Semantic-based Data Management in RFID assisted Supply Chains

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Abstract

Traditional Radio-Frequency IDentication (RFID) applications have been focused on replacing bar codes in supply chain management. Leveraging a ubiquitous computing architecture, we envision a framework allowing both quick decentralized on-line item discovery and centralized off-line massive business logic analysis, according to needs and requirements of supply chain actors. A semantic-based environment, where tagged objects become resources exposing to a RFID reader not a trivial identication code but a semantic annotation, enables tagged objects to describe themselves *on-the-fly* without depending on a centralized infrastructure. On the other hand, facing on data management issues, an effective *off-line* multidimensional analysis of huge amounts of RFID data generated and stored along the supply chain can be performed.

1 Introduction

A supply chain is a complex system for transferring products or services from a supplier to a final customer. The key for a successful supply chain of consumer products is an extended collaboration, which implies the integration of the firm with actors involved in the external logistic network. Information sharing clearly plays a pivotal role in logistics and marketing. As a result main retailers are investing in new technology in order to boost the information exchange. Radio-Frequency IDentification (RFID) [2] is a promising wireless technology allowing to link an object with its virtual counterpart, *i.e.* its representation within information systems. Currently, RFID tags attached to products only store an identification code, which is used as a key to retrieve relevant properties of the object from a database through a networked infrastructure. Traditional RFID applications have been focused on replacing bar codes in supply chain management and asset tracking. Two main issues restrain more advanced usages. First of all, the identification mechanism only allows a rudimentary code matching, providing exclusively yes/no replies. Furthermore, RFID-based solutions usually rely on stable support infrastructure and fixed database servers to retrieve information. To this aim, we envision a knowledge-based pervasive computing environment where tagged objects become resources exposing to a RFID reader not just an identification code but a semantically annotated description. This enables products equipped with RFID tags to describe themselves in a range of scenarios, *e.g.* during supply chain management, shipment, storage, sales and post-sale, without necessarily depending on a centralized infrastructure to extract and process on the fly information in the field. Leveraging a pervasive computing architecture, we allow both quick decentralized on-line processing and centralized off-line massive business logic analysis, according to needs and requirements of supply chain actors. The core idea is that an extension of current RFID technology supporting logic-based formalisms for knowledge representation allows semantically rich and unambiguous information to follow a product in each step of its life cycle. Semantic-based annotations are stored on RFIDs, exploiting machine-understandable ontological languages originally conceived for the Semantic Web effort. Product and process information can be queried, updated and composed during manufacturing, packaging and supply chain management, thus allowing full traceability up to sales, as well as flexible processing.

2 Challenges and Expected Results

In the current competitive arena there are specialized production and distribution processes and agreements grounded on the presence of rigid networks. As a result, while in the past market competition was among firms, from now the competition will take place among logistical chains. Thus, the supply chain cannot be longer represented as a static or linear one, but it needs to be evaluated dynamically, as a system of interactions and connections among the actors operating along the chain. Many empirical investigations have demonstrated there is a positive correlation between the level of firm performance and its propensity to be integrated into a higher system [3, 4]. This is the reason why the enterprises firms are more and more attentive to the opportunity offered by the coordination and the cooperation among their internal functions and the other external actors contributing in different ways to the production. In this context, information has become a strategic asset. It plays a key role in the logistics and marketing. In particular, the physical flow of raw materials and products and their related information are considered as fundamental for the quality standard of products/services. As a result the main retailers are investing in new technology in order to boost the information exchange. Leveraging a distributed architecture, it is possible to enable both quick run-time analysis (with respect to a local fragment of the overall infrastructure) and stand-alone massive business logic elaborations (with respect to a centralized Data Base Management System - DBMS) following needs and requirements of the supply chain actors. An extension of current RFID technology supporting logic-based formalisms for knowledge representation allows semantically rich and unambiguous information to follow a product in each step of its life cycle. Semantic-based annotations are stored on RFID tags, exploiting machine-understandable ontological languages originally conceived for the Semantic Web effort, such as OWL (Web Ontology Language). Product and process information can be queried, updated and in-

