Real-Time Traceability and Intelligent Product Management in the Supply Chain

Taxiarchis Belis, Stelios Tsafarakis and Anastasios Doulamis

Dept. of Production and Management Engineering
Technical University of Crete
Chania, Polytechnioupolis Campus, Greece

Abstract. In this paper we present an architecture that provides enterprises with the opportunity to apply a low cost traceability system which allows for the complete transparency of products in the supply chain. The proposed traceability system uses the RSS 2.0 format, while a product classification ontology is developed in order to enable intelligent product management. The above technologies are incorporated into an RFID architecture. The deployment of RFID technology in the supply chain is expected to increase significantly the amount of product data, raising the need of adoption of an effective ontology-based model for intelligent product information management.

1 Introduction

According to the European Community regulation (EC regulation 178/2002) from the 1/1/2005 all enterprises that deal in any way with the foods and drinks industry are compelled to implement reliable track and trace systems.

Traceability can be defined as “The ability to follow (in real time) or reconstruct (off-line) the logistic route of singular or compound products” [10].

The benefits of traceability concern the consumer’s safety as well as the complete transparency and automation of the supply chain, which cannot be adequately addresed with existing technology. In our study we focus mainly in the foods and drinks sector, since this sector appears to be more complex in implementing track and trace systems, due to the several complex procedures involved [11].

The supply chain can be defined as “A web of autonomous enterprises collectively responsible for satisfying the customer, by creating an extended enterprise that conducts all phases of design, procurement, manufacturing, and distribution of products” [2]. Supply chain can be considered as a collaboration among different enterprises. Critical factors for an effective collaboration constitute the coordination and synchronization between the processes and operations of all the actors along the chain. Technology limitations may put in danger the success of the above synchronization.

Several years ago, it was common to encounter problems of tracking certain items as they physically moved from one point to another in the supply chain. Some did not originally get shipped out due to a back order, an order cancellation, or a failure to pass quality inspection. Others got lost, stolen, or misplaced during the transport.

Belis T., Tsafarakis S. and Doulamis A. (2009).
Real-Time Traceability and Intelligent Product Management in the Supply Chain.
In *Proceedings of the 3rd International Workshop on RFID Technology - Concepts, Applications, Challenges* , pages 91-102
DOI: 10.5220/0001996300910102

Some were found improperly configured or packaged, or to have missing parts or inadequate data sensitivity labels when they arrived at a distribution center. Others got damaged, recalled or spoiled during their transport to final destinations. Items that were cannibalized, discontinued, or returned were not properly recorded into the system. Under these circumstances, excess, idle, and duplicate items piled up in the warehouse. Problems of tracking over-shipped, under-shipped, user-dissatisfied, and wrong items occur almost on a daily basis.

In this work we propose RFID (Radio Frequency IDentification) as an efficient solution to the above problems. This technology enables the complete real-time traceability in each point of the supply chain. Unlike bar-coded labels, RFID tags can include information on where in the supply chain the packages, items, and pallets were physically moved, how they were tracked, and when the tracking took place at each point of the chain. RFID tags for a case hold a wider range of data about the product and the manufacturer than the tags for individual items. This saves the time and cost required for opening the case, taking out each product to read its label, putting back the products, and repacking the case, as the pallets move from one end to another in the supply chain.

As mentioned before, systems like this handle enormous amounts of information. This requires the incorporation of an ontology that will provide the user with useful feedback. For example if there is lack of stock in a certain product category in the warehouse, the system should have the ability to know all the products that are unavailable without the use of the product database.

2 Related Work

The authors of [13] have proposed a RFID-based Material Tracking Information System. However their research specializes in internal traceability (factory bounded). In addition the system doesn't work with bar-code data. The system that we propose works with bar-code data as well as RFID. In this case real-time traceability is really impractical due to bar-code technology limitations, but the proposed system is still functional.

Only one extended research is directly related to the ontology-based products and services classification. The UNSPSC [9] is an open, global, multi-sector standard for efficient, accurate classification of products and services, available for use free of charge. However UNSPSC is a broad general purpose ontology. The ontology we have developed specializes in particular brands in a certain supply chain. Thus it can be directly incorporated into a particular management information system.

