SMART OBJECTS AND SERVICES MODELING IN THE SUPPLY CHAIN

Eddy Bajic, Aldo Cea (*)

Research Center for Automatic Control - CRAN - CNRS UMR 7039
University Henri Poincaré, Nancy, BP 239, 54506 Vandoeuvre-les-Nancy, France
eddy.bajic@cran.uhp-nancy.fr ; aldo.cea@cran.uhp-nancy.fr

Abstract: As management has developed throughout the years, the production and logistic processes have changed dramatically toward a product centric approach. Consequently, new capacities are expected for the products in their informational, sensory and decisional interactions with processes, information systems, operators and users. This article presents an approach that aims to transform a product into intelligent product or smart object. In the methodological solution and in the study case, product and data are upgraded to intelligent object and services, providing a high level of functional interactions in networked and ambient services architecture based on the RFID and UPnP technologies.

Keywords: Information technology, Automation, Architectures, Computer communication networks, Distributed computer control systems, Warehouse automation.

1. INTRODUCTION

Nowadays, increasing requirements of reactivity in the supply chain topic are observed among the product, the processes and the clients across the product lifecycle. For it, the interactions between the processes, the operators and the product since manufacture level until its use require more information and automated or intelligent exchanges between partners (Karkkainen, *et al*., 2003), in a sure and relatively quick way. High standards of product quality, increasingly short response time and product customization are factors relevant in the new market exigencies (Helander and Jiao, 2002). Specifically, the requirements that emerge in the supply chain are as follows:

- To find out the exact status of production lines and product achievements;
- To customize the product as soon as possible during production according to client demand;
- To trace all the interventions carried out on the product;
- To ensure that the product reaches the customer under the best conditions of perenniality and traceability;
- To allow accessibility of extended information about product usage or characteristics;
- To develop interactions between the products and their environment;
- To offer services on product knowledge, usage and practice, maintenance, dismantling, recycling, destruction;

This work aims to transform a physical object into intelligent actor (smart object), who can interact with other objects in a services environment during its lifecycle. Automatic Identification technologies by radio frequency (RFID) and UPnP (Universal Plug and Play) technology allows to conceptualize and to define

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the desirable characteristics of a distributed system integrated by product intelligent in ambient services architecture. This paper proposes a methodological solution incorporating a smart object frame and RFID & UPnP technologies. A case study is analyzed to show an industrial application in the supply chain.

2. INTELLIGENT PRODUCT AND SERVICES

The guide line of this work is based on the following proposition: "the product is an actor who manages his evolution in cooperation with the different actors from the supply chain (supplier, producer, distributor, and consumer)" (Bajic and Chaxel, 2002). Intelligent product concept (Wong *et al*., 2002), as actor in its lifecycle, respond to the proposition formulated. This one can be defined as a physical and informational object with the following capabilities:

- it possesses a unique identification;
- it is capable of communicating effectively with its environment (Kintzig et al., 2002);
- it can retain or store data about itself;
- it deploys a language to display its features, production requirements etc…
- it is capable of participating in or making decisions relevant to its own destiny (to what happens to it).

The physical and informational nature of a product is characterized conceptually as physical product and as virtual product. The **physical product** is a material entity identified and characterized by the intrinsic variables that describe it (such as forms, weight, size, etc.). The **virtual product** in addition is represented like information system, associated to some mechanisms of action and decision providing to the physical product new extrinsic capacities and possibilities of interaction capabilities with its environment. In this approach, a **process** is considered as a system (material, software and human) that realizes information, decision and action activities, connected to a product. Product lifecycle is decomposed into a number of different processes associated with each supply chain phase. An **interaction** is represented as a mechanism of exchange between a product and a process, allowing the deployment of an action initiated either by the product or by a process. The **service** concept definition is represented by a material and/or an information resource that offers a specific functionality, which can be locally available, or remotely through a network. Services are supported by the interaction concept.

