Ambient Services Interactions for Smart Objects in the Supply Chain

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ABSTRACT

In every day life, thousands of objects are fabricated, thousands of objects enter and exit warehouses, thousands of objects are sold in supermarkets. For a good quality of service, these places have to supervise every object, anytime and anywhere, during the passage of the object through theirs environments. So, the necessity of a smart object, that possesses a unique identifier, contains information about itself, could take care of itself and that communicate with the environment in which it is, using specialized services, has arrived. In this article we demonstrate the concept of a smart object, created using RFID and UPnP technologies.

Keywords: Smart Object, Ambient Services, RFID Technology, UPnP Technology.

1. INTRODUCTION

Increasing requirements of reactivity in the supply chain topic are observed among product, processes and clients across the product lifecycle. In this context, the interactions between processes, operators and product, beginning with manufacturing level until its use, require more information and automated intelligent exchanges between partners, in a sure and relatively quick way. Specifically, the requirements that emerge in the supply chain are associated to product customization, product traceability, product information management along its life cycle, and, in general, all kind of services related to the product lifecycle using internet technologies. In order to respond to these new requirements this paper develops an approach considering a physical object as an active actor managing its evolution in the phases of its lifecycle, cooperating with multiple actors in the supply chain (supplier, producer, distributor, and consumer).

The objective of this article is to demonstrate how a physical object can be transformed into a smart object, functionally integrated in an ambient network. In section 2, the smart object concept is presented. In section 3, ambient services architecture is defined for allowing to a smart object to provide information management and processing capabilities and event messaging in an ambient network. Then, RFID and UPnP technology are explained and justified as the technological support to develop services for the smart objects in an ambient services architecture based on internet standards. In section 5, our methodological proposition is detailed incorporating a smart object frame supported by the RFID and UPnP technologies. In section 6 a study case is presented. In section 7, a prototype is developed implementing the methodological proposition. Finally, conclusions and perspectives are briefly given in section 8.

2. SMART OBJECTS AND AMBIENT SERVICES

A smart object is able to communicate with its active environment, and interact with its users or other objects. According to [1] a smart object is able to acquire, to receive and to distribute information in a near or distant environment, and is able to carry out diverse actions on its own initiative, or request help from others objects. The smart object paradigm provides an ability to embed new capabilities into object allowing extended access information up to complex services invocation, and interactions. The smart object paradigm is based on ubiquitous computing concept [2], allowing interactions with smart object from virtually anywhere at any time, potentially transforming the way we live and work in a society of objects.

Ambient service is an abstract view of a system that provides information management capabilities, processing capabilities and event messages in an ambient network [3]. An object inserted in a local area network or a wireless network can appear or disappear in a service domain [4]. The access to the smart object in a service domain demands a spontaneous configuration and identification of nodes and their associated services in the ambient network [5].

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3. AMBIENT SERVICES ARCHITECTURES

Ambient service architecture must have essential characteristics to manage the smart objects, the equipments and the applications in a spontaneous and dynamic environment. There are several architectures that deal with the communication between computing entities [6]. The most used architectures are: Jini (Java intelligent network infrastructure), UPnP (Universal Plug and Play), OSGi (Open Services Gateway initiative), CORBA (Common Object Request Broker Architecture), and Web Services (WS).

The essential characteristics, that an ambient service architecture request, are:

- **Architecture:** It must be a distributed architecture, without central directory for service management;
- **Discovery:** It must use a mixed mode for service discovery (searching actively services and receiving services announces);
- **Description:** It must allows a rich description of the smart object services;
- **Control:** The execution of services must be based on data transfer and not in code mobility, for improved security;
- **Events:** It must send events when changes happens into smart objects;
- **System:** It must not depend on a specific programming language or a specific operating system (OS).

These properties help us to analyze, to synthesize, and to find the most adequate solution between the architectures presented.