There is also only one proposal concerning RSS-based product information [7] which is not relevant with traceability applications. In this paper we propose an RSS format that specializes in product tracking. Then we integrate this information into a RFID architecture in order to track (real-time) and trace (off-line) the product flow.

Finally there is one research in an ontology-based product tracking system [4]. However ontology and agent deployment premises common set of protocols, language and common ontology all over the supply chain. Thus there is lack of standardization. Also the above system architecture does not use RFID technology which is the key for real-time tracking.

3 Technologies Used

This section briefly describes the main technologies used in the proposed system.

3.1 RSS (Really Simple Syndication)

For efficient product description we need an XML-type document which will be used in transmitting product data according to the system architecture. XML gives us an incentive to describe product information semantically [7]. Any time the product XML is updated, generated or deleted, the system can log the information, which is the key for implementing traceability purposes.

Suitable vocabulary for structured representation of product data (XML) can be used in case of closed systems such as B2B merchandising. A common practice in these cases is the adoption of EDI protocols, which are quite expensive. However, if we use the web to transmit the RSS Feeds, the above cost can be minimized. In case of large-scale systems such as the supply chain, a product cannot be recognized semantically without standardization of vocabulary. The solution is given by RSS.

RSS 2.0 is one of standardized XML. All RSS files must conform to the XML 1.0 specification, as published on the World Wide Web Consortium (W3C) website [1]. The complete RSS 2.0 specification can be found at Harvard Law for internet technology [12].

3.2 Ontologies

Ontologies are used to capture knowledge about some domain of interest. An ontology describes concepts in the domain and also the relationships that hold between those concepts. Standardized ontologies for many disciplines are now being developed, which domain experts can use to share and annotate information in their fields. Ontologies on the Web range from categorizations of products and their features (such as on Amazon) to large taxonomies categorizing web sites (such as on Yahoo).

Usually the main reason for developing ontologies is for sharing common understanding, structured information among software agents. For the purpose of our project we developed an ontology in order to describe the relationships among different products of different classes. This will provide the user with the ability to query the ontology and receive certain useful responses. For example, assume that we have a retail-store, and there is lack of stock of a product. With the use of the ontology, the system is able to propose to the user a variety of similar products of different brands and classes.

3.3 Radio Frequency IDentification

RFID technology enables the optimization of multiple business processes. This can be done through the improvement and the automation of existing processes, and the emergence of new processes called intelligent or smart processes, which are automatically triggering actions or events.

A RFID system consists of three parts: radio frequency (RF) tags, RF tag readers and the middleware which in most cases is a savant server. RF tags consist of a microcontroller and an antenna (either wire or printed using conductive carbon ink). Readers interrogate tags for their contents through the RF antenna and pass the data to the servers net for further filtering and processing. Most RFID devices work in Industrial-Medical-Scientific bands which are freely available for use by low power, short-range systems [6], [8].

Barcode-based identification mechanisms are being replaced all over the world by RFID, as communication between a reader and a tag is not limited by the requirement of ‘‘line-of-sight’’ reading. In addition, unlike barcode, each RFID tag has a unique ID called EPC (Electronic Product Code).

3.4 Savant Servers

Savants are servers running Savant software in a Unix-type operating system or, if the RFID data streaming is not too overwhelming, a Windows platform server. This kind of server can control all the readers at one, or all the mini savant servers which process and filter information from a particular area in the supply chain. Savant servers allow customized filters to fix incorrect or duplicate data, monitor for event changes, log data into a database or remote servers, and send alerts to the intended recipients [5].

Protocols such as RS-232, RS-485, TCP-IP, need some sort of data management system in order to effectively cooperate. Unified servers are savants customized to receive all the different data between readers. Those servers can convert all data signals to Ethernet. We chose Ethernet because it offers the ability to multiplex up to 900 readers at a time, whereas protocols such as RS-232 allow only one. Furthermore, Ethernet can travel 100m, whereas RS-232 fails after about 5-10m.

4 Implementation Model

4.1 System Architecture

To deal with the product information management and real-time traceability we designed a system which consists of a typical RFID architecture integrated with the main product management system (Figure 1).