An actor is thus a **service producer / service provider** or a **consumer / client** that asks for services offered by other actors. In a classical approach, the product has usually a provider role and the processes are clients; the product is passive to its environment, and it responds to the process requests. Let's say for example: product identification, product information research, ... In a reactive approach, the product becomes a client asking for services and receiving benefits while the processes are service providers. The product invokes demands and actions - called services – towards the host process; for example during product use, or product maintenance, storage, recycling …, thus performing real product-driven interactions (Cea and Bajic 2004).

From the point of view of the technological implementation, RFID technology (Radio Frequency Identification) allows communication between the physical product and the virtual product by means of electronic tags mounted on the product, radio frequency protocols, and networks. Finally, to answer to the implicit requirements of this proposition, as services offering and requesting in an automated supply chain environment, an ambient services architecture is necessary to host intelligent interactions. Further on in this essay the features of such architecture are analyzed putting the emphasis on UPnP (Universal Plug and Play) technology.

3. SMART OBJETS AND AMBIENT SERVICES ARCHITECTURE

Conceptually, the terms of intelligent product and smart product (Kintzig *et al.*, 2002) are synonyms indicating the capability of an object to communicate with its active environment, and interact with its users or the other objects. 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. According to Upadhyaya *et al.* (2002), a smart object is aware of its environment and is able to perceive its surroundings through sensors, work with peers using short-range wireless communication technologies, and provide context-aware services to users in smart environments. In addition, smart objects can provide increasingly sophisticated services to users in smart environments when they are able to take advantage of nearby handheld devices in an "ad-hoc" way. In synthesis, the new paradigm of smart object provides an ability to embed new capabilities into object allowing extended access information up to complex services invocation, and interactions from virtually anywhere at any time, potentially transforming the way we live and work in a society of objects.

In order to develop interactions between an intelligent product and the other actors of the supply chain, ambient services concept is analyzed and characterized. In ambient services, the product is a **service provider** or a **service requester**, demanding the transparency and the associated control mechanisms of all the offered services in an environment. **Ambient service** is an abstract view of a system that provides information management capabilities, processing capabilities and event messages in an ambient network, representing a working environment. A product inserted in a local area network or a wireless network can appear or disappear in a **domain of work**. The access to the intelligent product in domain of work demands a spontaneous configuration and identification of nodes and their associated services in the ambient network.

Ambient architecture based on Internet technologies have been developed integrating concepts such as ad-hoc network, mobility management, and service discovery. A generic Ambient Services Architecture for intelligent products interaction management needs the following standard services:

- **Identification:** To know the product unique identity in the ambient network.
- **Localization:** To know where the product is in the ambient network.
- **Information brokering:** To identify the information sources allowing the execution of a given service.
- **Service Discovery and Registry:** To automatically discover and advertise for services in the ambient networks using communication mechanisms: to localize service, to retrieve service information and call parameters, to announce service offering. Each new service provider is registered at the time of its connection to the network.
- **Service Invocation:** Process by which a service is requested by a client.
- **Event notification:** When a change happens in the parameters or variables of a service in a provider, the interested users receive a service notification message to inform them of the modification. For it, those users must first subscribe to receive event notifications as they occur.

Currently most known services architectures are UPnP, Jini, OSGi, CORBA. The services protocols such as Salutation, SDP, SLP, WSDA allow to carry out the Process Service Discovery. UPnP generic architecture rely on Remote Procedure Call model instead of code mobility as do Jini and OSGi which are Java dependant and thus sensitive to code vulnerability problems. UPnP model is supported by Application Programming Interfaces for Windows and Linux, and makes large use of XML data exchange over IP networks. CORBA communicates distributes objects in a heterogeneous environment without dynamic reconfiguration capabilities in an information system. Finally, UPnP architecture can be considered well suited to developing the smart objects interactions concept related to the wide open and distributed aspects of the domains of works and offering pereniality according to standards TCP/IP, XML and Web technologies (Jeronimo and Weast, 2003).

4. RFID AND SMART OBJECTS

The automatic identification tech (Auto-Id) plays an important role in the identification method. In the near future, radio frequency identification (RFID) will be a real option for supply chain projects. RFID represent a reliable method for data transfer in object identification. 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. 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. (Paret, 2001). By attaching an electronic tag to a physical product, it can be automatically **identified** and **located** into the vicinity of a tag detection system. The identification of an object allows the union between the physical world (physical product) and the virtual world (virtual product). This union maximizes the use of the information and knowledge along the supply chain.

