Emerging Technologies for Traceability Platforms Design

by

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ABSTRACT

In the last decades, traceability proved its capability by bringing multiple advantages and improving different business processes from various fields. Nowadays, traceability is viewed as a needed strategic service in any production context. This paper describes some technologies that could emerge for new track and trace platforms development, as a response to recent business challenges.

Keywords: Traceability, eBusiness, Internet of Things, RFID, Multi agent systems

INTRODUCTION

E-business, as mentioned in the e-Business Watch Report constitutes an essential lever in facing issues such as traceability, logistics, and a series of internal processes. If we consider the case of chain traceability, according to the ISO 9001:2000 standard, chain traceability is the ability to trace the history, application or location of an entity by means of recorded identifications throughout the entire supply chain. Traceability is viewed as a needed strategic service in any production context. In recent years various organizations, businesses, end users and authorities in various markets around the world, have recognized the many potential benefits of traceability process. Thus, tracking and tracing individual entities (people, animal or objects) proves to be a very important feature, essential to many applications in various domains, like, elderly and patient care, supply chain applications, logistics, asset management, counterfeit detection, and product recalls. Still, there is a need to take down the barriers that impede the efficient and error-free traceability, such as the non-homogeneous information kept at various traceability partners.

Radio Frequency Identification (RFID) technology is a wireless technology that allows the precise and automatic identification and localization of individual entities (objects, people and animals). This paper proposes the use of RFID technology for implementing the traceability of various entities. The justification relies on some of the main characteristics and functionalities of the RFID systems. Thus, by attaching radio frequency tags to different entities (people and objects), RFID technology can provide the identification, tracking, locating, and the security, but also other features for various entities, by attaching radio frequency tags to these entities (people and objects). In fact, researchers consider that this technology has the potential of bridging "the growing gap between the digital networked world and the physical world" [1].

The traceability process is characterized by shared and distributed data and requires the communication flow of complex and disparate forms of information between various information systems of traceability partners or/and other settings. But, currently, in the systems of various organisations, the same information can be represented in many ways. There are no standards regarding either the internal organisation of the trading partner or the technology. And now, more than ever, due to the current economic crisis, consumers need to use systems which are cost-effective and do not fall into obsolescence. Developing a software multi-agent system that integrates with existing information systems of the traceability partners will support complex traceability queries or cross-organizational query processing.

This paper proposes an RFID-based traceability platform, named COHERENT, Comprehensive RFID-based Traceability Platform for the Internet of Things. The proposed platform will not substitute the existing information systems. Instead of trying to integrate the applications of traceability partners we accept their existence as autonomous entities, and take into consideration a holistic approach that addresses important aspects of the traceability process. Thus, this platform will focus on the interoperable traceability of the exchange of information among partners. Thereby it will prove to be a viable solution for the reduction of costs involved in acquiring infrastructure components of partner information systems and services. Also, it will contribute to improving the quality of products and to reducing costs.

The reminder of this paper is structured as follows: the first section gives a brief introduction to the RFID technology and Internet of Things concept. The next section summarizes the state of the art on the aforementioned topics. Section 4 presents a traceability solution that offers a holistic approach to Internet of Things. The paper ends with conclusions.

ENABLING TECHNOLOGIES

RFID Technology

Radio Frequency Identification technology (RFID) is an Automatic Identification and Data

Capture (AIDC) wireless technology that allows the precise and automatic identification and locating of individual entities (objects, people and animals).

The basic RFID system architecture has two components: contactless electronic tags and an RFID reader. The RFID tag is used to store unique identification data and other specific information whereas the RFID reader allows the reading and writing of these tags. Tags fall into three categories: active (battery-powered), passive (the reader signal is used for activation) or semi-passive (battery-assisted, activated by a signal from the reader). An RFID tag is attached to or embedded in the individual that is to be identified, thus allowing identification, tracking, locating, etc. Moreover, by combining RFID with sensor technology, the number of applications increases tremendously. For example, contactless RFID technology could be used to monitor various physical conditions during the production process or shipping of goods.

This paper proposes the use of RFID technology for the traceability of entities, justified by some of the main characteristics and functionalities of RFID systems: (1) Achieving low costs and power efficiency; (2) Non-contact and non line-of-sight functionalities that allow data access in harsh environments and through various substances; (3) Allowing data storage on RFID tags; (4) Allowing the integration of RFID with sensor technology.