Table 1: Ambient Services Architecture Comparison (- requirements not satisfied, 0 requirement partially satisfied, + requirement entirely satisfied)

	Jini	UPnP	OSGi	CORBA	WS
Architecture	0	+	-	0	0
Discovery	+	+	0	0	0
Description	+	+	+	+	+
Control	-	+	-	-	+
Events	+	+	+	+	+
System	-	+	-	+	+
Evaluation	***1***	***6***	***-1***	***2***	***4***

Table 1 summarizes the characteristics of the architectures analyzed. We have identified that UPnP architecture is the most suitable for achieving a high level of smart object interactions.

The automatic identification of the smart object allows the object to be represented in the ambient network and to configure its available services. These services help to support the interactions with the supply chain actors. In this case, the physical products are represented by smart objects that have two natures: service providers and/or service requesters.

4. RFID AND UPNP TECHNOLOGY

The automatic identification technology plays an important role in the identification methods. Radio frequency identification (RFID) is a support tool that allows to automate identification process and to improve operations managements reducing labor and eliminating human error [7]. RFID technology is being used by a wide variety of organizations to identify automatically objects in the supply chain processes. A traditional RFID system contains electronic labels or RFID tags, tag readers that can read and write data, and a controller (computer) that controls the system [8]. Additionally, the reading and writing process between the tag reader and the RFID tag can be realized from centimeters up to meters depending on the system characteristics. The stored information in the tag can be read or modified. It is possible to read simultaneously a set of tags. These tags can store from 64 bits up to some kilobytes and more in reading/writing modality. By attaching an electronic tag to a physical product, it can be automatically identified and located into the vicinity of a tag detection system. In addition, an object tagged can carry simple information such as the object code and some additional object information. Additionally, the object can carry a reference for networked or internet-based information. In others words, this represents the union between the physical object and its virtual representation for maximizing the use of the information and knowledge along product lifecycle in the supply chain.

UPnP is a distributed, open networking architecture that leverages Internet and Web technologies, such as Hypertext Transport Protocol (HTTP), Simple Object Access Protocol (SOAP), Generic Event Notification Architecture (GENA), Simple Service Discovery Protocol (SSDP) and eXtended Mark-up Language (XML) [9]. The generic UPnP architecture includes the two following entities: Devices (or controlled devices) and Control Points. The term **Device**, noted **UPnP(dv)**, is used to define a logical container of others devices and services, it is requested by controllers. The Services are logical entities providing a specific service to UPnP device network. Services are controlled by Control Points. A service exposes actions and models its state with state variables. A service in an UPnP device consists of a state table, a control server and an event server. A state table models the state of the service through state variables at run time and updates them when the state changes. A control server receives actions request, executes them, updates the state table and returns responses. An event server publishes events to interested subscribers anytime the state of the service changes. On the other hand, a **Control Point**, noted **UPnP(cp)**, is a logical entity that can control specific services provided by Device Points. An UPnP(cp) can have a dual role of Device and Control Point, noted **UPnP(dv/cp)**. A control point in an UPnP network is a controller capable of discovering and controlling other devices. After discovery, a control point could: retrieve the device description and get a list of associated services; retrieve service descriptions for interesting services; invoke actions to control the service; subscribe to the service's event source. Any time the state of the service changes, the event server will send an event to the control point. It is expected that devices can incorporate control point functionality, and vice-versa to enable true peer-to-peer networking.