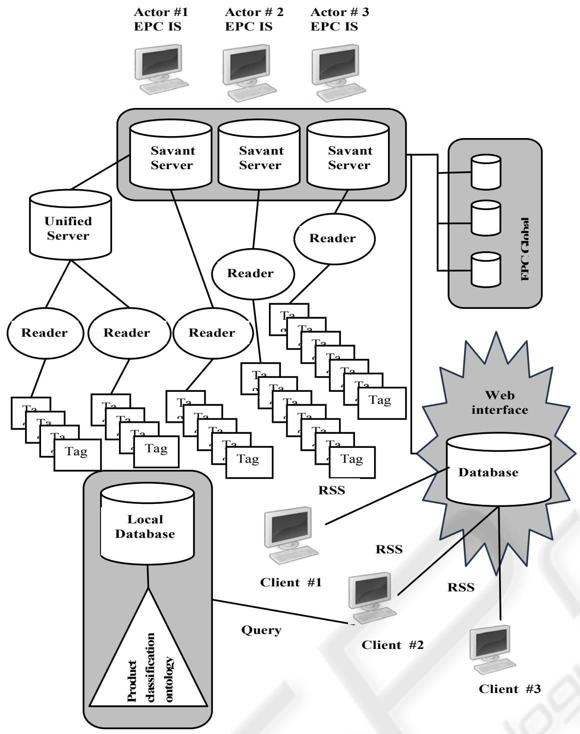

Fig. 1. RFID system architecture for real time traceability and intelligent product management in the supply chain.

The system works as follows:

1. Tags pass their EPC into the readers.
2. Readers pass the data to the unified savant servers (if readers support same protocols then skip step 2).
3. Readers pass the data to the savant servers.
4. Each actor's EPC Information System passes the data into the EPC Global and a central web interface that contains a database.
5. When the web server receives an update ping (new product add or product place status update) automatically generates an RSS Feed which contains the updated product information.
6. Each client that is subscribed to the product channel automatically receives the generated RSS Feeds.
7. RSS Feed aggregator stores Feeds into a local database for further processing.
8. Client's information system processes the Feeds in order to provide the real-time downstream traceability information and keeps a product history in order to provide off-line upstream traceability information.
9. Client's information system queries the product classification ontology. The ontology gives a feedback of certain information that allows user manage products efficiently.

In the next paragraphs we will describe some of the elements of the above architecture.

4.1.1 Web Service Implementation

The web interface was developed with use of PHP 5.2.0 and MySQL 5.0.27. The web service runs on Apache 2.2.3 server. It consists of a central login page that supports 128-bit encryption for maximum security, the central database and an RSS Feed generator. The feeds are generated from database fields of the updated products.

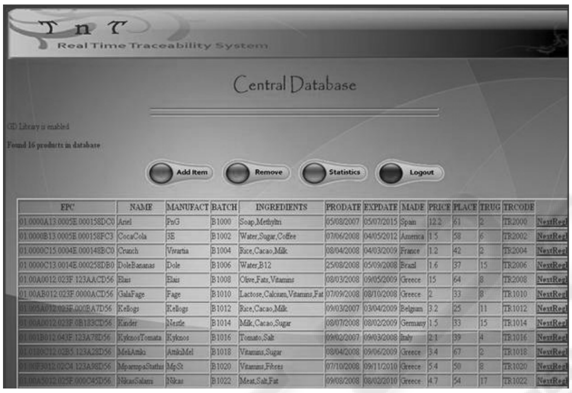

Fig. 2. Central product database.

The server is integrated with an on-line processing system that provides statistics such as portage percentage, traceability system usage and manufacturer unreliability. The system queries the central product database, processes the results and displays them in several chart types. The charts are generated with use of Fusion Charts software that is embedded in the web interface.

4.1.2 Client Implementation

The client is developed with the use of Visual Basic 2008, SQL server 2005 and XML 1.0. It consists of an RSS Feeds aggregator, a local database and a product classification ontology. The aggregator is responsible for reading the Feeds and storing them into the database.

The system primarily categorizes products according to their plant of origin. When a certain product is selected, the user can see the current location of the product in the supply chain, the product name and its ingredients, as well as the product location history. When a certain place of a product is selected the user can see the exact date and time that this product was located in this particular place. All the required information is being retrieved from the central database (Figure 2). A mini web browser connected with the web interface is also available (Figure 3). This provides the user with real-time feedback of the statistics and the database status. Finally the user has the ability to classify products according to the category they belong to or according to the attributes of the ontology.