RFID systems require software, network and database components that enable the information flow from tags to the information infrastructure of an organization, where the information is processed and stored. The systems are application-specific [21].

RFID technology is viewed as a key enabler for the Internet of Things concept. Next, we present a multi-agent background.

Multi-agent systems

Currently, there are numerous agent definitions, but one of the most comprehensive definitions of agents is the one provided by Wooldridge and Jennings (1995). They define an agent as “a hardware or (more usually) a software-based computer system that enjoys the following properties: autonomy - agents operate without the direct intervention of humans or others, and have some kind of control over their actions and internal state; social ability - agents interact with other agents (and possibly humans) via some kind of agent-communication language; reactivity: agents perceive their environment and respond in a timely fashion to changes that occur in it; pro-activeness: agents do not simply act in response to their environment, they are able to exhibit goal-directed behaviour by taking initiative" [26]. We consider an agent as a software component that has a well-defined role in the operation of a system. Also, an agent must have the ability to communicate with other agents or human users. A multi-agent system is a collection of such entities that cooperate with each other. The multi-agent systems include independent components that communicate in a reactive way, some of them can be instantiated and removed dynamically on demand. By using the multi-agent technology in the system implementation, the following advantages could be obtained [25]:

- *High performance*: agents can run in parallel. They can be cloned when their tasks and goals are very important;
- *High flexibility*: an agent can be developed for any context, providing the interface for different ontologies;
- *High modularity*: the number of connected sources can increase practically without limit.

Thus, developing a software multi-agent system that integrates with existing information systems of traceability partners could offer many advantages, like: scalability, intelligence, systematic management, logging of the information flows, and efficient interaction of users with the information system.

The Internet of Things (IoT) infrastructure will allow connections between different entities (i.e., human beings, wireless sensors, etc.), using different but interoperable communication protocols and makes a dynamic multimodal/ heterogeneous network. In this infrastructure, these different entities have the ability to discover and explore one another, gather, provide or transmit information that we can use to implement the traceability process. Next section presents some considerations about this new Internet of Things concept.

Internet of Things

In the Internet of Things concept the term "thing" can refer to people, objects (e.g., product, sensor, machine, etc.) and information. At the present moment, there are various definitions of "Internet of Things" and they vary depending on the context, the effects and the views of the person giving the definition. Thus, from a things-oriented and Internet-oriented perspective, the Internet of Things is viewed as "a world where things can automatically communicate to computers and each other providing services to the benefit of the human kind" [22]. According to [23], Internet of Things is viewed in a semantic-oriented perspective as "a world-wide network of interconnected objects uniquely addressable, based on standard communication protocols”. Most of the definitions of the Internet of Things have much in common, such as [24]:

- the ubiquitous nature of connectivity,
- the global identification of every thing,
- the ability of each thing to send and receive data across the Internet or across the private network they are connected into.

According to the identified research agenda for the Internet of Things [2], further research is needed in the development, convergence, and interoperability of technologies for identification and authentication that can operate at a global scale. Also, there is a need for an open architecture to maximise interoperability among heterogeneous systems and distributed resources including providers and consumers of information and services, whether they are human beings, software, smart objects or devices [2].

STATE OF THE ART

Food safety, product tracing, and product recalls are currently at the forefront of both government regulations and industry concerns around the world [4]. For instance, in the U.S. food-borne pathogens are estimated to cause 76 million illnesses and 5,000 deaths each year and societal costs are estimated between $2.9 and $6.7 billion per year [5]. Due to the recent high incidence of recalls in the food supply chain, government agencies and industry groups focus on the issues of traceability and food safety [20].

Traceability systems should be able to store minimum information related to a particular entity (usually a product) and show the route of this entity along all partner organisations (e.g., along the whole supply chain from the supplier to the retailer and distributor and finally to the customer). Throughout this process, secure, reliable and automatic product identification is crucial for providing effective and efficient traceability. In the past, barcode technology has been used for the identification of products. But these barcode-based systems do not meet the current traceability requirements pronounced by the current governments. Thereby, a new technology that allows automated recording of information is needed. To this extent, researchers propose various solutions and among them the RFID technology.