5. METHODOLOGICAL PROPOSITION FOR SMART OBJECT INTERACTIONS

The smart objects interactions demands effective communication standards and interoperability. In that respect, a methodological offer is proposed so as to create an effective integration between a physical object and its virtual representation. This offer is applicable in multiple services domains [4], along product lifecycle. To present the conceptual solution three generic cases are considered:

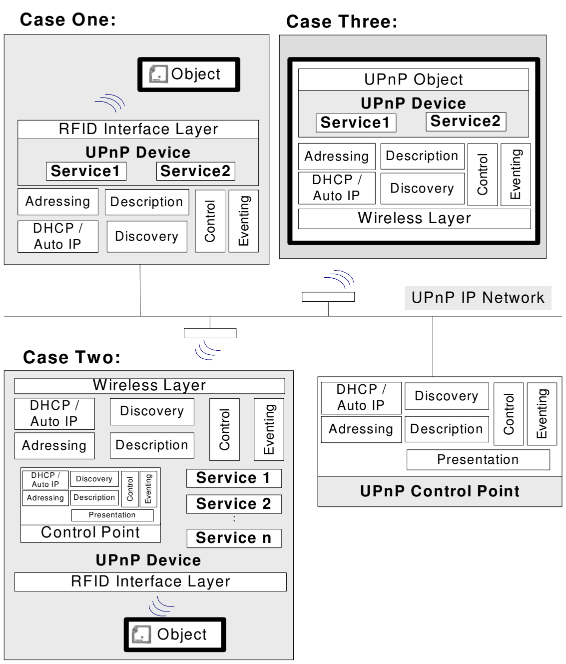

Figure 1. Methodological proposition integrating UPnP architecture with a RFID smart object.

- **Case One - UPnP assisted Passive Object:**

Case one on the Figure 1 represents an physical object carrying an electronic tag, which is managed by an UPnP(dv) plugged in an UPnP architecture. Process begins with the automatic identification of the tagged object by an UPnP(dv) using a RFID interface. When the device recognizes a physical product entering into the ambient network, services associated to the identified product type are mounted in the device memory by means of XML files uploaded from local memory or remote database. XML file is a document that summarizes the information about services, including actions and state variables [10]. Thus the services now available in the UPnP(dv) represent a virtual image of the product parameterized by the information stored in the tag or in a remote information system. At that time, all the services associated to the product are known and can be remotely called by all UPnP(cp) in the ambient environment. Conceptually, the merger between the **tagged object** and an **UPnP(dv)** plugged in an UPnP network forms an entity called **UPnP assisted passive object**, or in short, **service provider**. The service provider carries out its passive role responding to requirements of the supply chain actors plugged in the IP network such as automatic identification of the tagged object, related information about lifecycle of the object tagged, participation of the tagged object in decisions about its destiny [11]. It represents a low-cost solution with a versatile technological integration.

- **Case Two - UPnP assisted Active Object:**

In this case, the UPnP(dv) is enriched with Control Point capabilities, UPnP(dv/cp). Thus, the **tagged object** and an **UPnP(dv/cp)** plugged in an UPnP network form an new entity called **UPnP assisted active object**, or in short **service requester/provider**. This active object entity can be considered more intelligent that a passive object entity, offering services, because additionally an active object entity can demand and process information (service requester and service provider) to a services providers and thus makes its decision process according to the answers generated by the servers requested in the UPnP architecture [12]. A software layer in the control point is parameterized by identified information in the tagged product to manage product decision making and corresponding services calls in the UPnP ambient architecture.

- **Case Three - UPnP integrated object:**

In this situation, the UPnP device is embedded into the physical object, with no more need of RFID communication. The object embedded in an UPnP(dv) - or vice versa - is the most complex entity represented in the methodological proposition. Nowadays, industrial products of this nature are almost non-existent due to its high cost of manufacture and complexity. Nevertheless, a PDA with WiFi and RFID communication capabilities can act as a real smart object. Embedded computer power and energy storage or energy supplying actually impose limitations on such industrial development.

To extract real profit of this methodological offer, it is necessary to identify and to define in detail the interactions between all the actors of the supply chain - including the product - for every phase of product lifecycle. The interactions between the actors across the invocation or execution of services represent the key element in modeling process [12]. Therefore, the characterization of innovative services contributes a significant added value for the supply chain.

