express accepting the goods and unloading the goods, then checking the amount of goods. Second, because removing the aggregation relationship, the SSCC

which is the EPC of the group products will never be reused. We use the ObjectEvent to express this deletion operation. Action is DELETE because the EPC will never be used. Business step uses “killing”.

When user inventories the pallets in pallet storage zone, we record the EPCIS events as below:

QuantityEvent:
 EPC: GRAIs
 Action: OBSERVE
 Quantity: value
 Business step: inspecting

We use QuantityEvent to record this operation. The QuantityEvent focuses on quantity and doesn't need to identify each EPC, so the EPCs of pallets do not need to record the “SerialNumber”. Other field is filled with corresponding value. Recording the other pallet operations is similar as the above, filling corresponding value in fields of the EPCIS events.

We give some examples of EPCIS events for the pallet operations. Other pallet operations, we can record the EPCIS events like these patterns. Then, we can design what EPCIS events have to be record according to the pallet operations in a supply chain. By designing and recording these EPCIS events of pallet operations, we will have a series of pallet information in the supply chain. Then, we can query where the pallet passes through in the supply chain by the EPC of DS, and then query the EPCIS events from every EPCIS, and get a series of pallet information in the supply chain. By querying this information, we can get all data of pallet operations in a supply chain, and know where and when the status of the pallet in every time and every location, i.e., we can achieve the tracking and tracing of pallets

VI. SYSTEM ARCHITECTURE AND USER INTERFACE

To verify recording the EPCIS events in a supply chain can achieve tracking and tracing of pallets, we design the system to get the data of pallet operations and display the information of pallets in a supply chain, then user can know where and when the status of the pallet in every time and every location in the supply chain. Our system architecture is shown in Fig. 5.

We design five module, Pallet Information Module, Reader Control Module, Get EPCIS URLs Module, Events Query Module, and Filter Module. Pallet Information Module provides the graphic user interface to display pallet information, and user can enter the EPC of pallet or read the EPC from tag by click the scan button. Then, clicking the query button will query the information about the EPC of the pallet. Reader Control Module can control a reader, and scan the EPC

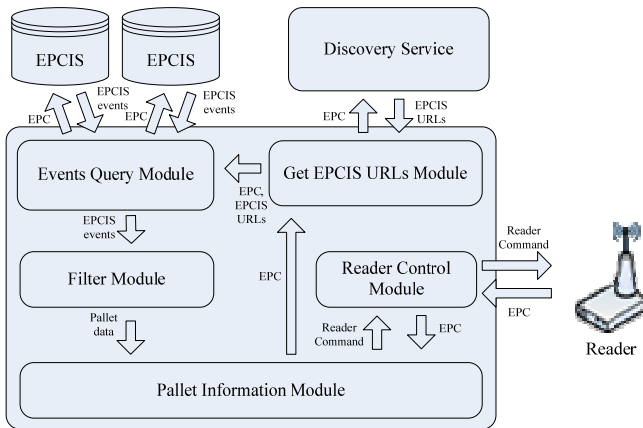


Figure 5. System architecture

compatible with each other and the information can be shared by partners.

To verify recording EPCIS events can achieve tracking and tracing of pallets, we design and implement a pallet management system. The system displays the information of the pallet. A decision maker can refer the information to make the strategy for future.

Furthermore, work can extend to tracking and tracing of products based on this paper, and increase the visibility in a supply chain. The system displays the information just for a pallet. Afterward, we can display information of many pallets and compute some data, then provide more useful information for decision makers.

