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Simulation of Supply Chain Management Based on the EPCglobal Enterprise Network

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Abstract
This paper presents the simulation environment of an RFID enterprise network based on EPCglobal architecture framework. The RFID enterprise network consists of tag/reader simulator, reader management server, identification server, EPC global Network, and application system. We implement two important application simulations of supply chain management: container yard management and warehouse management. Application scenarios are described in a scenario player using action scripts; application clients interact with reader simulator through an event server which also monitors operations of the Application Level Events (ALE) middleware and the EPCIS event repository. Tag data are transmitted to the ALE reader control module and filtered and aggregated by ALE data process module according to the ALE ECSpec, and then reports are generated and submitted to capture applications. Upon receiving ALE reports, capture applications will create relative EPC events that are stored in the EPC Information Service (EPCIS) event repository. User interface of operating the tag/reader simulator, ALE middleware, EPCIS event repository, and application scenarios will be demonstrated.

1. Introduction

The EPC global Architecture Framework [1] provides a standard platform for supply chain management. The supply chain partner can construct their own information platform, and share product information with other partners. In this paper, we present the supply chain management operation simulation based on the EPC global enterprise network architecture [2]. We present two applications of simulation: container yard management [3], [4], [5]and warehouse management[6], [7].

RFID enterprise network architecture is shown in 0which consists of the Class-1 Generation-2 tag/reader simulator[8]and Low Level Reader Protocol (LLRP) reader simulator [9], the Application Level Events (ALE)middleware[10], Reader Management Server (RM)[11], EPC global network which includes the EPC Information Service (IS) [12], Object Name Service (ONS)[13], and Discovery Service (DS)[14], and applications. Note that the specification of discovery service is currently in development by EPC global.

The scenarios of container yard management and warehouse manage application are described in a scenario player using action scripts. Application clients interact with reader simulator through an event server which also monitors operations of the ALE middleware and the EPCIS event repository. Tag data are transmitted to the ALE reader control module and are filtered and aggregated by ALE data process module according to prescribed ALE event cycle specifications (ECSpec), and then ALE reports are generated and submitted to capture applications. Upon receiving ALE reports, capture applications will create relative EPC events that are stored in the EPCIS event repository. User interface of operating the tag/reader simulator, ALE middleware, EPCIS event repository, and application scenarios will be demonstrated.