Modeling of interaction between smart objects and supply chain processes is thus supported by definition of a set of service classes associated to different stages of the product life cycle according to the capabilities of the tagged or smart object. These services are determined by: the nature of the product (product type), the interaction domain of the product (geographic localization, product's state, time,) and by the actor's profile. These services must adapt dynamically according to the geographical movements and of the changes of state of the physical products.

6. STUDY CASE

The case study analyzes the application of the methodological proposition in a Warehouse specifying Classes of Services. A warehouse is a traffic place of products, in which they are located and stored. The basic system is composed for pallets, box and products identifiable due to the tags, RFID readers, PDA's, UPnP Control Points and Temperature / Humidity Sensors. Figure 2 shows the components of the test case UPnP Architecture. Entry / Exit Point UPnP(dv/cp) RFID are situated at the entrance, at the exit of the warehouse and appropriate fixed places inside the warehouse to create the smart object. The tags allow the object identification (pallet / box / product). In addition, the tag contains Product Storage Conditions: storage temperature, storage humidity, product's dimensions, product's fragility, product's weight, and product's expiration date. Each UPnP PDA (cp) shows the list of services available and allows the user to define message subscriptions. The aims of UPnP(dv/cp) Warehouse Management System (WMS) are to control the flow of physical products in the warehouse and to manage the Warehouse's information. Finally, a UPnP(dv) Temperature / Humidity Sensor can monitor the temperature and the humidity in the place where the product is. A database associated to the physical objects allows offering augmented information to the warehouse's actors.

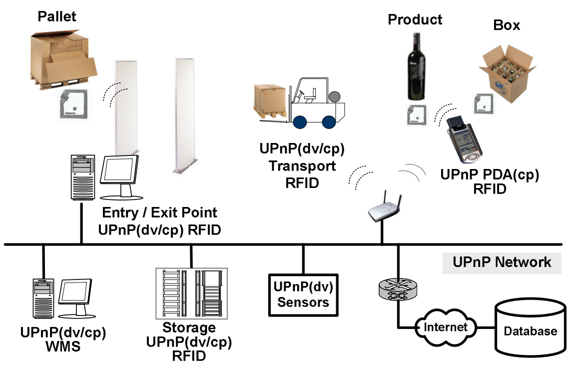

Figure 2: Architecture in a Warehouse.

In the first place, it is necessary to define the classes of services for the warehouse application in an UPnP IP network. A class of services groups the available functionalities for the actors of the supply chain. The product or the actors can offer its specialized services according to a role of "service provider" or "service requester". According to the methodological proposition it is possible to define a product as a passive or active object entity assisted in an UPnP network.

A. Services class for UPnP assisted passive object

In this case, represented by the case number one in the methodological proposition, a product, a box or a pallet managed by an UPnP(dv) act as Services Provider offering its services in the Warehouse. Service Requesters can be UPnP(dv/cp) WMS, UPnP(dv/cp) Transport RFID, UPnP(dv/cp) RFID System or PDA UPnP(cp). The functionalities are as follows:

- **Pallet / Box / Product Identification Service Class:** The objective of this Service Class is to identify a pallet, a box or a physical product either at the entrance, at the exit of the warehouse or in appropriate fixed. The relevant variables can be Product Code, Box Code, Pallet Code and any other product embedded information.
- **Product Storage Conditions Service Class**: The objective of this Service Class is to report the product storage conditions. The relevant variables are the Storage Temperature, the Storage Humidity, the Product's dimensions, the Product's fragility, the Product's Weight and the Product's Expiration Date.
- **Product Additional Information Service Class:** The objective of this Service Class is to report the product additional information (augmented information), such as the product's state, product traceability, production information and product recycling information.