The radio frequency identification technology enables the association of some easily-accessible data to a specific entity (e.g., person, product). Thus, using RFID tags, a product for example might become an information-storing and processing item, named a smart product. Then, this smart product can be connected to the enterprise information system, or even to the global network, constituting thus an Internet of Things as integrated part of the Future Internet. But the large-scale adoption of RFID-based traceability solutions is delayed due to technical, social and educational constraints. Because the existing solutions are mostly centralised and closed-loop, they are only effective in small-scale RFID tracking applications. As a result, to facilitate trade today, some researchers suggest the implementation of international standards and ensure the interoperability of the traceability systems. We propose a comprehensive platform as an easy to use solution to enable accessing traceability data efficiently and effectively across independent organisations (e.g., enterprises) in the Future Internet.

As a part of the future trends and developments the emerging Internet of Things and Future Internet will shape the world and the society. In order to reply to this challenge, the Future Internet has become the main focus of several research and development initiatives all over the world, from EU to Japan, and from USA to China and Korea. For example, European Commission's Framework Programme 8 (FP8) presents the research community's perspective of the Future Internet Assembly (FIA) on the priorities for Future Internet research. The Cluster of European Research Projects on the Internet of Things (CERP-IoT) developed in 2009 its Strategic Research Agenda (SRA). Also, Future Internet Research and Experimentation – FIRE, CALL 8, Objective 1.6. could be mentioned here.

On a worldwide level, one element that is increasing exponentially the diffusion of RFID in the automate logistics processes is the asserting of some international standards related to goods traceability, such as EPCglobal ([10]-[12]), GS1 (Global Standard 1) ([3], [4]) and ebXML (Electronic Business using extensible Markup Language) ([6]). The EPCglobal consortium, mainly represented by the GS1 organization, defines the standards for developing a universal identification system and an open architecture, able to guarantee interoperability and data sharing in a complex multi-vendors scenario. It proposes the Electronic Product Code (EPC) for uniquely identifying each item. The EPCglobal consortium proposes the EPCglobal network architecture as a computer network used to share product data between trading partners. In order to ensure the traceability, this architecture is composed of a set of standards for hardware devices (e.g., reader), software systems, network services, and data interfaces. Although, the use of these technologies promises many benefits, today's RFID and EPC adoption and deployment in the healthcare [3] and pharmaceutical sectors is still limited due to open issues, such as [13]: (i) hardware technology current weaknesses [14], [15] (e.g., data reliability, read rate in critical conditions, lack of unified standard for interoperability), (ii) software weakness (e.g., scalability, single-point of failure, integration with information systems), (iii) relatively high costs related to tags, software customization and systems integration, (iv) security issues [16], (v) lack of scientific literature on the evaluation of potential effects of RFID exposure on molecular structure and potency of drugs [17]-[19].

Agent technology is increasingly contributing to the development of value-added information systems for large organizations. Thus, developing a software multi-agent system that integrates with an existing information system could offer many advantages, like: scalability, intelligence, systematic management, logging of the information flows, efficient interaction of users with the information system. Also, a multi-agent system could be a time, cost and human effort–saving tool.

Worldwide, there are some multi-agent approaches to the traceability and supply chain issues. Thus, the multi agent system for optimal supply chain management developed by Choi et al. [7] is a multi-agent system based on the scheduling algorithm, a cooperative scheduling methodology which enables the formation and management of an optimal supply chain. By means of active communications among internal agents, a multi-agent system for optimal supply chain management makes it possible to quickly respond to the changes in the production environment such as machine failure, outage of outsourcing companies or the delivery delay of suppliers.

Al-zu'bi proposes MASSCM, a Multi-Agent System (MAS), in order to support the Electronic Supply Chain Management (E-SCM). The proposed model consists in a set of agents that are working together to maintain supplying, manufacturing, inventory and distributing. The main operations of the software agents include: (1) receiving information from customer orders (2) checking the inventory (3) making the production schedule (4) issuing the order of raw materials from the suppliers (5) receiving the raw materials (6) production (7) delivering products to the customer [8].

Charfeddine et al. [9] choose the multi-agent methodology for the design and implementation of an intelligent framework for traceability of containerized goods.

Middleware for RFID applications is used in order to facilitate communication between enterprise systems and automatic identification devices. Most of the conventional existing middleware solutions are costly, non-portable and heavily dependent on the dedicated software. Also, their performances dramatically decrease once with the increase of the number of working readers. There is a need for a robust and flexible RFID-based middleware, ensuring the interface between applications and various RFID readers.

But the new technologies will help ongoing research work continue to develop solutions for traceability open issues.

Next, we propose an RFID-based traceability platform, named COHERENT, Comprehensive RFID-based Traceability Platform for the Internet of Things.