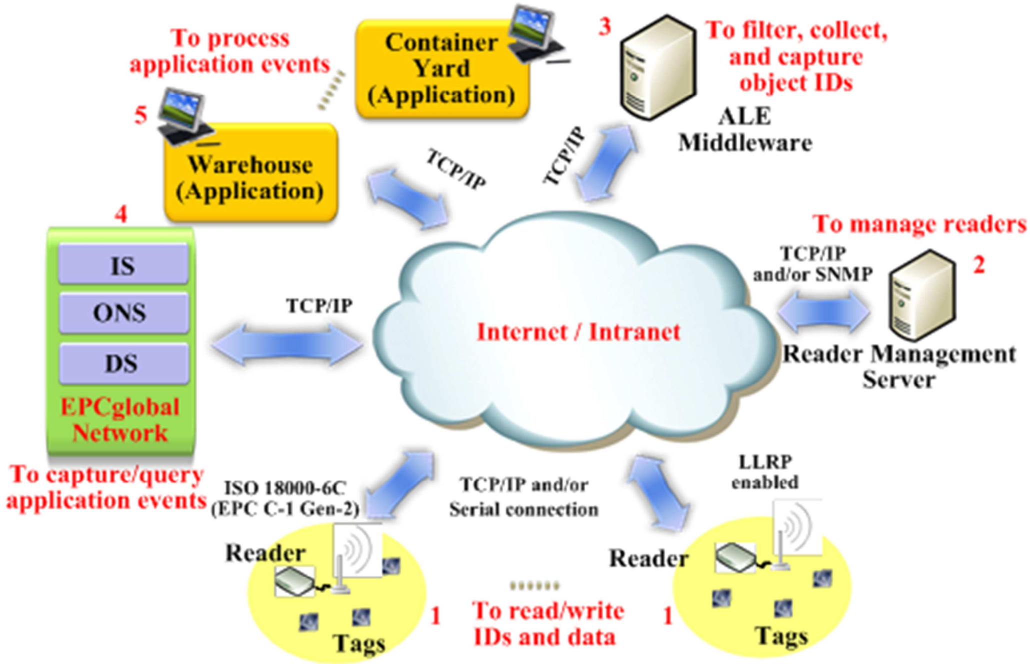

Figure 1. *Enreprise network*

In a practical application, tens or hundreds of readers may be deployed in the application field. Since the cost of commercial readers is very expensive, it is important to provide a simulation platform so an enterprise can evaluate the effect of RFID systems in their business applications. This simulation platform can save the cost of implementation, and reduce barriers to RFID technology development. It is also a useful solution for those who cannot build a real supply chain environment but with the need of developing applications on EPC global network.

The paper is organized as the following. In Section 0, we explain the enterprise network based on EPC global architecture framework. Application simulations of container yard management and warehouse management are presented in Section 3. Conclusions are given in Section 4.

2. EPCglobal Based Enterprise Network

The EPC global based enterprise network is shown in 0 We have implemented thetag/reader simulator of Class-1 Generation-2 protocol and Low Level Reader protocol, ALE middleware, and EPCIS Event Repository.

The five major parts of the enterprise network are:

1. Tags/Readers: The simulator fully implements Class-1 Generation-2 functions. An application may deploy a number of readers in the simulator that each reader can read and write the tags within its read range.
2. Reader Management Server: It is in charge of reader configuration and management commands for the deployed readers.Management strategies can be described using an XML file or sequence of SNMP commands.
3. ID Server: The major part of the ID server is the ALE middleware.The server is responsible for process electronic product code (EPC) for filtering and collection data from tags, and then delivering the event data to the designated applications.
4. The EPC global Network: the EPC global network including EPC Information Service (IS), Object Name Service (ONS), and Discovery Service (DS). These services are used to store, query, and tracking of electronic goods EPC and retrieve the relevant information.
5. Applications: An enterprise may contain a number of applications, such as purchase management system, sales management system, warehouse management system, production management system. Application system receives the EPC of the goods, performs capture or query applications according to their operation functions with EPCIS event repository.

Usually, readers, the reader management server, and the ID server are connected via the internal network (intranet) or internet. The EPC global network and the application systemare connected through the internet links.

There are three systems have been implemented.

2.1. Class-1 Generation-2 Reader/Tag Simulator

The reader/tag simulation system consists of two main objects, and an auxiliary object. The main objects are reader and tag. The system simulate the behavior of these two objects including the signal anti-collision, inventory, read and write tag data.

The auxiliary object, environment object, simulates the antenna coverage of all the tags in the reader antenna field. Once a tag moves out to the antenna coverage field, the tag will lose power. In order to simulate this function, the environment object detects the location of all electronic devices.

2.1.1. Tag Object

The tag object contains 14 commands, as well as a finite state machine to execute a command sequence. The 14 commands are Select, Query, Query Adjust, Query Rep, ACK, NAK, Req_RN, Read, Write, Access, Lock, Kill, Block Write, and Block Erase.

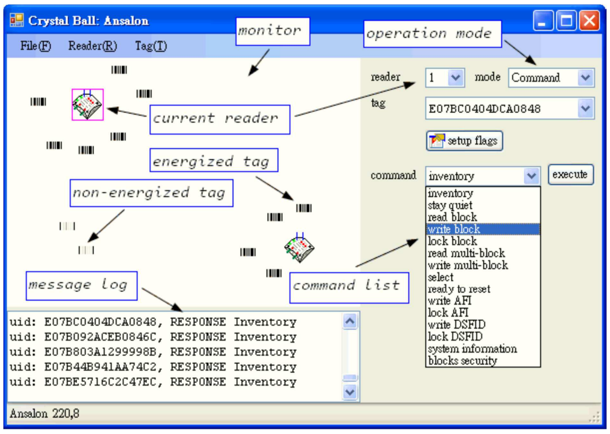

Figure 2. *Reader/tag simulation*

When the tag receives the command packet, following steps will be executed.

