Association for Information Systems
AIS Electronic Library (AISeL)

BLED 2007 Proceedings | BLED Proceedings

2007

Mobile RFID Management – An Application Scenario on the Handling of Industrial Liquid Containers

Goetz Botterweck
Lero – The Irish Software Engineering Research Centre University of Limerick, goetz.botterweck@lero.ie

J. Felix Hampe
Institute for IS Research University of Koblenz-Landau, hampe@uni-koblenz.de

Sven Westenberg
Institute for IS Research University of Koblenz-Landau, westi@uni-koblenz.de

20th Bled eConference
eMergence:
Merging and Emerging Technologies, Processes, and Institutions
June 4 - 6, 2007; Bled, Slovenia

Mobile RFID Management – An Application Scenario on the Handling of Industrial Liquid Containers

Goetz Botterweck

Lero – The Irish Software Engineering Research Centre
University of Limerick, Ireland
goetz.botterweck@lero.ie

J. Felix Hampe and Sven Westenberg

Institute for IS Research
University of Koblenz-Landau, Germany
{hampe|westi}@uni-koblenz.de

Abstract

This paper deals with concepts, challenges and design alternatives for the application of RFID technology within an industry context. We are especially interested in the combination of RFID technology with positioning information and mobile networks. To discuss these topics, we introduce an application scenario concerning the handling of industrial liquid containers along an integrated supply chain. First we describe the traditional approach and some of the problems involved with it. We then contrast this with an improved process using RFID technology. The scenario is augmented by a discussion of an appropriate application prototype. This paper thus contributes to the debate on RFID and highlights the challenges of integrating various mobile technologies in order to efficiently support supply chain processes.

Keywords: RFID, Supply Chain Management, Industrial Liquid Containers

1 Introduction

In recent years, numerous technologies have emerged from the research area of Ubiquitous Computing (UC). Many of these technologies have the potential to be used in an industry context (Fleisch, 2001; Fleisch et al., 2003). For instance, mechanisms like Radio Frequency Identification (RFID) (Strassner, 2005; Weinstein, 2005) and GPS-based positioning devices offer interesting possibilities in logistics and supply chain management. For a broader overview of RFID see (Auto-ID Center, 2002; Finkenzeller, 2003).

From the many RFID application scenarios which can be considered, we are going to further investigate and discuss one particular scenario which, in our opinion, offers a large potential for process optimisation in practice. The application scenario is based on current research by the authors undertaken in conjunction with a world market leader in the production of industry liquid containers.

From a methodological perspective our research approach can be considered as IT-Engineering, which delivers preliminary results and an IT-artefact for a Design Research study (Vaishnavi & Kuechler, 2007).

The rest of the paper is structured as follows: In Section 2 we discuss the application scenario involving the management of industrial liquid containers. In Section 3 we present a prototype solution illustrating some implementation aspects for this application scenario. We finish with a discussion of other, more general experiences and considerations relevant for future RFID projects.

2 Application Scenario: Handling of Industrial Liquid Containers

For the following discussion we will employ a real world application scenario, which covers logistic processes for industrial liquid containers. These containers facilitate the transport and storage of liquids in amounts of about 600 to 1200 litres and are used primarily in the chemical industry. A typical process chain involves the following parties:

- a **manufacturer** of industrial liquid containers
- a **filler,** who fills up the containers with a liquid that he or somebody else produces
- one or more **emptiers**, who extract liquids from containers as input for further production processes
- a **reconditioner**, who cleans and prepares used containers for reuse or recycling (in the present case, this participant is identical to the manufacturer)
- one or more **forwarders**, who transport the filled and empty containers

2.1 The Traditional Approach

In the traditional approach the usage of containers is supplemented with information exchanged by telephone or fax. It would also be possible to communicate information via Electronic Data Interchange (EDI). However, the identification would then still be based on barcode labels.

