EPC Virtual Lab:
Experiments using an RFID location simulator

Carlos Perdigão[1,2] and Miguel L. Pardal[2]

[1] Link Consulting,
Av. Duque de Ávila, 23
1000-138 Lisboa, Portugal
`carlos.perdigao@link.pt`
[2] Department of Computer Science and Engineering
Instituto Superior Técnico, Technical University of Lisbon
Av. Rovisco Pais 1,
1049-001 Lisboa, Portugal
`miguel.pardal@ist.utl.pt`

Abstract. Radio frequency identification (RFID) is an automatic data capture technology that has great potential to improve business. However, RFID projects have significant up-front costs: buying tags and readers, and installing them in business locations. Until now, a physical deployment was required to properly test RFID software and its integration with existing systems.

This paper describes *EPC Virtual Laboratory* (EPC VLab), a physical world simulation engine, that can be used to feed standard RFID information systems with realistic data. The simulator has proved to be useful for preliminary and exploratory testing.

1   Introduction

Radio frequency identification (RFID) is a technology that can be used to tag physical goods, allowing them to be detected automatically. *Readers* communicate with *tags* using a wireless power and data link [1].

The Electronic Product Code (EPC) framework [2] defines standards for a comprehensive supply chain management system based on RFID. It encompasses tags, readers, data, and information systems.

The working principles of RFID imposes specific requirements and constraints on software [3]. To properly assess them for a specific project, a pilot deployment, at least, is required. This approach implies significant up-front costs: tags, readers, and their proper installation in a business location. All these costs make RFID projects particularly risky, and can steer many companies away for experimenting with the technology.

This paper proposes *EPC Virtual Laboratory* (EPC VLab), a physical world simulation engine, that can be used to feed EPC information systems (EPCIS) with realistic data and test their integration with Enterprise Resource Planning (ERP) systems.

The *deliverable* is the identification of data sources and flows i.e. the "questions" that EPCIS and "ERP" should answer and what data is used to answer them.

2 EPC VLab

EPC VLab is a physical world simulator. Its main purpose is to allow the user to model an RFID location with minimal effort.

In the following sections the logical and physical architectures of the simulator are presented.

2.1 Logical architecture

The logical architecture of the simulator describes the software layers and their responsibilities. Each layer has its own set of possible actions and expected results, as depicted in figure 1.
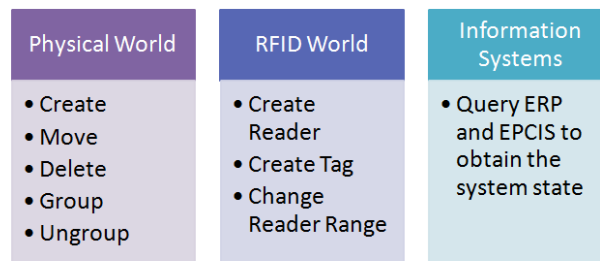

Fig. 1. EPC VLab Logical architecture.

Physical World The user interacts mainly with the 'Physical World', by creating, moving and deleting objects in a command console, shown in figure 2. The user gets feedback from the console and also from a graphics area, where an world representation is kept up-to-date.

Objects can be *aggregated* [4] for transport in boxes, pallets, etc.

RFID World The 'RFID World' layer is where the user can create RFID readers and tags. Each must be associated with an existing object. Moving the physical object moves the RFID entity as well.