1. Check correctness of command packet format,
2. Interpret command and parameters,
3. Execute the command following the finite state machine,
4. Generate responded frame,
5. Reply the response frame.

2.1.2. Reader Object

The reader object is responsible for generating commands and process replies. For the commands Query, Query Adjust, and Query Rep, the reader simulator must handle the signal collision according to the anti-collision algorithm.

The reader object handles commands with following steps:

1. Setflags in command specifications,
2. Generate command frame,
3. Send command frame.

When the reader receivestag data, the reader object perform the following steps:

1. Check the correct of the reply frame format,
2. Interpret the reply frame,
3. Retrieve the tag data.

2.1.3. Environment Object

In order to determine whether the tag object is in range of a reader antenna, the environment objects detect and records the location of all reader and tag objects.

The operation of the simulation system interface is shown in 0

The upper-left block is the environment object. The readers and tags are shown as icons. A number of tags and readers can be added using the menu bar Reader (R) and Tag (T).

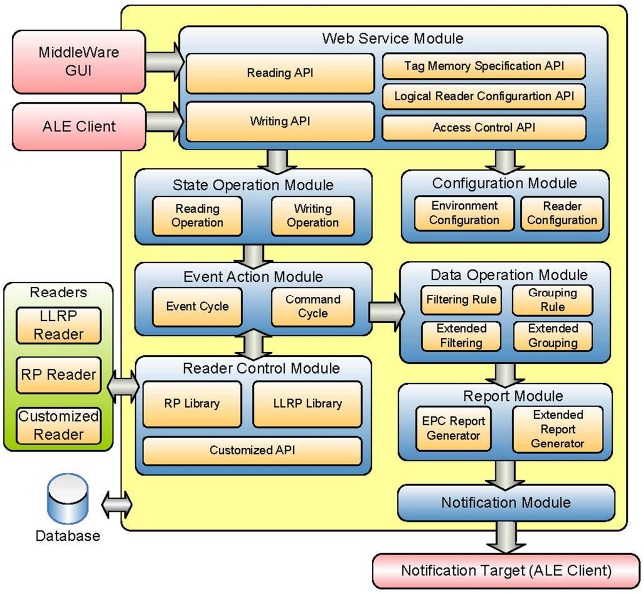

Figure 3. *System architecture of ALE middleware*

2.2. Application Level Events Middleware

ALE middleware plays the role of the application layer events, also known as RFID middleware.

The ID server receives raw data from readers and filter out the redundant duplicated tag data.

The ALE middleware architecture contains eight modules as shown in 0:

1. Web service module: Provides five service interfaces, including reading API, writing API, tag memory specification API, logical reader configuration, API, and access API to application clients.
2. State operation module: Responsible for state transition of event specification and command specification according to the state transition rule of each individual specification.
3. Configuration module: In charge of middleware system setup, including reader configuration and environment configuration.
4. Event action module: processes the cyclic operations defined by event and command specifications. It also

receives the event and command responses from reader control module.

5. Reader control module: communicate with physical readers by following various protocols such as LLRP library, and customized reader API. Reader control module also forward the result obtained from readers to event action module.
6. Data operation module: Responsible for filtering and aggregating EPC data using specified patterns.
7. Report module: generates EPC event and command reports according to the report format specified by application clients.
8. Notification module: Forwards event and command reports to the designated address specified by application clients.