COHERENT OVERVIEW

Rather than developing new information system to change the ones already installed and in use, the COHERENT platform will implement various mechanisms to collect traceability information records and to develop the interoperability of various existing information systems. Thus, in contrast to most existing approaches which focus on specific layers, the COHERENT platform (Figure 1) offers a holistic approach to the Internet of Things, considering heterogeneous systems and distributed resources from various types of manufacturers (like, mobile phones, various dedicated devices, RFID tags, various condition sensors such as motion detection, temperature, humidity and vibration, etc.) and diverse hardware and software, specific for each device.

Here are some assumptions regarding the assuring of a global traceability process within the COHERENT platform:

- A traceable entity (a person or an object) must carry an RFID tag that assures a global and unique identification within all data sources containing information related to that entity;
- The identification carrier (RFID tag) must remain attached to the traceable entity until that entity is consumed, sold for consumption, or destroyed;
- The RFID tag must store some information in order to be linked with the data sources of the traceability partners;
- Each traceability partner must ensure internal traceability;
- A minimum amount of traceability data must be exchanged between traceability partners in order to synchronize with the physical flow of the entities;
- The RFID-tagged entity (person or moveable object) can be tracked using RFID readers.

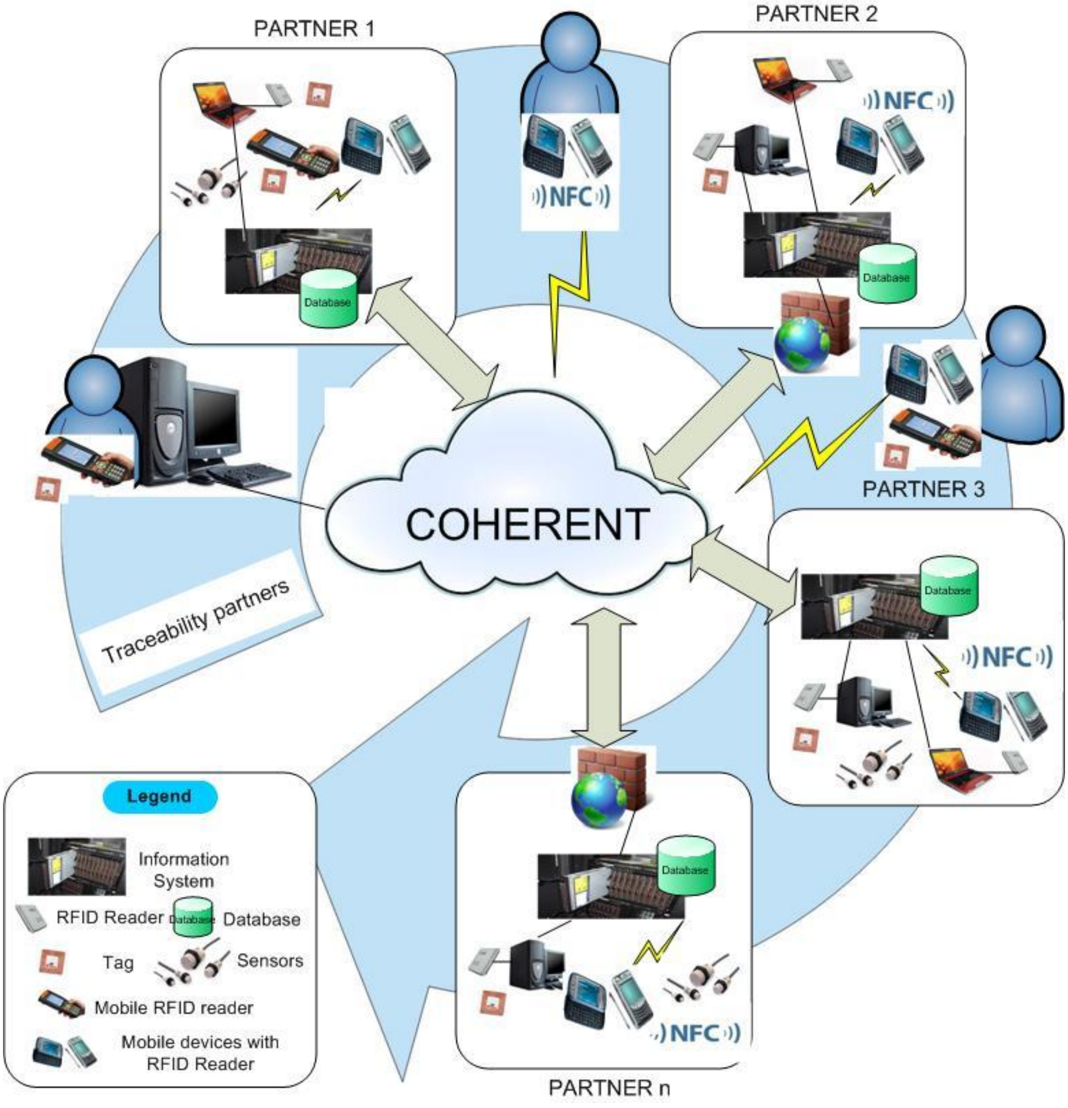

Figure 1. COHERENT platform

COHERENT platform will allow every group of traceability partners to define the desired traceability data set, necessary in order to meet their specific data requirements. Any traceability partner may request the tracing of any RFID-tagged entity. Because the traceability information is not all available internally, it must be requested from an external traceability partner. Thus, this user's request for tracing may trigger other tracing requests; the traceability query propagation is thus initialized, in order to answer traceability partner questions regarding the tagged entities.

Developing and integrating a multi-agent system will support complex traceability queries or cross-organizational query processing. Also, this multi-agent system will allow hiding data distribution across multiple databases from the applications of the traceability partners. Thus, we could define various agents, for example, to allow easy retrieval of traceability data from different individual repositories, or to handle the semantic mediation among heterogeneous systems of traceability partners.

But traceability is not only about obtaining the information history of an entity by means of pre-recorded identifications; it also implies the localisation of an entity. Our platform will offer a solution to assure the 2D or/and 3D indoor and outdoor localisation of an RFID-tagged entity. In order to assure the localisation of an entity, we can use various devices and methods. For example, to implement the outdoor localisation, we propose using GPS and/or GSM that allows the implementation of tracking applications. Indoor localisation is more challenging, given the weak GPS signals and the high spatial accuracy required. We propose to consider an RFID-based solution, allowing the localisation of an entity based on the localisation of nearby fixed things identified in Internet of Things. A hardware device with localisation capability would offer its functionality, for example, as a web service. Thus, device integration will be seen as service integration, and the user will focus rather on the functionality of the device than on its particular technology.

