Exploiting RFID digital information in enterprise collaboration

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Abstract
Purpose – The purpose of this paper is to investigate how a distributed network architecture, building on web-service orchestration, data-stream management systems and smart-tagging technologies, can be employed to enable enterprise collaboration and decision making.

Design/methodology/approach – The methodology is based on a technology review in order to propose a network design as well as a field survey to identify and evaluate the relevance of radio frequency identification (RFID)-enabled collaboration and decision-support scenarios to industry executives.

Findings – The paper demonstrates the relevance of the proposed architecture and corresponding RFID-enabled collaboration to business executives of the grocery retail sector. The responses show that some scenarios are more appealing to retailers than to suppliers and that certain processes should be done in collaboration.

Research limitations/implications – Research limitations and future research directions involve the evaluation of specific design alternatives, in the specific context as well as comparing the distributed architecture approach with a centralized architecture or with EDI which has traditionally been used to support enterprise collaboration.

Practical implications – The proposed architecture supports not only internal operations of network leaders, such as big retailers, but also suppliers who look into opportunities to benefit from the use of IT in enterprise relationships by gaining either process specificity or domain knowledge specificity.

Originality/value – The paper introduces a novel architecture that moves beyond the centralized web site paradigm to a distributed one. A European field survey is employed for the evaluation of several RFID-enabled collaboration scenarios, providing insights to both researchers and practitioners (retailers and suppliers in the grocery retail sector).

Keywords Business enterprise, Retailing, Radio waves, Decision support systems, Information retrieval

Paper type Research paper

1. Introduction
The emergence of new technologies, such as radio frequency identification (RFID), is expected to revolutionize many of the enterprise collaboration operations such as supply chain management by reducing costs, improving service levels and offering new possibilities for identifying unique product instances. On the other hand, the advanced data capture capabilities of RFID technology coupled with unique product identification and real-time digital information coming from different data sources, such as environmental sensors, define a new and rich information environment that opens up new horizons for efficient decision-making activities.
Currently, RFID implementations take place internally within a company mainly with the objective to automate warehouse and store management processes in the first run. The priority and effort placed behind such implementations by the US Department of Defence and global retailers such as Wal-Mart, METRO, TESCO, etc. combined with the pressure they put on their suppliers indicate that this technology has already become a market mandate.

However, on the suppliers’ side, RFID, as a tag that has to be placed on their products, is often considered to be an unfortunate strategic necessity (Barua and Lee, 1997) they have to comply with in order to satisfy the plans of their big customers for increased internal efficiency. For suppliers to benefit from RFID, they need to share RFID information with their partners and exploit this information in order to streamline enterprise collaboration and gain new market knowledge (Subramani, 2004; Lekakos et al., 2001).

Despite this widely shared notion among enterprises, the efforts aimed at enabling the exchange of RFID information between business partners are still in their infancy, with the electronic product code (EPC) Network and the ONS infrastructure as the most notable movements towards this direction. A recent report consolidating the views of industry leaders and many different companies on a global basis (GCI, 2005) identifies the need to establish clear information-sharing work practices and infrastructures between trading partners to support the use of free, standards-based information exchange and collaborative decision-support, enabled by RFID technology. In this context, this paper discusses how a distributed network architecture building on the possibilities provided by web-service orchestration, data-stream management systems (DSMS) and smart-tagging technologies, can be employed to enable enterprise collaboration in supply-chain processes and decision making.

Based on the outcome of a design research approach as well as on the results of a field survey, the paper discusses, on one hand, the network design and the selection of the proposed technologies from a technical perspective and, on the other, the relevance of RFID-enabled collaboration and decision-support scenarios to industry executives, including the associated benefits and barriers, from a broader research perspective.

In the following section, we look closely into the technology of RFID and the way it is employed in supply chain management. Section 3 then describes the proposed architecture and tries to explain why the selected technologies have been employed in order to support RFID-enabled collaboration and decision support. Section 4 discusses the relevance of specific collaboration scenarios to industry executives as well as the expected benefits and barriers associated with each scenario. Section 5 concludes with an overall critique and suggestions for further research in this area.