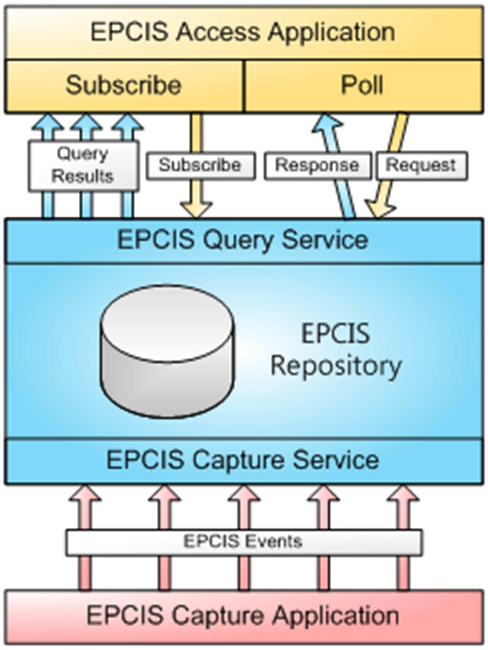

Figure 4. *System architecture of EPCIS event repository*

2.3. EPC Information Service Event Repository

The EPCIS implementation is based on EPC global standard using service-oriented architecture (SOA). The system architecture of EPCIS event repository is shown in 0Capture and Query interface with the IS Repository using web services. The modules of EPCIS are:

1. Capture interface: Capture (), process four event types: object event, aggregation event, quantity event, transaction event. It will interpret and save the event to repository.
2. Vocabulary: set Vocabulary (), extended the vocabulary item for user defined.
3. Query interface: subscribe(), unsubscribe(), and poll(), major query function is poll–Simple Event Query for querying event data and Simple Master Data Query for querying business vocabulary.
4. EPCIS repository: Storage of event data, including the four event type schema as defined in the EPCIS specification.

3. Application Simulation

In this demonstration, we simulate two applications based on EPC global enterprise network: container yard management and warehouse management.

3.1. System Architecture

The system architecture of application simulation consists of three subsystems: scenario player, event server, and kernel operations, as shown in 0Scenario player communicates with reader/tag simulator, ALE middleware and EPCIS event repository through the event server. The simulation system integrates front-end flash and back-end kernel operation of EPC global network.

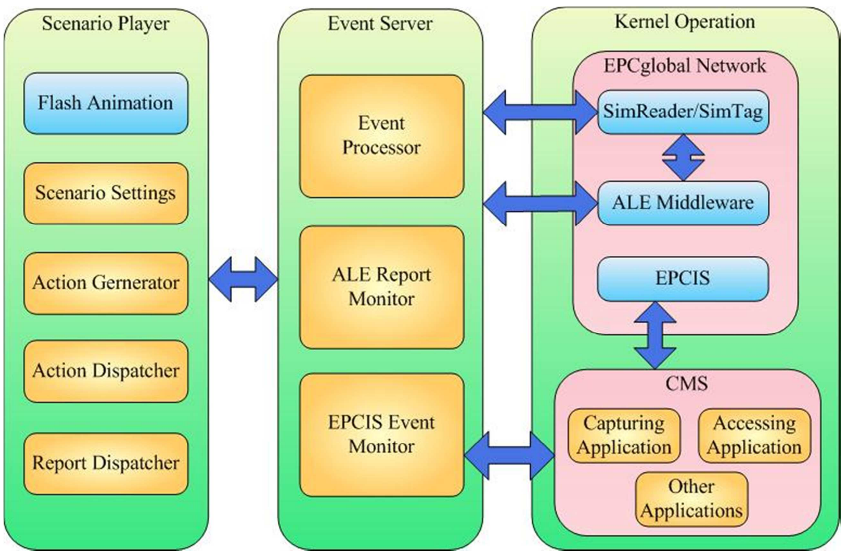

Figure 5. *System architecture of application simulation*

1. Scenario player: This module includes flash animation, scenario setting, action generator, action dispatcher, and report dispatcher. When running flash animation, action script will generate commands in different stage. The action commands are sent to event server by action dispatcher. The result will return report dispatcher of scenario player.
2. Event server: The event server includes event processor, ALE report monitor, and EPCIS event monitor. When receiving commands from scenario player, event server passes the commands to the related server in the kernel operation module and receives the results that are sent back to the scenario player.
3. Kernel operation module: This module includes the implementation of EPC global architecture framework, application programs for container yard management and warehouse management. According to the commands from the event server, kernel operation module executes the commands and sends back results to the event server.