5. UPNP TECHNOLOGY

The UPnP™ Forum is an industry initiative designed to enable simple and robust connectivity among stand-alone devices and PCs from many different vendors, leading the way to an interconnected lifestyle (UPnP Forum, 2004). 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) (Intel UPnP, 2004).

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. A 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.

6. METHODOLOGICAL PROPOSITION

Nowadays, the dynamic industrial and logistic context, demands high standards and interoperability for processes performance. In that respect, a methodological offer is proposed so as to create an effective integration between a physical product and the interactive world of the information technologies.

This offer is applicable in multiple domains of work, along product lifecycle. To present the conceptual solution three generic cases are considered (Cea and Bajic, 2004):

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

Case one on the Figure 1 represents a product carrying an electronic tag and plugged in UPnP architecture. The merger between the tagged object and an UPnP(dv) forms the entity of Intelligent Product. Process begins with the automatic identification of the product by an UPnP(dv) using a RFID interface. When the device recognizes an object 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. 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 (Cea, *et al.*, 2004). At that time, all the services associated to the product are known and can be remotely called by all UPnP(pc) in the ambient environment. In addition, the product is a passive entity managed by the device, thus it is called an UPnP assisted passive object, at low cost and versatile integration.

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

In this case, additionally to the characteristics described in the previous case, the UPnP device has Control Point capabilities to act as an active entity, UPnP(dv/cp). The product by means of a dual role of a server (as a service producer) and a consumer (as a service requester) can support an intelligent behavior (Cea, *et al.*, 2004). A software layer in the control point is parameterized by identified product information to manage product decision making and corresponding services calls in the UPnP ambient architecture. The intelligent product can demand services to a services provider and thus makes its decision process according to the answers generated by the servers requested in the UPnP architecture

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

In this situation, the UPnP device is embedded into the physical product, with no more need of RFID communication. The intelligent product 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 high cost of manufacture and complexity. Nevertheless, a PDA with WiFi and RFID communication capabilities can act as such an intelligent object. Wireless technology is an alternative contribution to mobility and to automatic identification of a product, for the use of intelligent services in an UPnP network (Zahariadis *et al.*, 2004). 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 value added for the supply chain.

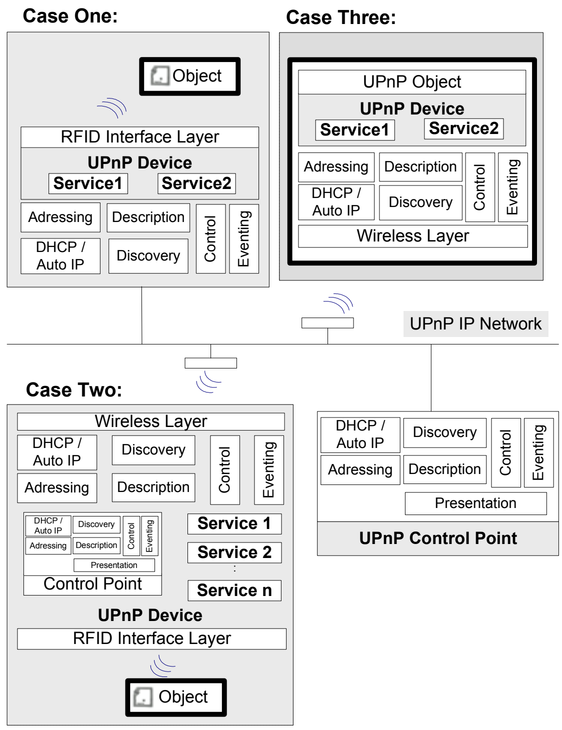

Fig. 1. Methodological proposition integrating UPnP architecture with a RFID smart object.

7. SERVICES MODELING

To model the services and interactions between a product and the processes the UML language (Unified Modeling Language) is utilized. Referring to Figure 2 the Class Diagram summarizes the relationship between device, services, state variables and actions (Jeronimo and Weast, 2003).