Information systems The 'Information Systems' layer is where the (simulated) world is captured and given data representation. Here the user can query the EPCIS, and the "ERP" stub to confirm the correct operation of the whole system.
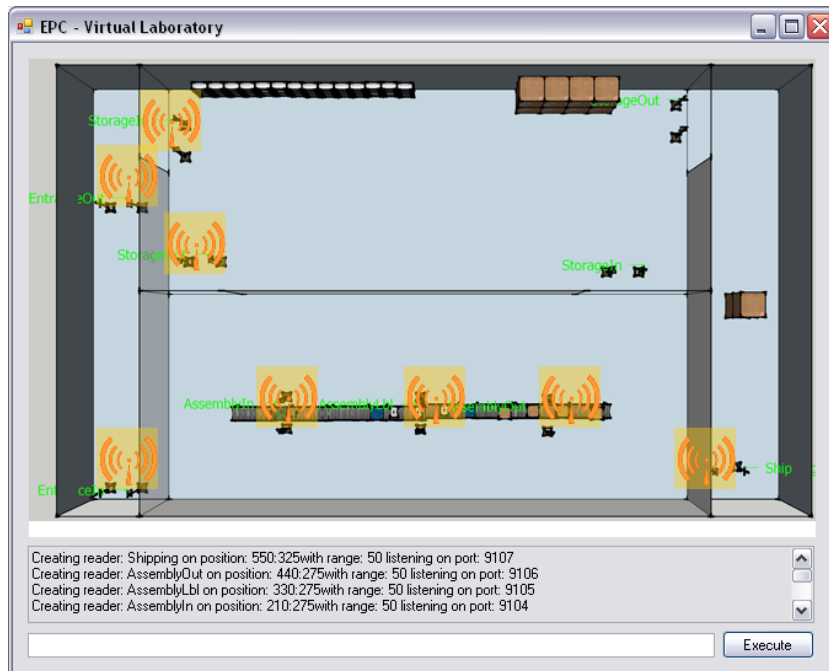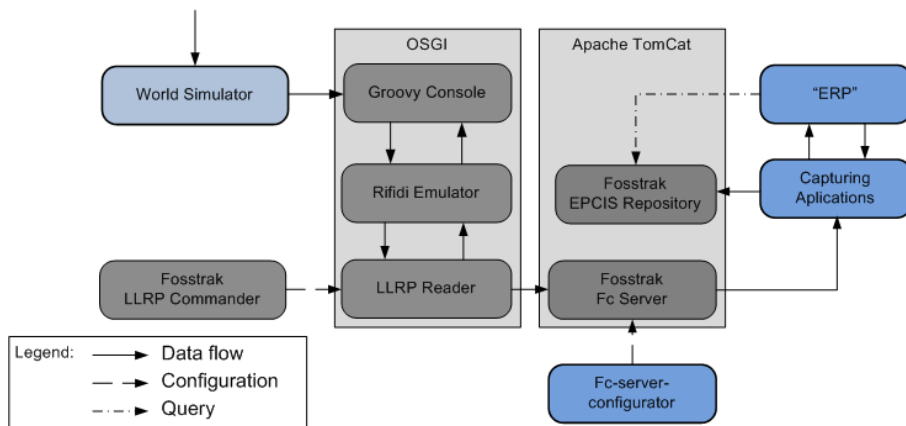
Fig. 2. VLab - Simulator User Interface.

Fig. 3. EPC VLab physical architecture.

2.2 Physical architecture

Figure 3 presents an overview of the physical architecture.

The World Simulator module is the responsible for the interaction with the user by executing the commands that control the objects.

Whenever the command received is related with readers or tags, the World Simulator communicates with the Rifidi[3] Emulator. The Rifidi Emulator is then used to instantiate each reader, and manage the detected tags.

The Fosstrak[4] fc-Server is then configured to periodically consume Application Level Events (ALE) reports from each reader, and deliver them to Capture Applications. The Capture Applications communicate with the "ERP" and EPCIS to obtain context to create a business event and inserted it in the EPCIS.

The "ERP" stub is a Microsoft .Net[5] Web Service.

The Fosstrak LLRP Commander is used to configure each reader once it is deployed.

3 Case study: laptop factory

The case study for the simulator was a laptop factory[6]. The laptop factory's main activity is to assemble components from different parts of the world into a final product. After the laptop is produced, it can be shipped to customers.

A factory's RFID system should be able to track each object inside the factory area, and benefit from automatic stock keeping, automated production and shipping control.