3.2. Container Yard Management

0illustrates the layout of container yard management simulation. The container yard is divided into entrance/exit gates, control station, empty container area, export container area, import container area, and loading/unloading area.

In order to perform real-time tracking and management of containers, to avoid the container stacked into the incorrect storage areas, incorrect ships. RFID readers are deployed in entrance/exit gates, control station, container areas, and the shore loading/unloading area.

The simulation environment is preset as follows:

3.2.1. Tags

- All containers are attached by aC-1 Gen-2 tag.
- The tag has an EPC linked to the container identification.

3.2.2. Readers

- Readers in the entrance/exit gates scan the container identification. Relative information is retrieved from EPCIS for checking the correct transactions.
- Readers in the empty container area, the import container area, the export container area is issue alert messages when container in the wrong area. Records track and trace data of the container.
- Readers in shore make sure the containers are loaded/ unloaded in the correct dock.
- Handheld readers are used to read container information when necessary.

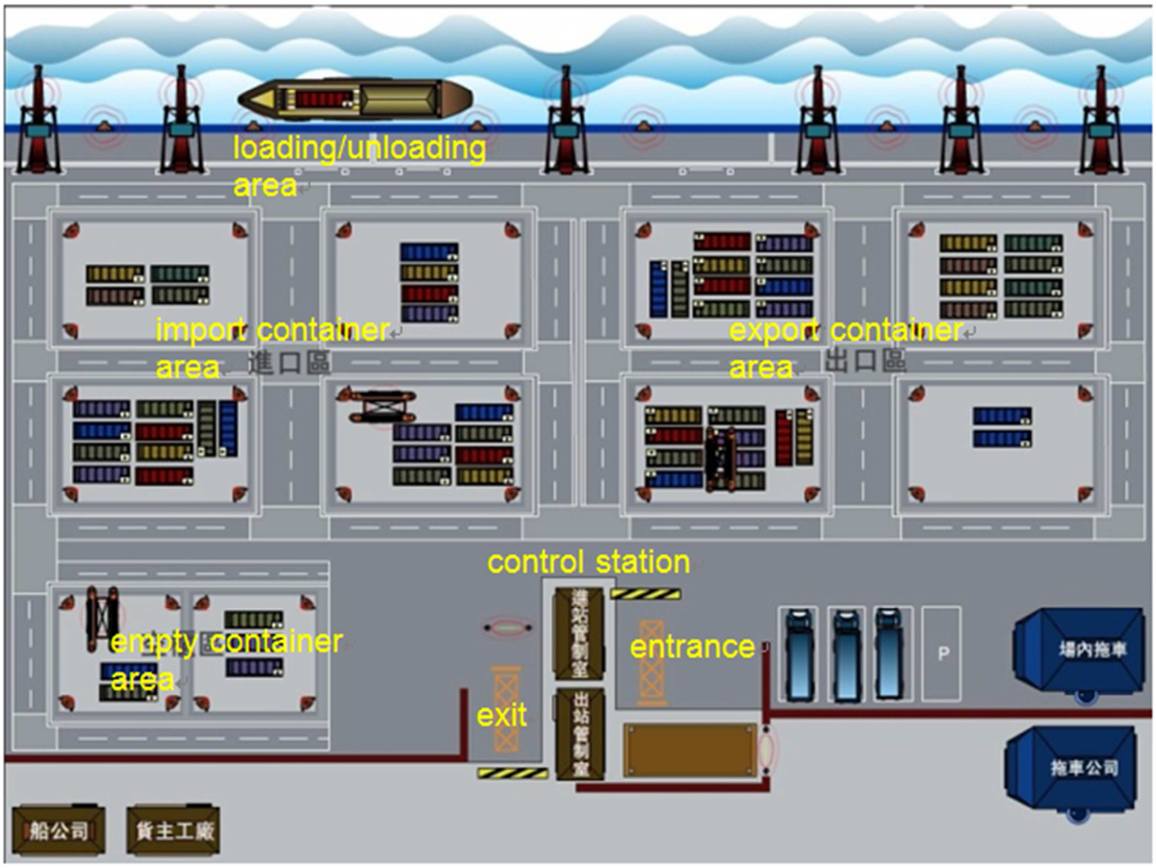

Figure 6. Container yard layout

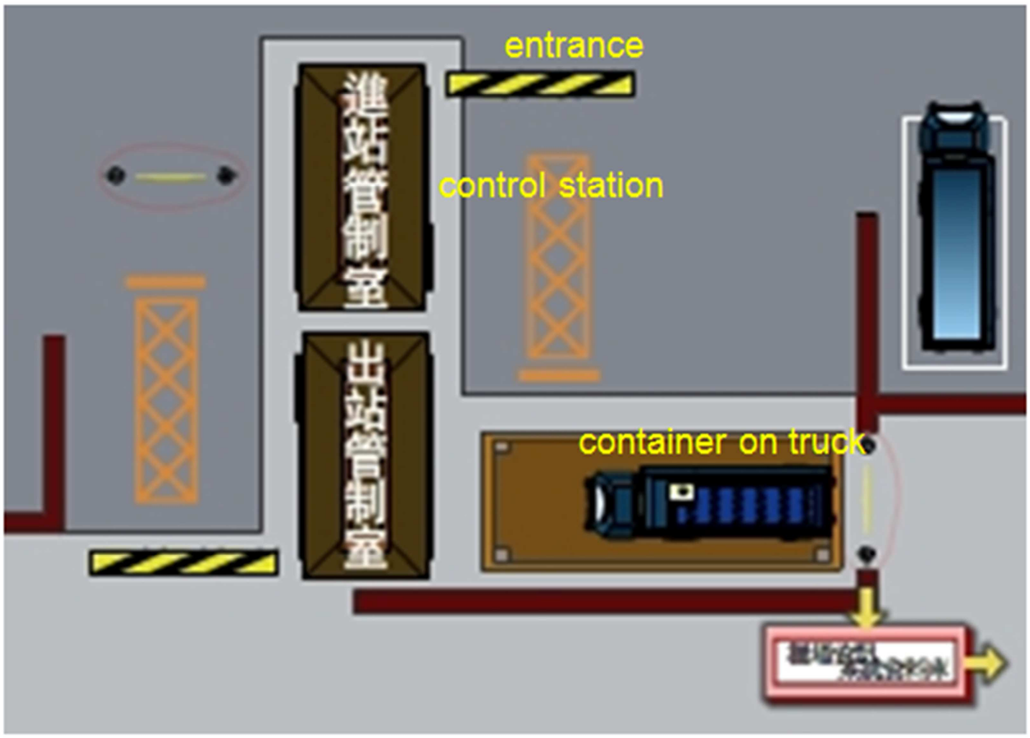