B. Services class for UPnP assisted active object

In this case, represented by the case number two of the methodology, the product managed by a UPnP(dv/cp) form an active object entity that can demand and offer services in an ambient network. The functionalities that an UPnP assisted active object can demand are as follows:

- **Warehouse's Information Service Class:** The objective of this Service Class is to report the warehouse's information, to set and to adjust the temperature / humidity level inside the Warehouse in defined time intervals. Service Provider is the UPnP(dv/cp) WMS. The relevant variables are the Warehouse Identification, the Warehouse Description and the Temperature / Humidity in the Warehouse.
- **Flow Control System Service Class:** The objective of this Service Class is to report the vector (item, product localization, time and temperature / humidity). Service Provider is a UPnP(dv/cp) WMS. The Vector (item, localization, time, temperature, humidity) represents the relevant information.
- **Product Localization Service Class:** The objective of this Service Class is to report the product geographical localization. Service Provider is an UPnP(dv) embedding a RFID Reader and a GPS device or a mapping software. The vector Product Localization is represented by coordinates (x,y,z).
- **Transport Information Service Class:** The objective of this Service Class is to report the

information related with the transport activities within the warehouse. Service provider are the UPnP(dv/cp) Transports RFID. The smart object must generate a contract with the transport entity.

- **Temperature / Humidity Product Service Class:** The objective of this Service Class is to report values of temperature / humidity for a product. Service Provider is a UPnP(dv) Temperature / Humidity Sensor for monitoring the local temperature / humidity in the Warehouse.

7. EXPERIMENTAL PLATFORM FOR TESTING SMART OBJECTS INTERACTIONS

To validate our concepts we have develop a test platform. Using this platform, a physical product is transformed into a smart one, by enhancing with communication and reaction capabilities, through the use of advanced services. The experimental platform supports smart object interactions related to the warehousing activities in the supply chain. The services are differentiated by service domains and types of objects.

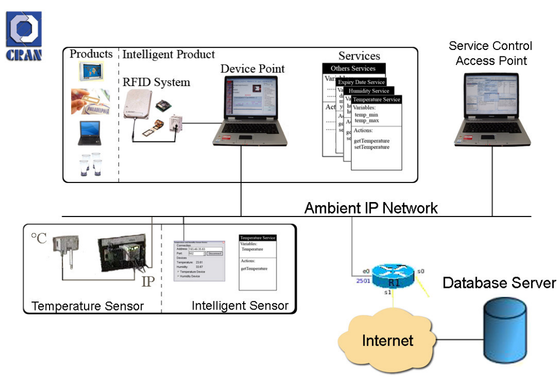

Figure 3. Advanced Service Architecture with RFID and UPnP technologies.

The tools used to model the Services and the UPnP Devices come from Intel [13]. After the generation of code for each Service and Device, with the help of Microsoft C#, we have developed our applications. In Figure 3 the architecture is presented, formed by three applications that interact for demonstrate high level object to object and user to object interactions.

The main component of the platform is the **RFID Device Point**, represented in the upper left corner. It is composed by an RFID system and an UPnP Device Application. The finality of this component is to generate a Smart Object, a distributed virtual entity in an Ambient Network. The mechanism of transforming from a physical product into a smart one begins with the attachment of a RFID tag to product. This gives to the product the capability to memorize personalized information and to interact with the Supply Chain Environment thought the RFID Device Points that can read and write it. The role of the UPnP Device Point application is to detect the object that is in the range of the RFID reader, to read the RFID tag in case it has discovered one and to generate the Services associated to the product. As RFID tags we have used the ICode1 tags from Philips, which has a unique 64 bits code and can store 48 bytes of user data. Using the first page of 4 bytes, we have separated the Services in families that represent the application case (example supply chain management). As result, we can have 255 (1 byte) families of 24 (3 bytes) services each. The service information is saved in the rest of 44 bytes from of tag's memory.

The UPnP Service Architecture helped us to easy manage the developing and execution of the services. One property of the application is the dynamic load of the services. This gives to the user the possibility to develop new services and to form his Services family. As services for the supply chain management, mainly related to the warehouse, we have developed: Electronic Product Code (EPC), object's dimension, object's composition, object's fragility, object's expiry date, temperature and humidity supported by the object, object traceability, etc. Using these services, the object can take decisions about its state or can communicate with the Warehouse Management System (WSM). Because the tag's memory dimension is restricted, an information database is used in order to offer augmented information to a physical object. The unification of the physical product, the RFID system, the UPnP Device Point and the Services represents the Smart Object.