Through its high-level of generality, COHERENT platform allows the specific particularisation for the identification and traceability of various physical entities in space and time. Requiring no software modifications, the platform could be used in various fields of activity. The platform will only need to be configured to the users' requirements, and will ensure high performance and flexibility. The graphic user interface will be easy to use and allow various configurations, depending on the user's preferences and necessities. Thus, the related information regarding the traceability process can be displayed in a user-friendly interface on PC and/or mobile devices (like PDA, mobile phones).

Thus, the COHERENT platform could be easily adopted by just about every traceability partner.

Since COHERENT does not substitute the existent information systems, it is a viable solution for reducing the costs involved in acquiring infrastructure components for the information system and services of traceability partners. Economically, the level of interoperable supply chain information-exchange among partners is expected to reach considerable values. By focusing on the interoperability of supply chain information systems, it will be possible to improve the product quality and reduce costs. Also, the COHERENT platform will support design and implementation solutions that approach new technologies in order to extend the operational life of software. The interactions of enterprises with COHERENT platform will provide them with good opportunities to strengthen their abilities to survive the current worldwide economic crisis and to sustain their competitive position into the future.

CONCLUSIONS

RFID technology is gaining significant momentum for tracking and tracing individual entities. The existing solutions for entity traceability are mostly centralised and closed-loop, being only effective in small-scale RFID tracking applications. The business of today's complex organizations such as supply chain partners relies on sophisticated information systems which often inherit many weaknesses from the past.

In contrast to most existing approaches which focus on specific layers, the COHERENT platform offers a *holistic approach* to the Internet of Things, where things are heterogeneous systems and distributed resources (e.g., mobile phones, various dedicated devices, RFID tags, various condition sensors such as motion detection, temperature, humidity and vibration sensors). Therefore, the COHERENT platform could assure interoperability among heterogeneous systems and distributed resources including providers and consumers of information and services, whether they are living or non-living entities (viewed as things). Procedures of tracking and tracing individual entities (things) could have impact in many applications from different domains, like, elderly and patient care, supply chain applications, logistics, asset management, counterfeit detection, product recalls, etc.

The actual increase in international supply chain contacts and the real need to exchange product-related information among partners (even in cross-border contexts), pave the way towards the implementation of such systems in the field of supply chains.

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