Figure 7. *Scenario of container yard managemet*

Scenario and Configuration

0shows the scenario of container yard management at the entrance station. When a container approaching the entrance gate, the control station reader gets container ID from tag, Application system issues the relative information for checking by inspector. The ECPIS event is generated and stored in EPCIS repository.

ALE EC spec:

We assume that the reading distance is 30 meters from reader to entrance station, the speed of container truck is 20 KM per hour, the truck forwards 5.6 meters per second, and total reading time is 6 seconds. The event cycleboundary parameters of the EPC Specare: repeat periods = 10000 ms, duration = 6000 ms. the reader name in entrance station is checkpoint. The ECSpec is presented as below:

```
<?xml version="1.0" encoding="UTF-8"?>
<ale:ECSpec xmlns:ns2="urn:epcglobal:ale:xsd:1">
  <logical Readers>
    <logical Reader>check_point</logical Reader>
  </logicalReaders>
  <boundarySpec>
    <repeatPeriod unit="MS">10000</repeat Period>
    <duration unit="MS">6000</duration>
    <stableSetInterval unit="MS">0</stableSetInterval>
  </boundarySpec>
  <reportSpecs>
    <reportSpec>
      <reportSet set="CURRENT"/>
      <output includeRawHex="true"
              includeRawDecimal="true"
              includeEPC="true" includeTag="true"/
    </reportSpec>
  </reportSpecs>
</ale:ECSpec>
```