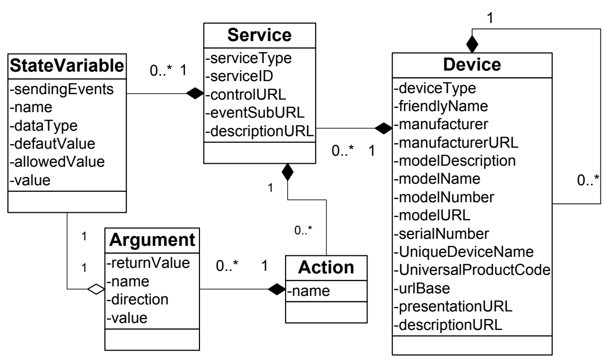

Fig. 2: Class Diagram: Device, Service, Actions and State Variable in UPnP.

Static view in the service modeling considers that each UPnP service has a service type Uniform Resource Identifier (URI) that uniquely identifies the service. Every service also has a serviceID URI that uniquely identifies the service among all of a device's service.

Additionally, every service maintains three URLs that provide the information necessary for control points to communicate with services, as follows: the ControlURL is where control points post request to control this service; the EventSubURL is where control points post request to subscribe events; the DescriptionURL tells controls point the location from which they can retrieve the service description document. Each service has zero or more state variable. Each state variable has a name, a type, and a current value. A state variable also has a set of allowed values used to describe the range of permissible values for the variable. Any of the state variables can trigger events on state changes as determined by the implementer of the service. Every input argument to an action is associated with one of the service's state variable.

In a dynamic view, for example Sequence Diagram in the Figure 3, shows the message flow when a control point invokes an action on a device service. The control point application uses the device description to determine the service definitions and then retrieves the corresponding service description documents for the discovered device.

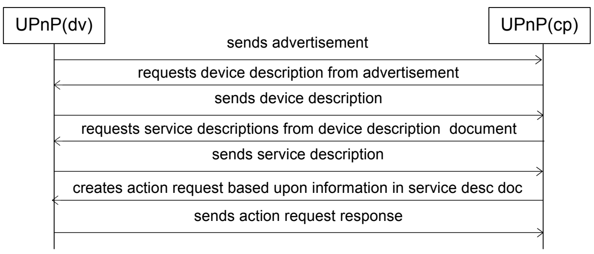

Fig. 3. Sequence Diagram: UPnP(cp) invoking action.

Service modeling is based in the methodological proposition and has to be specified for each industrial application considering a product as a service provider and a service requester. In the following section, a case study in warehousing activity is presented to indicate and describe the classes of services for an intelligent product.

8. CASE STUDY

The case study conceptually 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 and products identifiable due to the tags, RFID readers, PDA's, UPnP Control Points and Temperature Sensors. Figure N° 4 shows the components of the test case UPnP Architecture. **RFID reader systems UPnP(dv/cp)** are situated at the entrance, at the exit of the warehouse and appropriate fixed places inside the warehouse to determine the product position. The **tags** allow the pallet / product identification. In addition, the tag contains Product Storage Conditions: storage temperature, product's dimensions, weight, and product's expiration date. Each **PDA UPnP(dv/cp)** shows the list of services available and allows the user to define message subscriptions. The aims of **Warehouse Management System UPnP(dv/cp)** are to control the flow of physical products in the warehouse and to manage the Warehouse's Information. Finally, a **Temperature Sensor UPnP(dv)** can monitor the temperature in the place where the product is.

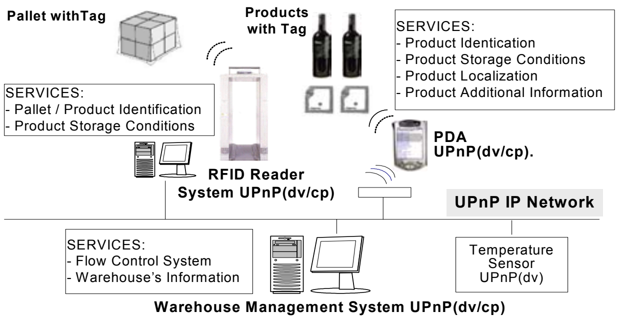

Fig. 4. Architecture in a Warehouse.