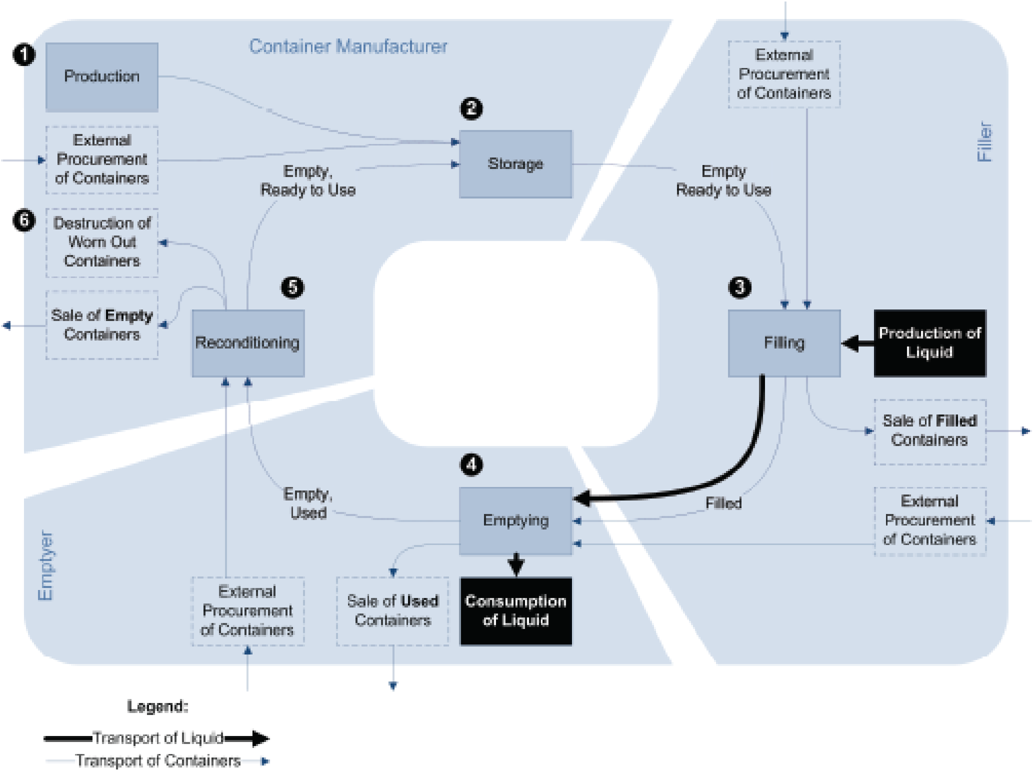

Figure 1: Overview of the process circle

Since containers can be used several times, the overall process is organized as a circular chain (Figure 1):

- After production ❶ a container is put into an interim storage ❷.
- The usage of a container is initiated by the filler who orders empty containers by telephone, fax or EDI. The manufacturer then sells containers to the filler (instead of leasing them) and charges for delivery.
- Similarly, an emptier orders filled containers from the filler. During the filling process ❸ the product name of the particular liquid is stuck on the container both as clear text label and as a barcode.
- After delivery of the filled containers the emptier ❹ extracts the liquid. The emptied containers are put into interim storage. When a certain threshold number is reached, the emptier sends a fax to the reconditioner asking for the pick-up of the containers, which usually happens within 30 days and is free of charge for the emptier.
- A container is then reconditioned in a special process ❺. Depending on its current state and its previous filling, a container is either scrapped, repaired or cleaned. Unless it was scrapped, it is then stored ❷ and sold as a reconditioned empty container.

The process is semi-open in the sense that only parties involved in a particular supply chain can take part (closed). As these supply chains change or are extended, other parties can also join the system (open). It is also possible to sell or procure containers to or from parties outside the circular supply chain, for instance by selling an empty container after reconditioning. However, this is an exceptional case.

2.2 Problems with the Traditional Approach

The described circular process in its current form is faced with the following problems:

- **Optimal logistics are lacking.** The forwarders often have to undertake oneway transports or drive with half-empty trucks.
- The **identification of liquids** is difficult. Labels and barcodes are hard to read, pasted over or missing, which complicates the reconditioning process. Since liquids can be highly toxic or possess other dangerous properties, combined transport may have to be omitted.
- There is **no tracking** of a container over its **full life cycle** with a unique identifier. For instance, it would be helpful to get more information on all previous fillings, all parties who handled this container, the reconditioning cycles, and any previous problems with this container.
- The process involves many **manual steps and media breaks.** For instance, the interpretation of the pick-up request at the reconditioner's site and the associated determination of fillings is prone to ambiguities and errors.
- **Additional emptied containers** cannot be announced. Due to the time span between the pick-up request and the pick-up itself, there are often some containers which were not listed, but are now due for transport. Hence, it is hard to forecast the transport space required, and the reconditioner is not aware of these additional containers until they arrive.

