Product Informations modelling within the supply chain based on communicating object's approach

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PRODUCT INTERACTIONS MODELLING WITHIN THE SUPPLY CHAIN BASED ON COMMUNICATING OBJECT'S APPROACH

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Abstract
This article aims to analyze and contribute to the implementation of the communicating object concept in the supply chain. This approach considers a product as a service provider or a service requester. The proposed methodology is based on the ambient services architecture concept in order to manage product's services in an automatic and ubiquitous way. The UPnP technology (Universal Plug and Play) was chosen to manage the services of the communicating objects. In this approach, the direct communication with the products is supported by means of the automatic identification of the products using RFID technology. UML (Unified Modelling Language) was used with the aim of modelling the interactions and the services associated with the physical products. Finally, laboratory prototypes were created to validate the feasibility of the methodological proposition in order to manage the supply chain based on services interactions of communicating objects.

Keywords:
Communicating object, RFID technology, UPnP Technology, Service Modelling, Supply Chain.

1 INTRODUCTION

This article presents academic research activities developed at CRAN Laboratory concerning a high level services environment definition based on low cost RFID tagged product in an ambient service architecture based on standard IP technologies. This works was carried out within the Ambient Production System Group (SYMPA) with the aim of developing product-centric approaches in order to enhance product-process interactions from simple data exchange to high level service providing and innovation at the product level.

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

2 COMMUNICATING OBJECT´S APPROACH

Nowadays, in the manufacturing field, it's necessary to manage, in real-time, the information related to the interactions between products, processes and customers along the product lifecycle. These requirements generate the communicating object concept, which represents a physical product equipped with memory, perception, communication, actuation and decision-making capabilities in order to interact in its physical environment. Thus, a product with these new capabilities will be able to interact with other physical or informational entities and to bring significant transformations in the supply chain management.

Conceptually, the terms of intelligent product [1], smart object [2] and communicating object [3] are synonyms indicating the capability of an object to communicate with its active environment, and interact with its users or the other objects. According to [3] a communicating 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 communicating object's approach provides an ability to embed new capabilities into objects allowing extended access information up to complex services invocation, and interactions. This approach is based on ubiquitous computing concept [4], allowing interactions with others object from virtually anywhere at any time, potentially transforming the way we live and work in a society of objects.

This contribution aims to analyze and contribute to the implementation of the communicating object concept in the supply chain, in order to allow intelligent interactions between products and actors, such as processes, users or other products, in the phases of transformation, distribution, storage, use or even in the recycling [5]. This approach considers a product as a service provider or a service requester. The product, as services provider, has a passive role with the aim of answering to the interactions initiated by the supply chain actors. As a service requester the product has an active role with the aim of initiating interactions towards the supply chain actors. In this approach the interactions between a product and the

supply chain actors are supported by the ambient service concept.

Ambient service is an abstract view of a system that provides information management capabilities, processing capabilities and event messages in an ambient network [6]. An object inserted in a local area network or a wireless network can appear or disappear in a service domain [7]. An ambient network is characterized by offering a continuous and transparent connection in an IP environment (Internet Protocol) to all the actors demanding and/or providing services anytime and anywhere [8].

2.1 RFID Technology for Communicating Objects

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 [9]. 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 [10]. 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.

3 AMBIENT SERVICES ARCHITECTURE

Ambient service architecture must have essential characteristics to manage the communicating objects, the equipments and the applications in a spontaneous and dynamic environment. There are several architectures that deal with the communication between computing entities [11]. 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 allow a rich description of the communicating 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 communicating objects;
- **System:** It must not depend on a specific programming language or a specific operating system (OS).

These properties allows 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 communicating object interactions.

The automatic identification of a communicating 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 communicating objects that have two natures: service providers and/or service requesters.

4 UPNP TECHNOLOGY

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) [12]. 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 PRODUCT- PROCESS INTERACTIONS

The communicating 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 [7], along product lifecycle. To present the conceptual solution three generic cases are considered:

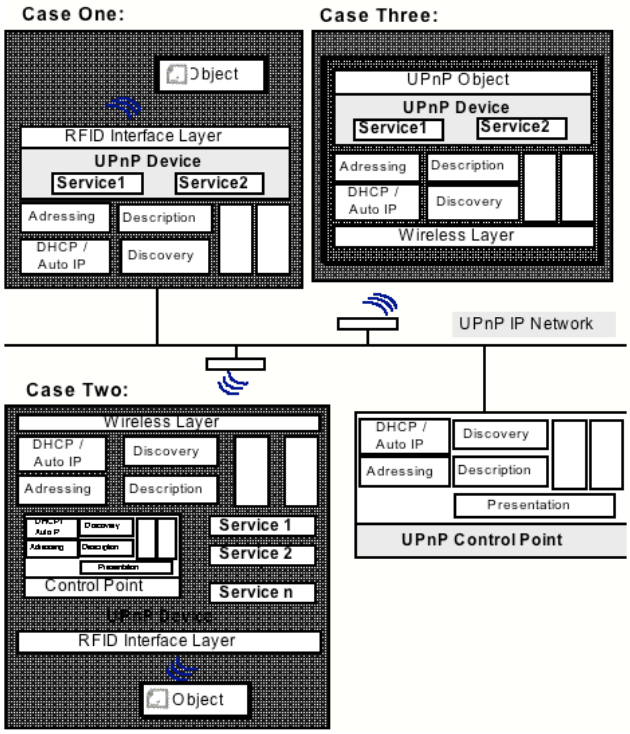

Figure 1: Methodological proposition integrating UPnP architecture with a RFID communicating object.

- **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 [13]. 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 [14]. 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 [15]. 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. UML Class Diagram in Figure 2 summarizes the relationship between devices, services, state variables and actions.

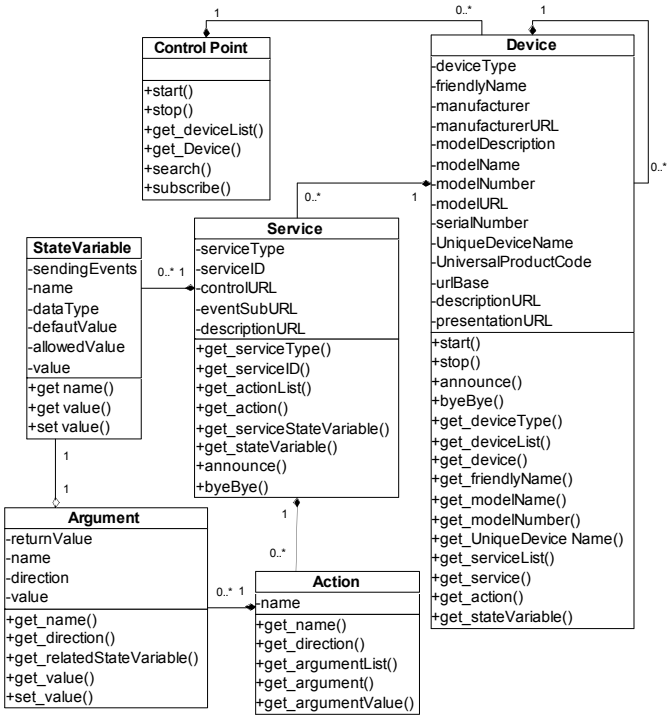

Figure2: UML Class Diagram: Device, Service, Actions and State Variable in UPnP.

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

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 Mote Device (Wireless Sensor Network) or a PDA with WiFi and RFID communication capabilities can act as a real communicating 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. Therefore, the characterization of innovative services contributes a significant added value for the supply chain. Modeling of interaction between communicating 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 communicating 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: WAREHOUSE APLICACTION

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 3 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 communicating 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, 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.

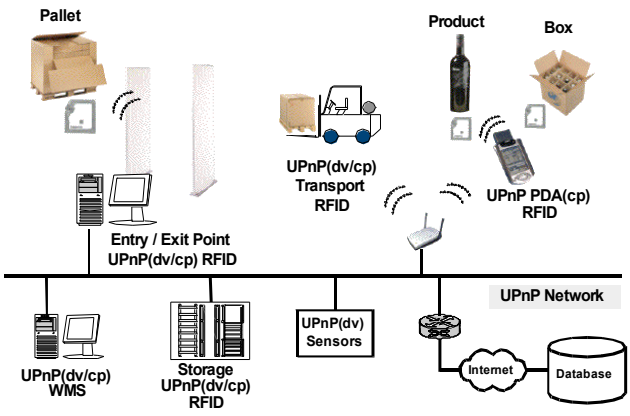

Figure 3: Architecture in a Warehouse.

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 communicating product as a passive or active object entity assisted in an UPnP network.