### 2. Employment of RFID technology in enterprise operations

RFID technology is concerned with the identification of objects through the transmission of radio waves from and RFID tag (microchip) attached to an antenna to an RF reader. The information (including object’s serial number for instance) transmitted by the RF tag is reflected back into digital information that can be passed on to an enterprise information system. The EPC is the standard adopted in this case. RFID applications include access control systems, livestock management systems, automated toll collection systems, theft-prevention systems, electronic payment systems, and automated production systems (Agarwal, 2001; Smith and Konsynski, 2003).
In the retail sector, RFID can potentially empower a broad spectrum of applications, ranging from upstream warehouse and distribution management down to retail-outlet operations, including shelf management, promotions management and innovative consumer services, as well as applications spanning the whole supply chain, such as product traceability (Pramatari et al., 2005). However, most RFID implementations currently take place internally within a company, mainly with the objective to automate warehouse management processes or store operations in the first run. A recent industry report (GCI, 2005) identifies certain application areas (specifically, store operations, distribution operations, direct-store-delivery, promotion/event execution, total inventory management and shrink management) as the major opportunities for the deployment of RFID technology in the short and mid-term.

In the various application areas, the contribution of RFID can be sought across the following axes:

- the automation of existing processes, leading to time/cost savings and more efficient operations;
- the enablement of new or transformed-business processes and innovative consumer services, such as monitoring of product shelf availability or consumer self check-out;
- the improvement achieved in different dimensions of information quality, such as accuracy, timeliness, etc. (Ballou et al., 1998); and
- the formation of new types of information, leading to a more precise representation of the physical environment, e.g. a product’s exact position in the store, a specific product’s production, distribution and sales history, etc.

The last two axes in particular, ask for new decision support algorithms and tools for the associated benefits to be exploited, opening-up a whole new research area for decision support systems (DSS). Furthermore, for the full benefits to be ripped, the information needs not be exploited locally but be shared with supply chain partners in a complex network of relationships and decision making.

If RFID technology is only exploited internally by a network leader looking solely at internal benefits, e.g. a big retailer trying to improve store operations, then suppliers confront RFID technology as another unfortunate strategic necessity (Barua and Lee, 1997). This is already an existing trend in the market expected to have a negative impact on RFID market acceptance and adoption rates. Subramani (2004) argues that suppliers benefit from information technology (IT) use in supply chain relationships when they use IT either in order to gain higher business-process specificity or in order to gain higher domain-knowledge specificity. We could say the first two axes above are associated with business-process specificity while the latter two are associated with domain-knowledge specificity. Under this perspective, the question that arises is how to enable collaborative processes and decision making exploiting the aforementioned RFID capabilities, so that not only network leaders-retailers but also suppliers can benefit from the employment of RFID both in improving process management and in gaining domain knowledge.
3. A proposed architecture for RFID-enabled collaboration and decision making in a networked business environment

In this section, we describe a proposed architecture that can support new RFID-enabled decision-support and collaboration practices in a networked business environment. As a field case, we consider the grocery retail sector which is characterized by an intense supply-chain environment on one hand, handling thousands of products and supply-chain relationships on a daily basis, and increased competition and consumer demands on the other.

In this context, the key requirements that should be considered from a decision-support perspective include:

• the immense amount of data that need to be processed in real time; already today that products are identified at product-type level through barcodes, the handling of information in real-time for decision-support purposes is quite a technical challenge;

• the need to ensure synchronized product information between supply chain partners (Roland-Berger, 2003); although the sector has adopted barcoding technology as a standard to identify products, yet the information is maintained at different levels in either the retailers’ or the manufacturers’ systems causing serious integrity issues when data exchange and synchronization is required;

• the many different business relationships that need to be supported; each retailer may collaborate with hundreds of suppliers and vice versa;

• the different collaboration scenarios that may be applicable in each supply-chain relationship; a retailer may collaborate with one supplier on efficient warehouse replenishment following CRP/VMI or on category management with another supplier, etc. (Pramatari, 2007); and

• the need to support seamless information sharing and collaborative decision-support through automated and secure interorganizational system links.

In order to cope with the above requirements, the proposed architecture employs:

• DSMS, supporting real-time analytics and decision support based on continuous queries of transient data streams; and

• web-service orchestration, enabling secure and seamless information sharing and collaboration in a distributed environment.

Until recently, DSS were based on data that were stored statically and persistently in a database, typically in a data warehouse. Complex queries and analyses were carried out upon this data to produce useful results for managers (Chatziantoniou, 2003). In many applications, however, it may not be possible to process queries within a database management system (DBMS). These applications involve data items that arrive online from multiple sources in a continuous, rapid and time-varying fashion. This data may or may not be stored in a database.

For this reason, applications have recently been developed in which data is modelled not as persistent relations but rather as transient data streams. A good example of such an application would be one that constantly receives data about EPC observations across a chain. In data streams, we usually have “continuous” queries rather than “one-time”. The answer to a continuous query is produced over time,
reflecting the stream data seen so far. Computing real-time analytics (potentially complex) on top of data streams is an essential component of modern organizations (Chatziantoniou and Johnson, 2005).