2.3 Enhancement of the Traditional Approach by the Introduction of RFID Technology

The main interest of the research project presented here is to improve the traditional container handling processes by the introduction of RFID technology integrated with positioning devices and mobile communication networks.

Each container is outfitted with an RFID tag during production. This enables the unique identification of the container over its full life cycle. In contrast to visual identification, such as barcode labels, reading out information via radio transmission is more efficient in automated processes. A container record is simultaneously created, which augments the raw identification with additional information such as a history of usage. To make use of this, however, all involved parties must record container-related events and associated information. For instance, during production the manufacturer records the production date, the capacity in litres, the tare weight and other features of the container; during filling the filler records information on the particular liquids and so on. All recorded events can be augmented with qualitative location data ("at country A, city B, company C, production site D, gate #X"), quantitative location data (GPS coordinates) and timestamps.

Even for steps where the container is not involved physically, the container data can be used to semantically enrich the communication. For instance, for a pick-up request, the emptier can simply transmit the data of all containers waiting for transport. Since the relevant data is already available in digital form, it is easier to implement electronic communication (EDI) so that the information arriving at the reconditioner's office is more current and less error-prone.

2.4 Goals and Requirements

During the planning and conception of the project covered by this application scenario, the following business goals were identified:

- **Increased transparency** of the process. This should be realised by increased availability of information about containers and liquids.
- Increase **awareness of opportunities** for improvement. For instance, it is easier to identify forwarders with a high rate of damaged containers or analyse quality problems caused by improper handling of containers.
- Higher **quality of collected data** and improved efficiency of the overall process. This should be accomplished by the substitution of paper communication via EDI and the consequential reduction of ambiguities and errors.
- The opportunity to **transmit relevant data to external parties,** such as customs, transport police, tax and environment authorities.

To reach these business goals, the following technical requirements were identified:

- **Assign unique identifiers to containers.** The handling of the identification in practice should be as efficient as possible. For instance, it is desirable to identify incoming containers at the receiving area in a fully automatic or at least semi-automatic way.
- **Augment the raw identification with additional data**. This can be done by either storing data in the tag itself or by logically connecting the identification with databases (see section 2.6).
- **Establish quality criteria** and **evaluate suitability for an industrial environment**. The hardware components and software systems selected or developed for this project have to fulfil criteria such as reliability, safety, and maintainability (ISO, 2005).
- **Select specific RFID technology** with respect to its applicability for the usage in proximity to liquids and metal containers.

In addition to these business goals and technical requirements we have to consider the following aspects:

- The **long term perspective** and yield of the proposed system, e.g. return on investment, flexibility, integration with (the systems of other) companies, protection of investment by standardised components and procedures (see 2.6 below).
- Security, data privacy, and protection against industrial espionage.

2.5 Implementation and Runtime Dependent Challenges

The proposed introduction of RFID technology implies numerous challenges and research questions:

- All parties involved in the supply chain have to use the new technology and modify their business processes accordingly.
- Storage and management and ownership of the data collected and processed during the container handling must be clarified.
- How does the business model work? Who pays for the investment in new processes and technology? Should this be included in the price of a container?
- Who benefits from the return on the investments in the long run?

- How should the right technologies be chosen – especially with a long-term strategy? What is the role and maturity of present standards? Which standards will prevail in the long run, observing strong market forces in other massapplication areas?

2.6 Architectural Decisions and Implications

Depending on architectural design decisions there are two options for storing the container-related information:

- **Alternative 1 – Information in the tag.** If the RFID tag holds most of the information, anyone who handles the container could directly access this information without a network connection to additional databases. However, this also means that anyone in the proximity of the container can potentially read or modify the information. Hence, we have to prevent access by unauthorized persons in order to prevent industrial espionage or other abuse (Weis et al., 2004). It is impossible to initiate a data update from a centralised server towards containers. With this design it is also much harder to change or extend the data model of the overall application, since the data in the tags of most containers is not accessible from a centralised server.
- **Alternative 2 – Information in a centralised database.** If the information is stored in a centralised database, the tag only identifies the container. Access to the information can then be controlled by security mechanisms for distributed applications, such as encryption, passwords or certificates restricting access to a web service providing container-related functions. Besides the actual access control, this also enables the monitoring of the correct usage of the application by all involved parties (e.g. to enforce business rules).