3.1 Modeling

The factory is divided in four areas: Entrance, Storage, Assembly Line, and Shipping. In a normal operation, the components are accepted and checked in the Entrance. After this initial step, all components are taken to the storage area until they are needed for the assembly line. Each laptop is stored after production, until a shipping order is received.

The following table summarizes the areas where the business steps take place:

Entrance	Storage	Assembly Line	Shipping
Unpack	Storage	Prepare components	Pack
Check	Pick	Assemble	Ship
-	-	Test	-
-	-	Pack	-

3.2 Implementation

Figure 4 is a graphical representation of the virtual factory, with all the readers identified.

---

[3] `http://ridifi.org`

[4] `http://www.fosstrak.org/`

[5] `http://www.microsoft.com/NET/`

[6] The case is based on an actual product, but the factory is fictional.

Fig. 4. Test Case - Factory Plant.

The first chosen reader position was the organization border, the place where the components enter (EntranceIn), and the exit where laptops leave (Shipping). After this on the storage area we created two gates for components/laptops storage (StorageIn), and another two gates for components/laptops picking (StorageOut). The remainder readers cover specific points on the factory, such as the product checking entrance (EntranceOut), the entire assembly line (AssemblyIn/AssemblyLabel/AssemblyOut).

Each reader has an IP port in the range [9100,9200] and an associated capture application (running at ports in range [9000,9100]). Finally we considered an EPCIS running on endpoint: /factory-epcis/ and a simplified version of an "ERP", that would return the dynamic information of the results processed by the capture applications.

3.3 Findings

The following table summarizes the findings using simulations. It contains the business questions that the laptop factory RFID system needs to answer, and which system holds the data required for the answer: EPCIS or "ERP".

Business Question	Case requirement	EPCIS	"ERP"
When was the item produced?	No	Yes	No
What is the bill-of-materials of the product?	Yes	Yes	Yes
What is the history (trace) of detections ?	Yes	Yes	No
By which partners did the item pass?	Yes	Yes	No
How many modifications did the product suffer?	No	Yes	No
What is the object state?	Yes	Yes	No
Who modified the product?	No	Yes	Yes
Was the object consumed or destroyed?	No	Yes	No
What is the most likely future position of the object?	No	Yes	Yes

4 Conclusion and future work

This paper described the implementation of EPC-VLab, an RFID location simulator, capable of representing the physical world, and supplying tag read data to an EPC-compliant information system. The simulator proved useful to analyze the "laptop factory case study": system limitations, the position and range of readers, information written on tags, and all the configurations needed to deploy the system.

The next stage in development is to simulate more than one location. The idea is to ultimately represent a complete supply chain, and to identify requirements for a discovery service, to support the creation of federations of business partners that share business data. The simulation of errors in the multiple layers will be extended to further explore RFID constraints. The validation of EPCIS and "ERP" systems will have automatic assertions rather instead of manual inspections.

References

1. K. Finkenzeller, *RFID Handbook: Fundamentals and Applications in Contactless Smart Cards and Identification*, 2nd ed. John Wiley & Sons, Ltd, 2003.
2. K. Traub, F. Armenio, H. Barthel, L. Burstein, P. Dietrich, J. Duker, J. Garrett, B. Hogan, O. Ryaboy, S. Sarma, J. Schmidt, K. Suen, and J. Williams, *The EPCglobal Architecture Framework 1.2*, GS1 Std., 09 2007. [Online]. Available: http://www.epcglobalinc.org/standards/architecture/
3. C. Floerkemeier, C. Roduner, and M. Lampe, "RFID application development with the Accada middleware platform," *IEEE Systems Journal, Special Issue on RFID Technology*, 12 2007. [Online]. Available: http://www.fosstrak.org/publ/FosstrakIEEESystems.pdf
4. BRIDGE, "Requirements document of serial level lookup service for various industries," University of Cambridge and AT4 wireless and BT Research and SAP Research and ETH Zurich and GS1 UK, Tech. Rep., 08 2007.

Acknowledgments