Being able to efficiently perform complex real-time analysis on top of streams of RFID measurements is the reason DSMS are employed by the proposed architecture. This choice supports certain collaboration and decision-support scenarios, as will be further described in the following section. In addition, a relational DBMS is used in order to support less information-intensive scenarios and other elements of the application.

As far as the interorganizational system links and collaborative processes are concerned, the technology of web services is employed in order to support them. A web service, as defined by the W3C Web Services Architecture Working Group, is:

... a software application identified by a URI, whose interfaces and bindings are capable of being defined, described, and discovered as XML artifacts. A web service supports direct interactions with other software agents using XML-based messages exchanged via internet-based protocols (W3C, 2002b).

In general, a web service is an application that provides a web API, supporting application-to-application communication using XML and the web. Others refine this definition further by requiring the description be a Web Services Description Language (WSDL) document and the protocol be SOAP (Ferris and Farrell, 2003). UDDI registries are further used to identify and locate web services.

To move beyond the “publish, discover, interact” model, it is required to have the ability to define logic over a set of service interactions. This not only enables the composition of a set of services, but it also enables the definition of the interaction protocol of a single service by specifying a sequence of its operations. The two prevalent standards – the Web Service Choreography Interface and Description Language (WSCl, WS-CDL) (W3C, 2002a) and Business Process Execution Language for Web Services (BPEL4WS) (W3C, 2002a) – are designed to reduce the inherent complexity of connecting web services together. The terms orchestration and choreography have been employed to describe this collaboration:

- **Orchestration** refers to an executable business process that may interact with both internal and external web services. Orchestration describes how web services can interact at the message level, including the business logic and execution order of the interactions. These interactions may span applications and/or organizations, and result in a long-lived, transactional process. With orchestration, the process is always controlled from the perspective of one of the business parties.

- **Choreography** is more collaborative in nature, where each party involved in the process describes the part they play in the interaction. Web services choreography aims at the coordination of long-running interactions between distributed parties, which use web services to expose their externally accessible operations (Muehlen et al., 2005).

The two notions, however, are not completely distinct. For instance, BPEL4WS can be used both to describe orchestration and choreography issues (Viroli, 2004). Furthermore, Muehlen et al. (2005) classify choreography standards proposals into two categories: REST- and SOAP-oriented standards, which are not necessarily
competing, as REST represents a navigational style of design and SOAP represents a procedural style. As we recognise that developments in this area have not yet converged into a single prevailing standard, in the proposed architecture we choose to use BPEL4WS and SOAP for implementing the notion of web services orchestration. However, the other standards could also have been used for this purpose.

Figure 1 shows a schematic representation of the proposed architecture. As we see on the figure, this is a distributed architecture, where the application layer runs on the system of each collaborating partner and web services are used as the interface between the different partners’ systems using SOAP requests and responses. The data layer is implemented by both a relational database system (DBMS) and a DSMS providing the application with a continuous stream of EPC information. The central orchestration engine coordinates the exchange of messages between the web services following the logic of specific process scenarios. Finally, the collaboration registry is the implementation of a UDDI directory enhanced with additional higher-level information regarding a collaborative relationship, including which partner collaborates with each other under which process scenario and with what security privileges.

Since, this architecture is meant to support collaborative processes and decision making in the grocery retailing/fast moving consumer goods sector, it is deemed necessary to interlink it to the GDSN and ONS/EPC Network infrastructures or similar infrastructures used for the same purpose. The Global Data Synchronization Network (GDSN), established by the GS1 standardization organization and the Global Commerce Initiative (GCI) aims at providing supply chain partners with accurate product catalogue information and is implemented through a collection of data pools and global registries. On the other hand, the EPC Network, supported by the Object Name Service (ONS) infrastructure, has started materializing under the administration
and directives of EPCglobal and with the support of global standardization bodies and leading industry forums (GS1, GCI). The difference between the GDSN and the EPC Network is that the former is meant to support information sharing about product type (what is currently identified via a barcode) whereas the latter is meant to support information sharing about unique product instance (identified via an RFID tag, following the EPC standard) (EPCglobal, 2004). The proposed architecture connects to either these two or similar directory services in order to get the master product information associated with a specific product type identified via a barcode (GDSN) (e.g. product name, manufacturer, weight, dimensions, etc.), or additional information associated with a specific product instance identified via an EPC (ONS/EPC Network) (e.g. production date, distribution history, expiration date, etc.).