ALE ECReport

When reader reads container EPC, the ALE middleware will generate anECReport according to ECSpec.The ECREport is shown as below:

```
<?xml version="1.0" encoding="UTF-8"?>
<urn: ECReportsspecName="EpcSpec_current"
  date="2014-08-01T20:45:38.203+0800"
  ALEID="RFID_ALE1"
  totalMilliseconds="10000"
  terminationCondition="DURATION"
  xmlns:urn="urn:epcglobal:ale:xsd:1">
  <reports>
  <report reportName="ECReport_current">
  <group name =' '>
  <groupList>
  <member date="2014-08-01T20:41:06.000+0800"
          LogicalReader="check_point"
    <epc>urn:epc:id:sgtin: 8424495807.902.229596491295
    </epc>
    <tag>
      urn:epc:tag:sgtin-
96:2.8424495807.902.229596491295
    </tag>
    <rawHex>
      urn:epc:raw:96.x3049F6239ABFE1B575046E1F
    </rawHex>
    <rawDecimal>
      urn:epc:raw:96.14944694415198139112961109535
    </rawDecimal>
  </member>
```

```
    </group List>
    </group>
    </report>
    </reports>
</urn: ECReports>
```

Capture Application

In capture application, XML property mapping is generated in advance for EPCIS event. The mapping properties based on Core Business Vocabulary (CBV) standard defined by EPC global[15].

When capture application receives the EC Report, it generates the EPCIS event field value by mapping properties as below:

```
<?xml version="1.0" encoding="UTF-8" standalone="no"?>
    <Capture Application Properties>
    <base_ level>
        <fieldname>groupList</fieldname>
    </base_level>
    <oneofone_level>
        <fieldname>member</fieldname>
    </oneofone_level>
    <oneoftwo_level>
        <fieldname>epc</fieldname>
    </oneoftwo_level>
    <check_Point>
        <BizLocation>urn:epc:id:sgln:0614141.00300.1
    </BizLocation>
        <ReadPoint>urn:epc:id:sgln:0614141.00300.1
        </ReadPoint>
        <Disposition>urn:epcgloal: cbv: disp: processing
        <Disposition>
        <BizStep>urn:epcgloal:cbv:bizstep:inspecting</Biz
Step>
        <event type>object event</event type>
    </check_Point>
</Capture Application Properties>
```

EPCIS Event Generation

Capture application maps the properties and generatesan EPCIS event. The EPCIS event is stored in EPCIS event repository for query request by other applications. A sample of EPCIS object event is shown as the following:

```
<epcis: EPCIS Document
  xmlns:epcis=”urn:epcglobal:epcis:xsd:1”
  xmlns:xsi=http://www.w3.org/2001/XMLSchema-instance
  creationData=”2014-08-01T11:30:47:OZ”
  schemaVersion=1>
<EPCISBody>
  <EventLists>
    <ObjectEvent>
      <EventTime> 2014-08-01T20:9:05:17Z</EventTime>
      <EventTimeZoneOffset> 08:00</EventTimeZoneOffset>
      <EPCList>
        <EPC>
          urn:epc:id:sgtin:8424495807.902.229596491295
        </EPC>
      </EPCList>
      <Action>current</Action>
      <BizStep>urn:epcgloal:cbv:bizstep:inspecting
      </BizStep>
      <Disposition>urn:epcgloal:cbv:disp:processing
      </Disposition>
      <ReadPoint>
        <Id>urn:epc:id:sgln:0614141.00300.1</Id>
      </ReadPoint>
      <BizLocation>
        <Id>urn:epc:id:sgln:0614141.00300.1</Id>
      </BizLocation>
    </ObjectEvent>
  </EventLists>
</EPCISBody>
```

3.3. RFID Warehouse Management

The functions of warehouse management in logistics operations include receiving, storing, picking, and shipping. Based on these five logistics operations, we design a warehouse management simulation.