  The centralised nature of a database also eases the extension of the data model during the evolution of the technological project which introduces the usage of RFID technology.

  On the other hand, a centralised architecture requires network access to the server by anyone who wants to read or update information about a container.

These alternatives are summarized in Table 1.

Where is the information stored?	Alternative 1: In the tag	Alternative 2: In a centralized database
Advantages	No network access necessary during handling of container	Possible to do centralized update Evolution of data model easier to implement Monitoring of usage / enforcement of business rules easier
Disadvantages	Potential access to all data from the proximity of the container (can be a security problem) Centralized update impossible Evolution of data model difficult Monitoring of usage / enforcement of business rules difficult	Requires network access during handling of container
Protection by	Encryption of tag content	Security mechanisms for distributed systems / web services applied to DB access

Table 1: Alternatives for the storage of container-related information

3 Description of an Application Prototype

We designed and implemented a prototype in order to provide an additional foundation for the discussion of the application scenario. The industrial project partner is currently starting a large scale realisation based on the results of our prototype development.

3.1 Architecture

The general architecture of the prototype consists of four subsystems as shown in Figure 2: a mobile front-end (❶), a desktop front-end (❷), various networks (❸), and a back-end (❹). These subsystems are described in the next sections in more detail.

3.2 Back-End

The façade (Fowler et al., 2002) of the back-end, as seen by the front-ends, is provided by a web service (🕚 in Figure 2), which is implemented on top of a standard web server.

This web service offers a single point of centralised access to all data and functionality required by the front-ends. Firstly, it handles domain-specific data stored in a relational database system. This includes, for instance, the container records. Each of these records stores all the data and history information related to a particular container. Secondly, the web service can be integrated with an enterprise resource planning (ERP) system to inform this system about business events, such as the arrival of a new container.