From a functional perspective, the proposed architecture can support different collaborative processes and decision-support scenarios. Each of these scenarios can be supported by separate components at the application layer, as for example the following indicative interconnected modules:

- store management module (SM);
- promotion management module (PM);
- product traceability and reverse logistics module (TRL);
- inventory management and collaborative replenishment (ICR); and
- Consumer information services (CIS).

Each of the SM, PM, TRL, ICR and CIS modules performs different functionality on each site; depending on what is the role of the collaborating partner, e.g. supplier, distribution centre, retail store. The functional decomposition of the application and the way it interacts with the rest of the elements in the architecture is schematically shown in Figure 2.

As an example, Figure 3 shows an indicative scenario supporting dynamic pricing enabled by the PM, where the supplier collaborates with the retailer in order to reduce the price of some products approaching their expiration date.

**Figure 2.** System functional decomposition
4. Evaluating the business relevance of the proposed architecture and enabled scenarios

While with the development of the internet, the centralized application architecture initially dominated the field of both web-based DSS (Jichang et al., 2004; Zhang and Goddard, 2005) and collaborative supply chain management systems (Pramatari, 2007), we would argue that a decentralized-application-architecture presents bigger advantages in the context presented in this paper. Schuff and Louis (2001) have analyzed the benefits of centralisation vs decentralisation of application software. Based on their analysis, we can conclude that in the specific context, the centralised software architecture is expected to lead to serious scalability issues and delays in system response, especially due to the exponential information increase associated with the employment of RFID for unique product identification and the need for real-time analytics and decision-support. Furthermore, a distributed-application-architecture allows for better integration of the application with internal business processes, as compared to the use of an external web site (Pramatari, 2007). Web services further provide the means to enable this integration in a standard way (Sayah and Zhang, 2005).

In that respect, the proposed system can be categorized as a distributed web-based DSS as described by Zhang and Goddard (2005), where the data and decision-support tools from multidisciplinary areas can be located on computers distributed over a network. In such a distributed environment, a web-based DSS needs a distributed framework to manage and integrate the data and tools in a seamless way. In the case described in this paper, this framework is provided by web services, the web service orchestration engine and the collaboration registry.

The proposed architecture is a generic distributed architecture that can potentially enable various supply chain collaboration and decision support scenarios, whether these are enabled by RFID technology or not. What is important to understand though is which of these scenarios make sense to implement from a business perspective.
Companies in the sector already have a more-than-ten-years collaboration history and some collaboration processes have become standard business practice across Europe, such as CRP/VMI employed in retail warehouse replenishment or category management dealing with the marketing aspects of managing product categories in the store (Pramatari, 2007).

In order to understand the business relevance of alternative scenarios that can be supported by the proposed architecture, we conducted a field survey based on questionnaires addressed to top executives representing retailers and suppliers/manufacturers in the European food industry. According to Hevner et al. (2004), examining the relevance of a solution is a fundamental step in the design approach of information systems research, and this has been the key motivation behind this field survey. The objective of the survey was two-fold:

1. to understand the relevance of some new RFID-enabled processes to business executives and the degree these fit with their current strategies; and
2. to examine the degree to which collaboration is a prerequisite in these processes.

Furthermore, the survey provided useful input regarding the RFID readiness of companies and the degree they are already involved in supply chain collaboration activities.

The survey focused on the following eight alternative RFID-enabled collaboration scenarios:

1. **Back-room and shelf visibility.** The store personnel receive real-time information about the backroom inventory level of each product. If a product is not on the shelf (out-of-shelf – OOS), but there is available stock in the backroom, the store personnel is informed to refill the shelf; otherwise, if there is no stock in the store at all (OOS), a new replenishment order is placed. The salesman of direct-store-delivery suppliers has also direct access to this information through a PDA.

2. **OOS response.** Retailer and supplier get statistical information about shelf availability, i.e. the level of stock on the store shelves, in order to monitor the level of OOS, which is considered one of the major problems the retail sector faces today (Roland-Berger, 2003). While the previous scenario requires real-time information flows to support daily operations, this scenario is more about business intelligence and decision support.

3. **Remote shelf management.** Retailer and supplier get real-time information for the actual shelf layout. RFID readers “scan” and “read” the shelf and provide its “digital image” including information about the size, specific products’ position and layout, as well as information about the shelf’s performance.

4. **Smart pricing.** Retailer and supplier have the possibility to identify products that are close to their expiration date or are standing still on the shelf for a long time and dynamically reduce their price, in order to boost consumer demand and reduce waste.