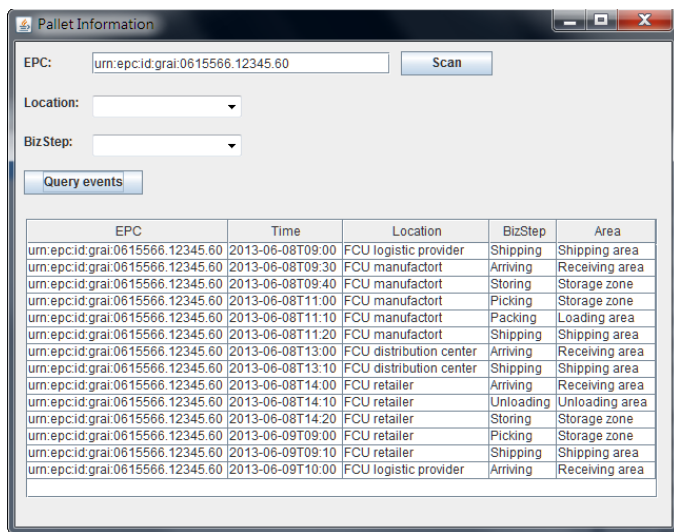


Figure 6. User interface

from the tag, then return the EPC to Pallet Information Module. Get EPCIS URLs Module can query the EPCIS URL's with EPC, and return the result. Events Query Module uses the result of Get EPCIS URLs Module querying, and then it queries EPCIS events by using each EPCIS URL's of result. Filter Module get the EPCIS events from Events Query Module, and then it filter the EPCIS events. Finally, Pallet Information Module gets the filter data of pallet, and display the information on graphic user interface, as shown in Fig. 6.

User can get the history track of the pallet, and know the last operation, location, and time. Therefore, our system verifies that recording the EPCIS events can achieve tracking and tracing of pallets.

VII. CONCLUSION AND FUTURE WORK

This paper presents tracking and tracing of pallets by using RFID technology. Also, this paper introduces two models of pallet management. By following the specification of the EPCglobal proposed for supply chain management, the software and hardware can be

REFERENCES

- [1] M. G. Gnani, G. Lettera and A. Rollo, "A Simulation Comparison Analysis of Effective Pallet Management Scenarios," in *Proceedings 2011 IEEE International Conference on Industrial Engineering and Engineering Management*, pp. 1228-1232, 2011.
- [2] K. Traub, F. Armenio, H. Barthel, P. Dietrich, J. Duker, C. Floerkemeier, J. Garrett, M. Harrison, B. Hogan, J. Mitsugi, J. Preishuber-Pfluegl, O. Ryaboy, S. Sarma, K. Suen and J. Williams, "The EPCglobal Architecture Framework v. 1.4. Technical report," GS1, EPCglobal, 2010.
- [3] EPCglobal, "EPC Information Services (EPCIS) Version 1.0.1 Specification. Technical report," GS1, EPCglobal, 2007.
- [4] EPCglobal, "Data Discovery (DD JRG) Requirements Document. Technical report," GS1, EPCglobal, 2009.
- [5] B. Fabian, T. Ermakova and C. Müller, "SHARDIS: A Privacy-Enhanced Discovery Service for RFID-Based Product Information," *IEEE Transactions on Industrial Informatics*, Vol. 8, No. 3, pp. 707-718, 2012.
- [6] GS1 France and WP9 partners, "Returnable Transport Items: Requirements to Improve Reusable Asset Management," Work Packages BRIDGE WP09, BRIDGE Project, 2007.
- [7] GS1 France and WP9 partners, "Returnable Transport Items: the market for EPCglobal applications," Work Packages BRIDGE WP09, BRIDGE Project, 2007.
- [8] Q. Zhang, J. Wei, G. Cheng, Z. Wang, D. Yan and S. Zhao, "Pallet Rental Information System Based on RFID," in *Proceedings of the 4th IEEE Conference on Industrial Electronics and Applications*, pp. 886-891, 2009.
- [9] S. Jin, M. Jiang, Z. Yao, H. Ge and D. Feng, "Study on the Pallet-bank and its Construction," in *Proceedings of the IEEE International Conference on Automation and Logistics*, pp.

885-889, 2007.

2010.

[10] EPCglobal, "GS1 EPC Tag Data Standard 1.6. Ratified standard," GS1, EPCglobal, 2011..

[11] EPCglobal, "Core Business Vocabulary Standard. Ratified standard," GS1, EPCglobal,