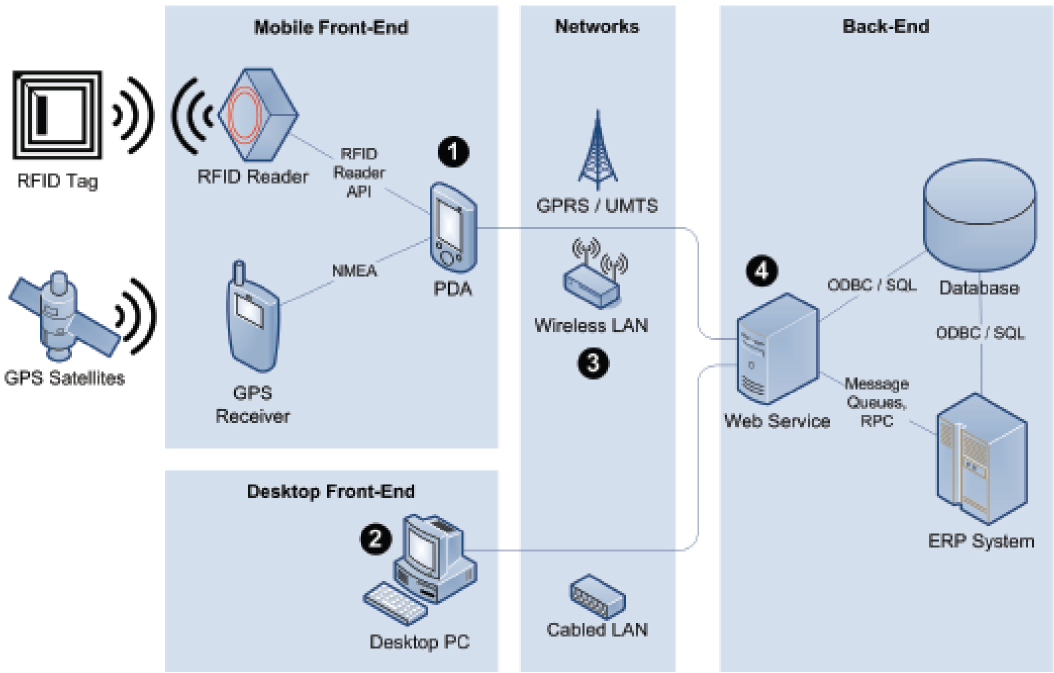

Figure 2: Architecture of the Application Prototype

3.3 Mobile Front-End

The mobile client application running on a PDA (❶ in Figure 2) provides the mobile access to the functionality of the overall application. The PDA is extended by a RFID reader and a GPS receiver. For the prototype we decided not to use a fully integrated system, and instead use a combination of separate devices. The RFID reader and the GPS receiver are connected to the PDA as a CF-Card or via Bluetooth respectively. This enables us to evaluate different hardware and software variants with relatively low setup costs.

This mobile front-end can be used by all personnel to record events for any container. By using the RFID reader each piece of information is automatically associated with the correct identification of the container. Using the GPS receiver, the application records GPS coordinates if available. These can be augmented with qualitative location information (“at production site A, gate 1”).

3.4 Desktop Front-End

The desktop front-end (❷) enables stationary access to the same functionality, but offers more screen space to give the user a better overview of complex situations or long lists of data.

3.5 Communication and Security

The communication between the front-ends and the back-end is implemented by various networks:

The communication between the mobile front-end and the back-end is over wireless networks (❸). Depending on availability, we can switch between GPRS/UMTS access with almost global coverage and wireless LAN access with higher bandwidth and lower costs.

The desktop front-end is usually connected over cabled LAN, but nothing stops us from using a laptop connected by wireless LAN, resulting in a somewhat semimobile" front-end.
Regardless of the network used, the communication is secured by typical security mechanisms for web services such as HTTPS (Rescorla, 2000) and WS-Security (Nadalin et al., 2006).

4 Further Aspects of RFID Projects

Following a detailed requirement analysis, a market screening for appropriate devices and technologies (including standardisation issues), a specification of a process solution and its prototype implementation, the next logical step is be a pilot project. As this is currently under way and controlled by the industrial partner, it will take some time before results relevant to our research become available. Thus some intermediate insights are presented here, which can be of generic relevance for similar projects and the discussion in general.

4.1 RFID Projects are Complex

The decision whether to introduce RFID depends on many application-specific factors, such as:

- The cost savings potential
- The structure and stability of the supply-chains between the involved parties
- The granularity and number of the objects to be identified (1000 litre liquid containers vs. pencils)

Hence, whether to introduce RFID and in which form cannot be answered in general, but has to be assessed for every industry or application-scenario.
Additional complexity is caused by the fact that such application scenarios usually involve multiple organisations. In the end, an RFID application is just another form of an inter-organisational system. The involved parties, e.g. along a supply chain, often have varying technological infrastructures and can have conflicting business goals with respect to the introduction of RFID and the necessary changes in processes and technical systems. For instance, one of the parties involved might become superfluous due to the reorganisation of logistic processes. These complex structures lead to multiple challenges, for instance (Yang & Jarvenpaa, 2005):

- If one organisation in a supply chain is interested in introducing RFID technology, it is not certain that its business partners share this interest.
- It is hard, if not impossible, to predict the efficiency improvements and cost savings in advance. The same is true for the distribution of this "return on investment" between the involved parties; consequently, it is hard to decide who should pay for the necessary investments.

4.2 Standardisation Required

Although there are emerging standards (Walk, 2006), during the hardware evaluation and analysis of alternatives for the prototype's architecture, it became evident that, the insufficient standardisation and the missing availability of standardized hardware and software components are major challenges to the success of RFID projects.

This is not too much of a problem as long as one can use commercial off-the-shelf (COTS) devices. However, if additional flexibility is required, for instance when RFID technology is to be integrated with other components, additional standardisation is desirable to increase the flexibility, and allow us to combine hardware and software components into an application-specific solution (Westenberg, 2006).

Moreover, one can expect that standardisation along with the implied substitutability leads to an increased flexibility in purchase decisions and, in the end, to decreased prices for RFID components.