Fig. 3. Client for real-time traceability and intelligent product management.

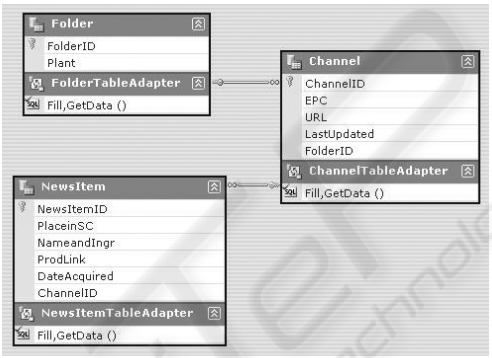

Fig. 4. Client dataset.

The client retrieves data from the web interface through RSS Feeds. In order to receive the HTTP retrievable RSS Feeds the client does the following:

1. Sends a web request to the specified RSS URL.
2. Gets response of the RSS Feeds stream.
3. Stores Feeds temporarily.
4. Converts response data into XML Document.
5. Loads the XML.
6. Reads the specified items.

Further processing of the generated XML involves LINQ. The LINQ Project is a codename for a set of extensions to the .NET Framework that encompass language-integrated query, set, and transform operations. It extends Visual Basic with native language syntax for queries and provides class libraries to take advantage of these capabilities. In this project LINQ is used to query the complicated XML that describes the ontology.

Once we read the feed we need to store the received information into the local database. For data representation the client uses the dataset illustrated in Figure 4.

4.1.3 Ontology Development

A precisely defined product terminology, relevant for linking and classifying product information, can enable accurate information integration in the enterprise.

In order to build the ontology we used OWL [3] and Protégé 4.0 beta editor. OWL is the most recent development in standard ontology languages and has been developed from the World Wide Web Consortium (W3C). Protégé OWL is based on a different logical model which makes it possible for concepts to be defined as well as described.

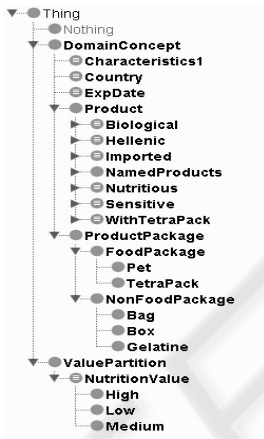

Fig. 5. Inferred product classification ontology.

When the logical model development is completed we can use a reasoner which checks whether or not all of the statements and definitions in the ontology are consistent. The reasoner can also recognise which concepts fit under which definitions. In this project in order to examine the product classification ontology for consistency we used the Fact++ reasoner.

The ontology we developed describes several named products, their attributes and the relations that hold between them. This structured representation enables the system to query the XML that contains the ontology and pass the results into the graphical user interface. Figure 5 shows the inferred ontology developed. The inferred ontology can be exported in different formats. We chose to export ontology in XML format in order to be embedded and deployed by the client software.

4.2 RSS-based Product Information

As mentioned before RSS feeds are XML representations of the entries in frequently updating websites, which enable users to subscribe to those syndicated contents using suitable software, called feed readers. Moreover, since feeds are XML documents, they can be extended to include other semantic data besides titles and descriptions of products, such as traceability data.

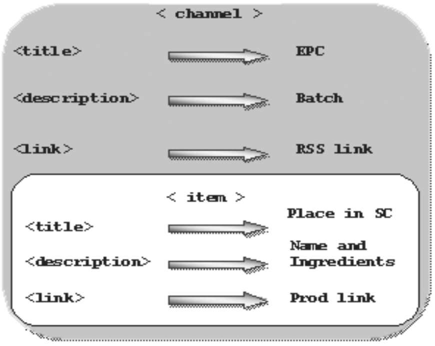

Fig. 6. RSS-based product information.

Figure 6 shows a simple correspondence of the standardized basic RSS tags with the desired product traceability information. This correspondence can be extended with other standardized optional RSS tags in order to transmit more detailed information.

In this case overwhelming data stream may take place, thus we need to consider the available network resources.