The UPnP technology also helps in the distribution and distant execution of services to permit interactions between smart objects and users. The application used to interact with the smart objects in the Ambient Network is the **Service Control Access Point**. We have developed this UPnP Control Point application to ease manage and interact with the UPnP Services. For this, we have enclosed some special features that facilitate the use of the services. As example we have the classification by colors of the different UPnP Devices and the executions of background processes, which react at the different events, received from the Ambient Network, and execute specific user defined scenarios. The application has been developed for PC and PDA. The PDA Control Point increases the mobility of users that can be announced about the devices wherever they are.

Until now, we have presented the Smart Object only like a service provider, providing product and application case dependant services. The Smart Object is also a service requester. Services like temperature and humidity offer an allowed interval in which the product can be stored. So, we have included UPnP Control Point capacities in these services to request information related to the environment in which they are placed. The services are generated by the **Intelligent Sensor** application. This application enhances a normal sensor with UPnP capabilities. In the lower left part of the architecture we represent the two components: the physical sensor, from which we read the values and which is connected to the Internet, and a service provider application. The communication between the application and the sensor use MODBUS/TCP protocol.

The Intelligent Sensor device has the role to read the values from two sensors, temperature and humidity, and to create two UPnP Devices that provide the real-time values of physical ones. The UPnP control points can receive the modification of the values as events, so, the two services from the smart object can verify the values and give alarms in case of something wrong. Another application case for this application is the surveillance of a physical environment, where the sensors are deployed.

With the combination of RFID Device Points, Service Control Access Points and Intelligent Sensors the conception of Smart Object is demonstrate. Thus a smart object is an entity that interacts with its environment, supply chain actors, others Smart Objects and users. Actually, the presented prototype is being applied in experimental cases related to the supply chain. The current research is based on the integration of Wireless Sensors Network in the architecture.

To conclude, the active object entity, in a role of smart object, can negotiate with the WMS and make decisions about its storages conditions (temperature, space, duration, humidity …). In an unfavorable case, the product can looks for another warehousing. In addition, in the case of unexpected fluctuations in the storage conditions, the smart object can be informed by event notifications and thus to request the fulfillment of the storage conditions or to look for an alternative warehousing. Finally, this internal and automatic process reflects the behavior of a smart object in an ambient network environment demanding quality standards for its warehousing.

8. CONCLUSIONS AND PERSPECTIVES

This paper has proposed a methodology approach offering a high level of integration of a physical object into an IP ambient network for developing wireless communication and intelligent interactions with the supply chain actors during product lifecycle. A smart object is an entity with capabilities of services management (provider / requester) to fulfill intelligent interactions. RFID technology permits to identify and seamlessly link the physical object to its virtual image for maximizing the use of the information and knowledge along product lifecycle. Ambient services architecture based on IP network provides high-level standards functionalities for discovering and learning about product's services in a services domain. UPnP is an open networked architecture based on internet technologies that allows the communication and automatic ambient interaction between services-based devices. The methodological proposition aims to transform a physical object into an UPnP entity assuring intelligent interactions in an IP ambient network. This UPnP assisted object represents a smart object that advertises and informs about its capabilities to the actors of the supply chain. Service modeling is the key element for developing specializing services according to object purpose and its context in the supply chain. The prototype validates the proposed methodological approach supported by smart objects acting in a warehouse application thus providing real benefits and efficiency in the treatment of the product storage conditions.
We identify two research perspectives. We propose to standardize the services for a product along its lifecycle using service description based on XML language. Also, the evolution of the physical product towards a sensitive product, equipped with sensors for controlling the environment, allows the creating of new industrial applications in the supply chain management.

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