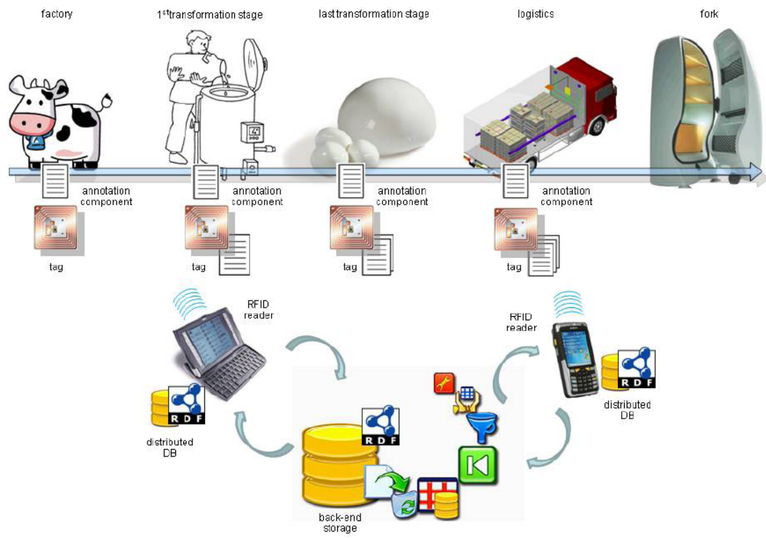

Fig. 1. An example of reference

tegrated during manufacturing, packaging and supply chain management, thus allowing full traceability up to sales, as well as intelligent and de-localized querying of product data. To this purpose we extend the EPCglobal RFID standard , enabling semantic-based services in a pervasive matchmaking framework while also preserving original legacy applications. A semantic-based approach would provide several benefits with respect to traditional ones, thus justifying higher complexity. In accordance with the original vision of the Semantic Web as proposed by Tim Berners Lee et al. [1], in order to enable automated knowledge management and integration for a wide array of activities, formal ontologies will be adopted and items will be described with respect to them. A simple reference example will clarify the proposed setting, also highlighting its benefits, as shown in Figure 1. Let us suppose to monitor the life cycle of a typical product of the Apulia region, mozzarella, and to follow production steps from farm to fork surveying and extracting relevant product/process information. Each production stage will see the progressive addition of annotations to enhanced RFID tags, attached for instance to milk tankers (first production stage), to containers (logistic step) up to product packages (final sale phase). Because of traceability requirements, a tag will store: (1) quantitative data pertaining to the product besides the Electronic Product Code (EPC) identifier; (2) high-level qualitative information about production or delivery/logistics processes, expressed as semantic annotations w.r.t. a reference ontology of the particular application domain. Information extracted via RFID can be used for a variety of purposes. First of all -at each stage of the product evolution- accurate verifications can be performed about expected quality requirements of the product/process. Moreover, intelligent deliveries can be routed from the warehouse to different production departments according to their specific characteristics. A product can inherit (relevant parts of) the semantically annotated description of its raw materials, through properties defined in the ontology. Further product attributes can also be stored on the RFID tag, such as weight, production date or expiration date. Finally, after sale, the product endowed with a RFID tag attached to its package enables advanced matchmaking applications. Beyond previous rather basic feature enabled by a data-oriented usage of RFID, the proposed semantic based approach enables further interactions. After purchase, mozzarella could be stored at home in a RFID-enabled smart fridge, which -for example- can suggest the best recipes to use the product when its near expiration is detected. In such a process, a distributed database (under control of a central DBMS where storage devices are autonomous and decentralized) will play the role of storing data for both real-time elaborations along the supply chain and periodic multidimensional analysis on massive amounts of data. It may be stored in multiple devices located in the same physical location, or may be disseminated over a network of interconnected computers. A relevant aspect of the proposal is that the semantic-enhanced RFID technology allows to share information, so optimizing the supply chain and improving performance both in terms of logistic features and by providing innovative services available for all involved actors. The implementation of a smart supply chain is more easily achieved if it is coordinated by leading channel companies (especially the large retailer groups) able to promote the use of technology for smaller companies.

3 Conclusion

In this paper we envisioned an innovative approach for data management in supply chains based on RFID identication technology. Both on-line semantic-based object discovery and off-line analyses involving large amounts of RFID data are enabled. The approach may provide several benefits. Information about a product is structured and complete; it accurately follows the product history within the supply chain, being progressively built or updated during object lifecycle. This improves traceability of production and distribution, facilitates sales and post-sale services thanks to an advanced and selective discovery infrastructure.

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