5. **Smart recall.** Retailer and supplier have the possibility to identify the location of products with specific characteristics and recall them from the market, e.g. in case there is a risk with consumer safety, fast and at the minimum cost.
(6) **In-store promotion management and promotion evaluation.** Customers get direct information about special offers and promotions relevant to the product they just got off the shelf. Retailer and supplier can manage better their promotion plans and evaluate in real-time the efficiency of their in-store promotion activities.

(7) **Demand management.** Retailer and supplier have the possibility to monitor the inventory and the sales of products and relocate them if needed (e.g. in case of a special promotion event) in order to eliminate lost-sales opportunities.

(8) **Traceability information.** The consumer at the end-point-of-sales has a clear view of the product’s history and origin. At special information desks, the consumer can get details about production date and origin, expiration dates and other unique product’s information that can ensure product authenticity and safety.

These are new scenarios that capitalize on RFID’s capabilities for automatic data capture and identification of unique product instances in combination with other information that can be derived in association with RFID, such as the shelf location, the context of an in-store promotion event, etc. Some of the scenarios focus on the management of specific operations and processes (e.g. 1, 4, 5), others focus more on supporting decision making and building domain-knowledge (e.g. 2, 3), and others combine both aspects (e.g. 6, 7, 8).

An exploratory field survey[1] was conducted (SMART, 2007) in order to provide insights with respect to the scenarios described above (Figure 4). About 77 executives from 25 companies throughout Europe (mainly from Germany, Greece, Cyprus, Ireland, and the UK), representing retailers (54 per cent) and suppliers (34 per cent) from the grocery retail sector, participated in the survey. The findings demonstrate that retailers and suppliers agree that “back-room and shelf visibility” as well as “demand management” are important possibilities that can contribute to their company’s strategies. However, suppliers seem to value more than retailers the possibility for promotion evaluation and promotion management while retailers are more interested in being able to locate and recall products from the stores.

![Figure 4. Field survey results: relevance of alternative scenarios](image-url)
When retailers and suppliers were asked to indicate the top three areas in which they need to work collaboratively with their supply-chain partners, most of them mentioned supply-chain cost reduction (which was placed among the top three areas by more than 50 per cent of respondents), product safety and traceability and increasing shelf availability (Figure 5). These answers reveal that the companies in the retail sector have already adopted a collaboration mentality and are willing to use infrastructures supporting collaborative processes and decision-support, as the one proposed in this paper.

The executives that have responded to the survey declare that they work collaboratively with supply chain partners in CRP/VMI and category management programs to an adequate degree (4.8 out of 7) and that they have heard about RFID technology and follow the developments in the area, but have not yet been involved in an RFID pilot.

5. Conclusions
Following developments in the RFID field, this paper proposes a distributed network architecture that can support new RFID-enabled collaboration and decision-support scenarios. The proposed architecture is based on the technology and notion of web service orchestration in order to enable interorganizational process links and seamless information flows.

The proposed architecture can be categorized both as a web-based DSS that moves beyond the centralized web site paradigm to a distributed one, and as an enterprise collaboration system. As such, it aims at supporting both internal operations of network leaders, such as big retailers, but also suppliers who look into opportunities to benefit from the use of IT in enterprise relationships either by gaining process specificity or domain knowledge specificity (Subramani, 2004).

Based on the results of a European field survey, the paper discusses the relevance of the proposed architecture and corresponding RFID-enabled collaboration and decision support scenarios to business executives of the grocery retail sector. The responses show that some scenarios are more appealing to retailers than to
suppliers and vice versa, while there is a well-grounded belief shared by both retailers and suppliers that some processes should be done in collaboration.

Rather than evaluating the relevance of the proposed scenarios from a business perspective, what is even more important is to evaluate the degree to which the proposed architecture adequately supports the corresponding scenarios and fulfils the requirements from various perspectives, which is a clear next direction of research in this area. One such perspective is the consumer’s attitude towards the use of RFID and the monitoring of purchase activities which may raise privacy or trust issues (Angeles, 2007) and requires further investigation. Other directions for future research relate to evaluating specific design alternatives, such as the use of different Web Service Choreography standards rather than BPEL4WS, in the specific context as well as comparing the distributed architecture approach to a centralized architecture or to EDI which has traditionally been used to support enterprise collaboration (Pramatari, 2007).

Note
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References


W3C (2002a), Web Service Choreography Interface (WSCI) 1.0, available at: www.w3.org/TR/wsci/


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