5 System Evaluation

In this paper we introduce an intelligent and effective traceability system. Nowadays the adoption of protocols such as EDI for transmitting traceability data in B2B applications is a common practice. However this could be very expensive because we usually need WAN connections with large bandwidth, maintenance engineers and operational staff. Also in case of connection loss the whole system breaks down and certain part of the data is being lost.

The use of RSS for transmitting data provides us the advantage of using the Web instead of a straight forward, expensive and unreliable WAN connection. As described in previous sections the system is designed to be autonomous, so we don't need extra operation staff for this purpose.

RSS-based product information can be extended with other standardized optional XML tags in order to transmit more detailed information that suits a particular enterprise. The combination of these information and real-time tracking of a particular product, results the complete transparency in the supply chain.

Current RFID applications in the supply chain use EPC, which is a standard that identifies products according to owners and types. The system we implemented incorporates an ontology that creates relations among different types of products of different manufacturers. This provides user with an intelligent tool that has the ability of submitting more descriptive queries to the database.

The system we developed supposes that all the supply chain actors share the same database. In the future we are going to extend the service in order to support additional data representations by developing patterns for the RSS-generator. Thus the system will be interoperable.

6 Conclusions

This paper puts forward a solution of a RFID system architecture for real-time traceability and intelligent product management in the supply chain. A RSS-based product information model for transmitting traceability data is also proposed, as well as a simple product classification ontology. In this paper we specialized in the sector of food and drinks. Nevertheless the system works for most enterprises as well, with little modification and special ontology incorporation. The system can also work with barcode data as but in this case real-time traceability is unfeasible. The proposed system provides enterprises with the opportunity to apply a low cost traceability system which allows transparency of products in the supply chain. The incorporation of the ontology optimizes the product management system which obtains intelligence.

7 References

1. Bray, T., Paoli, J., Sperberg-McQueen, C. M., Maler, E., & Yergeau, F. (2008, Nov.). Extensible Markup Language (XML) 1.0 (5th Edition). W3C. Retrieved December 5, 2008.
2. Chidambaram, S., Whitman, L., & Cheraghi, S.H. (1999). A Supply Chain Transformation Methodology. *Proc. of the 4th Annual Inter. Conf. on IETAP*, San Antonio, USA
3. Horridge, M., Knublauch, H., Rector, A., Stevens, R., & Wroe, C. (2004). A Practical Guide To Building OWL Ontologies Using The Protege-OWL Plugin and CO-ODE Tools Edition 1.0, The University Of Manchester.
4. Ketkar, V., Whitman, L., & Malzahn, D. (2002). Ontology-based product tracking system. *Proceedings of the Industrial Engineering Research Conference*.
5. Lamont, M. (n.d.). Savant Web Server. Retrieved July 18, 2008, from http://savant.sourceforge.net/index.html
6. Myerson, J. (2006). RFID in the Supply Chain: A Guide to Selection and Implementation, Auerbach Publications.
7. Nakano, Y., Sagawa, H., & Tarumi, H. (2005). A Proposal of RSS WebCrawler Model of Product Information Product Information Service with RSS 1.0, *Proceedings of the IEEE International Conference on Active Media Technology*, 147-151.
8. Syed, A., & Mohammad, Y. (2008). *RFID Handbook Applications, Technology, Security and Privacy*. CRC Press, Taylor & Francis.
9. UNSPSC (n.d.). United Nations Standard Products and Services Code. Retrieved July 21, 2008, from http://www.unspsc.org/Defaults.aspv
10. van Goor, A.R, Ploos van Amstel, M.J, Ploos van Amstel, W. (1996). Physical Distribution: Thinking in Added Value, Stenfert Kroese, Leiden.
11. Vernede, R., Verdenius, F., & Broeze, J. (2003). Traceability in food processing chains : state of the art and future developments Agrotechnology & Food Sciences Group, (Rapport 015), 46.
12. Winer, D. (2003, July). RSS 2.0 at Harvard Law. Berkman Center. Retrieved December 5, 2007, from http://cyber.law.harvard.edu/rss/rss.html
13. Zhang, M., Li, W., Wang, .Z, LI, .B, & Ran, X. (2007). A RFID-based Material Tracking Information System, *Proc. of the IEEE Inter. Conf. on Automation and Logistics.*