6.1 Services class for UPnP assisted passive object

In this case, represented by the case number one in the methodological proposition, the product or pallet managed by an UPnP(dv) act as services provider offering its services in the warehouse. Service Requesters can be UPnP WMS(dv/cp), 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, 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.

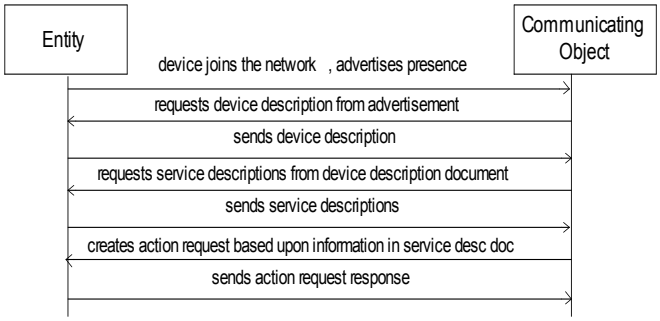

Figure 4: UML Sequence Diagram describing interactions between communicating objects and entities.

6.2 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. UML Sequence Diagram in Figure 4 shows the message flow when a active communicating object retrieve the description documents and later invokes actions on a entity (resource, machine …). 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 communicating object must generate a work 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 COMMUNICATING OBJECTS INTERACTIONS

To validate the methodological proposition a test platform was created at CRAN laboratory. Using this platform, a physical product is transformed into a communicating object, by enhancing with communication and reaction capabilities, through the use of advanced services. The experimental platform supports communicating object interactions related to the warehousing activities in the supply chain. The services are differentiated by service domains and types of objects.

The tools used to model the Services and the UPnP Devices come from Intel [16]. After the generation of basic code for each Service and Device, with the help of Microsoft C#, the applications were developed. In Figure 5 the architecture is presented, formed by three applications that interact for demonstrate high level object to object and user to object interactions.

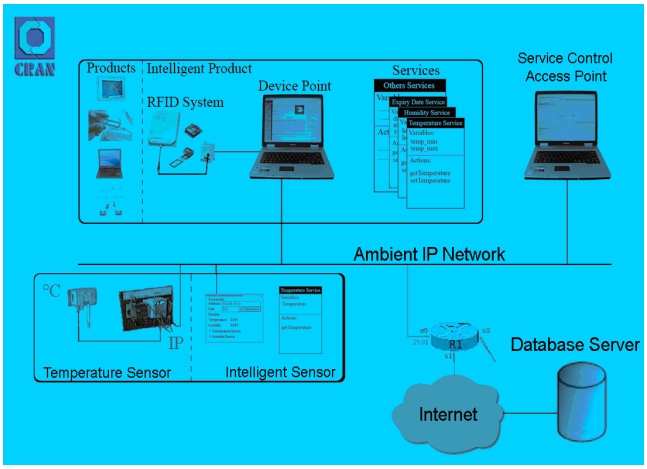

Figure 5: Advanced Service Architecture with RFID and UPnP technologies.

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 communicating object, a distributed virtual entity in an ambient network. The mechanism of transforming from a physical product into a communicating object 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. ICode1 RFID tags from Philips were used, which has a unique 64 bits code and can store 48 bytes of user data. The services are classified by families according to product type (products, box or pallets).

The UPnP Service Architecture allows the developing and execution of the services easily. 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. The services for the supply chain management, mainly related to the warehouse, are: electronic product code (EPC) service, product's dimension service, product's composition service, product's weight service, product's fragility service, product's expiry date service, temperature and humidity service (supported by the product), product traceability service, 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 **communicating object**.

The UPnP technology also helps in the distribution and distant execution of services to permit interactions between communicating objects and users. The application used to interact with the communicating objects in the Ambient Network is the Service Control Access Point. UPnP Control Point application allows the interaction with the UPnP Services. For this, some special features was enclosed to facilitate the use of the services. As example, the control point application runs background processes for reacting at the different events received from the ambient network, and thus to 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 here, the communicating object was presented only as a service provider, providing product and application case dependant services. The communicating 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 capabilities within the communicating object using 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 the two components are presented: 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 communicating 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 communicating objects is demonstrate. Thus a communicating object is an entity that interacts with its environment, supply chain actors, others communicating objects and users. 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.

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

8 CONCLUSIONS AND PERPECTIVES

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 communicating 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 communicating 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 experimental platform validates the proposed methodological approach supported by communicating 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.

9 ACKNOWLEDGMENTS

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