8.1 Classes of Services:

A class of services groups the available functionalities for all the actors of the supply chain, where the product or the actors can offer its specialized services according to a role of "service provider" or "service requester". In the case study, the classes of services are as follows:

- **Pallet / Product Identification Service Class:**

The objective of this Service Class is to identify a pallet or a product either at the entrance, at the exit of the warehouse or in appropriate fixed places inside the warehouse. Service Provider is a Pallet or a Product. Service Requester is a RFID Reader System UPnP(dv/cp) or a PDA UPnP(cp). The relevant variables are the Universal Product Code and the Pallet Code. The Actions allow to get the Universal Product Code and to get the Pallet Code.

- **Product Storage Conditions Service Class:**

The objective of this Service Class is to report the product storage conditions. Service Provider is a Product. Service Requester is a RFID Reader System UPnP or a PDA UPnP(dv/cp). The relevant variables are the Storage Temperature, the Product's dimensions, the Product's Weight and the Product's Expiration Date. The Actions get the information of each variable.

- **Product Localization Service Class:**

The objective of this Service Class is to report the product geographical localization. Service Provider is a UPnP(dv) embedding a RFID Reader and a GPS device or a mapping software. Service Requester is a Product or an UPnP(cp) in the Warehouse. The vector Product Location represented by coordinates **(x,y,z)** is obtained across of the service Actions invoked by the UPnP(cp).

- **Product Additional Information Service Class:**

The objective of this Service Class is to report the product additional information, such as the product traceability data, production information and product recycling information. Service Provider is a database. Service Requester is an UPnP(cp) in the Warehouse.

The Vector represented by the Item x at Point y at Time z allows coding of product tracking and traceability information. Others relevant factors are the Production Information, Guarantee and Recycling Information among others. The Actions are of the type "Get Information" across the UPnP IP Network.

- **Temperature Product Service Class:**

The objective of this Service Class is to report values of temperature for a product. Service Provider is a Temperature Sensor UPnP(dv) monitoring the local temperature in the Warehouse. Service Requester is an UPnP(cp) in the Warehouse. The Action is "Get Product's Temperature".

- **Flow Control System Service Class:**

The objective of this Service Class is to report the vector (item, product localization, time and temperature). Service Provider is a Warehouse Management System UPnP(dv/cp). Service Requester is a Product or PDA UPnP(cp) for human operator use. The Vector (item, localization, time and temperature) represents the relevant information. The Actions gets the vector indicated.

- **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 level inside the Warehouse in defined time intervals. Service Provider is the Warehouse Management System UPnP(dv/cp). Service Requester is a Product or a PDA UPnP(cp). The relevant variables are the Warehouse Identification, the Warehouse Description and the Temperature in the Warehouse.

Finally, the role of an intelligent product, in this studied case, is to make a decision for its storage place by interfering with the Warehouse System to negotiate its storage 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 intelligent product can be informed by event notifications and thus to request the fulfillment of the storage conditions or to look for an alternative warehousing. This internal and automatic process reflects the behavior of an intelligent product in an ambient network environment demanding quality standards for its warehousing.

9. CONCLUSION

Nowadays, supply chain actors demand new requirements for a product in terms of traceability, product information, product services and decision making along product lifecycle. Answering to this problematic, the article shows how a physical product can be transformed into an intelligent product, functionally integrated in an ambient network for decision making and actions invocation by means of services. A product is no longer just a physical part carrying data or information, but tends to an active entity that can act as a service provider or as a service requester, i.e. a smart object. Ambient services architecture allows the basic functionalities standard to deploy. The potentialities of UPnP and RFID as open and flexible standards represent the foundation technologies to develop product services modeling and components design to support intelligent product interactions in an ambient services network architecture based on internet standards. Methodological proposition integrates effectively a physical product and the UPnP Devices in an ambient network offering classes of services for all supply chain actors. Based in this framework, a detailed model of these services generates the bases to create new functionalities for a physical product. Case studied shows the feasibility for implementing the conceptual proposition presented. The methodological approach is continued to define classes of services and demonstrators corresponding to the product lifecycle phases in the supply chain.

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