4.3 Mobile Approaches

From our point of view, some of the most interesting RFID application scenarios become possible when RFID technology is combined with mobile networks and positioning approaches.

However, the main difference between mobile and stationary approaches does not lie in the technology, but in the processes and the flexibility that becomes possible with mobile approaches.

4.4 Security

One further aspect, which we could only touch on in this paper, is the security challenge that emerges by the introduction of RFID. For instance, the raw tag IDs are usually not encrypted and much easier to read from a distance than barcodes.

Other security questions arise if we consider that multiple parties with conflicting goals are involved in an RFID-enabled logistic process. Who is authorized to read or modify which information? Who “owns” the information and decides who has access – including the option to completely shut out a previously involved party?

5 Conclusion

We are strongly convinced that a wide area of innovative application scenarios will emerge in the near future due to the combination of RFID and mobile communication technology.

However, based on the experience gained from the design and evaluation of our IT-artefact (prototype solution), we conclude that the missing standardisation of hardware and software components remains one of the main challenges during the development of RFID applications. This becomes even more evident if we compare the current state of RFID technologies to the level and maturity of worldwide standardisation in areas such as GSM or WLAN (IEEE 802.11).

On the other hand, the existent broad literature base on RFID as well as our research experience not surprisingly indicates that the success of RFID projects will strongly depend on well-specified process models, data models and most importantly on well understood integration along technical and organisational dimensions.

References

Auto-ID Center, (2002). Technology Guide, Auto-ID Center White Paper.

Finkenzeller, K., (2003). "RFID handbook : fundamentals and applications in contactless smart cards and identification", Wiley, Chichester, England ; Hoboken, N.J.

Fleisch, E., (2001). Betriebswirtschaftliche Perspektiven des Ubiquitous Computing, "Information Age Economy", pp. 177-191, Physica-Verlag, Heidelberg, Germany.

Fleisch, E., Dierkes, M., & Kickuth, M., (2003). Ubiquitous Computing: Auswirkungen auf die Industrie, Industrie Management, Vol. 2003, No. 6, pp. 29-31.

Fowler, M., Rice, D., Foemmel, M., Hieatt, E., Mee, R., & Stafford, R., (2002). "Patterns of Enterprise Application Architecture ", Addison Wesley, Reading, MA, USA.

ISO, (2005). ISO/IEC 25000:2005 Software Engineering -- Software product Quality Requirements and Evaluation (SQuaRE) -- Guide to SQuaRE, ISO/IEC, Geneva, Switzerland.

Nadalin, A., Kaler, C., Monzillo, R., & Hallam-Baker, P., (2006). Web Services Security: SOAP Message Security 1.1 (WS-Security 2004). http://docs.oasis-open.org/wss/v1.1/

Rescorla, E., (2000). RFC2818: HTTP Over TLS, IETF. http://tools.ietf.org/rfc/rfc4346.txt

Strassner, M., (2005). "RFID im Supply Chain Management -Elektronische Daten Auswirkungen und Handlungsempfehlungen am Beispiel der Automobilindustrie", Deutscher Universitäts-Verlag, Wiesbaden, Germany.

Vaishnavi, V., & Kuechler, B., (2007). Design Research in Information Systems. http://www.isworld.org/Researchdesign/drisISworld.htm

Walk, E., (2006). RFID Standards 2006, "ident Jahrbuch 2006", pp. 54-61

Weinstein, R., (2005). RFID: A Technical Overview and Its Application to the Enterprise, IT Professional, Vol. 7, No. 3, pp. 27-33.

Weis, S. A., Sarma, S. E., Rivest, R. L., & Engels, D. W., (2004). Security and Privacy Aspects of Low-Cost Radio Frequency Identification Systems, Security in Pervasive Computing, pp. 201-212.

Westenberg, S., (2006). Integration mobiler RFID-Erfassung in das Supply Chain Management, University of Koblenz-Landau, Koblenz, Germany.

Yang, G., & Jarvenpaa, S. L., (2005). Trust and Radio Frequency Identification (RFID) -- Adoption within an Alliance HICSS ’05 - Proceedings of the 38th Annual Hawaii International Conference on System Sciences - Track 7, p. 208.201.