0illustratesthe layout of warehouse management simulation. The warehouse layout is divided into three areas: receiving area, storage area, shipment Area. The items are received and inspected in the receiving area. Then, they are moved to the storage area. According to the shipment order list, picking operation is carried out in the storage area, and then goods are move to shipment area. A truck will ship and deliver them to destination. In warehouse management system, item information prepare in advanced, such as item description, item number, unit price, EPC. In traditional operation, warehouse manager inspects the number with document. The RFID system will collect the item number and quantity automatically.

Figure 8. *Warehouse floor layout*

In the warehouse management application, we simulate the pallet-in and pallet-out operations to simplify the process of picking and classification.

4. Conclusions

Large-scale application of RFID system implementation requires expensive equipment investment, and will limit the enterprise to adopt practical applications of the RFID system. In this demonstration, we provide various system to allow enterprise simulate their applications before actual deployment of RFID systems.

The logistic operation simulation platform is a set of business processes to simulate a system of RFID application. Users can define different operating environment definition of processes, through a business scenario simulation system to simulate field operations scenarios. Since no hardware set up cost at the physical application site, it can save a lot of cost and reduce the barriers of developing RFID systems.

References

[1] EPC global, "The EPCglobal Architecture Framework Version 1.2," EPCglobal, Inc., 2007

[2] S. F.Wamba, L. A. Lefebvre, and E. Lefebvre, "Enabling Intelligent B-to-B eCommerce Supply Chain Management Using RFID and the EPC Network: A Case Study in the Retail Industry," in *Proceedings of the 8th International Conference on Electronic Commerce*, Vol. 156, pp. 281-288, 2006.

[3] I. Vacca, M. Bierlaire, and M. Salani, "Optimization at Container Terminals: Status, Trends and Perspectives," in Proceedings of the 7th Swiss Transport Research Conference, 2007, pp. 1-21.

[4] G. Miragliotta, A. Perego, and A. Tumino, "RFID Technology in a Container Port: an Activity-Based Model to Assess Costs and Benefits," in Proceedings of the Logistics Research Network Annual Conference, 2007, pp.101-106.

[5] T. C. Lirnand M. S.Chiu, "A Study of the SMART Container Monitoring System in the Ocean Shipping Industry," in Proceedings of the 14th International Symposium on Logistics, 2009, pp. 351–358.

[6] E. H. Frazelle, *World-Class Warehousing and Material Handling*, McGraw-Hill, 2001.

[7] A. Garcia, Y. Chang,A. Abarca, and C. Oh, "RFID Eenhanced MAS for Warehouse Management," International Journal of Logistics Research and Applications , Vol. 10, No. 2, pp. 97–107, 2007.

[8] EPC global. "EPC Radio-Frequency Identity Protocols Class-1 Generation-2 UHF RFID Protocol for Communications at 860 MHz–960 MHz, Version 1.2.0," EPC global, Inc., 2008.

[9] EPC global. "Low Level Reader Protocol (LLRP), Version 1.1,"EPCglobal,Inc., 2010

[10] EPC global, "The Application Level Events (ALE) Version 1.1," EPC global, Inc., 2008.

[11] EPC global, "EPCglobal Reader Management 1.0.1," EPC global, Inc., 2007.

[12] EPC global, "EPC Information Services (EPCIS) Version 1.0.1 Specification," EPC global, Inc., 2007.

[13] EPC global. "EPC global Object Name Service (ONS) Version 1.0.1,"EPCglobal,Inc., 2008.

[14] VeriSign. "VeriSign Discovery Services: Discovery Service Implementation Guide," 2004.URL: http://www.verisign.com/stellent/groups/public/documents/guides/029243.pdf.

[15] EPC global, "Core Business Vocabulary Specification," EPC global, Inc., 2009.