A Framework for Lifecycle Management Based on IoT and RFID

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Abstract: The Internet of Things (IoT) envisions a multitude of heterogeneous objects and interactions with the physical environment and in the same time requires software architectures that are able to deal with a large amount of information, queries and computation. This paper presents a semantic modelling approach for addressing the functionalities provided by these objects in an IoT framework. In particular, the paper focuses on RFID networks integration by using dedicated association mechanisms, and proposes solutions for solving important issues such as enabling high level semantic interoperability, developing RFID middleware for providing identification, authentication, validation, monitoring of IoT devices and of encapsulated "real-world services, ensuring compatibility with standards and managing specific applications. As a novelty, the paper brings in a framework for developing solutions for lifecycle management of assets, which includes a three-tier architecture using algorithms of artificial intelligence to facilitate the association of context-aware systems with intelligent IoT devices.

Keywords: RFID, IoT, middleware, semantic interoperability, block functions, context-aware, cloud computing, assets management

1. INTRODUCTION

Radio frequency identification (RFID) (Finkenzeller, 2003) is a technology that can be used to tag physical goods and objects, allowing them to be detected and identified automatically. RFID is already being used in various applications, the most numerous in important domains like Food, Pharmaceuticals, Medical Devices, Agriculture, Retailing, and Maintenance. The basic functionality of an RFID system is asset management because it permits to implement functions like: identification, authentication, validation, monitoring, alerting. The difference of RFID when compared to other radio technologies, like WLAN and Bluetooth is that the transponder relies on the reader for its power. RFID can work on two distinct principles: "inductive coupling in the electromagnetic near-field with load modulation at LF/HF" or "wave coupling in the electromagnetic far-field with backscatter at UHF/MW" (Pardal and Marques, 2011).

RFID technology has advanced significantly over the last years, due to the technological advances in microelectronic which have reduced the size and costs of HF and UHF RFID infrastructure, permitting longer and faster reading rates. RFID technology is now able to deal with applications involving mobility. The increasing of the number of tagged objects and of software and hardware elements which can be connected in an open service environment now enable specific functionalities and offer important advantages for their identification and addressing. These new situations require a more robust, flexible and complex associations such as sensor networks (including RFID networks), and also an effort to resolve issues at different layers of the communication architecture in different application contexts. The most promising solution for all issues is the integration of RFID networks in Internet of Things (IoT)

IoT consists of large-scale, distributed multi-agents placed in dynamically changing environments that present wireless connectivity. In its beginning IoT vision was to enable such devices to transfer data from various objects into the web, providing sensor network common interface, query optimization, integration of data from various sensors, sensor network monitoring, and intelligent sensor data processing. In this regard, this paper aims to offer arguments for RFID networks integration in IoT supported applications, involving not only the processing of static information (such as object identification and description), but also effecting the up-to-date service requirements of an environment with multiple reader sensors and multiple protocols, in particular for performing life-cycle management.

2. RELATED WORKS

Our research objectives are linked to two emerging areas of study. The first area addresses the solutions for integrating RFID networks (typically as a particular case of Wireless Sensor Networks) in applications with intensive use of IoT and Cloud Computing. The second area is related to the use evolved techniques (usually imported from Artificial Intelligence) - like the context awareness concept - in the performance improvement of control procedures. In particular, our objective was to place RFID networks in a position that can take advantage of the facilities offered by the top achievements in these two areas.

Related to the first area, we mention as a basic solution the method to couple "objects" to the Internet of Things by giving them identities as virtual representations through low-cost RFID tags (Elmstrøm et al., 2013). The solution includes a dedicated architecture for RFID reading that supports the interconnection of components with an access mechanism based on open network protocols. The architecture of a traceability information system for intelligent logistics pallet based on IoT is proposed by (Lin, 2013). The system allows the integration of RFID, GIS, GPS, with Internet technology in order to develop applications in business and manufacturing, providing reengineering capacity. In (Fera et al., 2013) is presented an economic evaluation framework of an RFID system implementation with IoT support. The analysis highlights the economic impact on logistics resources and cost reduction. The evolution of the RFID technology towards the more effective Near Field Communication (NFC) technology is discussed in (Katiyar et al., 2014). The authors present the advantages that result from the connection between the context aware NFC technology and the ubiquitous web services of IoT technology in enhancing the performance of ambient intelligent systems. The same issue of the association of web services with RFID applications is addressed in (Abad et al., 2012), pointing out the advantage of using RFID middleware to manage generic RFID inside a homogeneous acquisition network with IoT support. Two new concepts are introduced in this paper, an access mechanism and a language to define RFID Reader networks. The use of RFID-Sensor Networks (RSNs) is proposed for an application in which sensory systems embedded in smart devices are interconnected as a collective cloud of data sources which can satisfy end-users service requests (Al-Turjman et al., 2013). The authors assert that such structure outperforms other schemes in terms of minimizing delay, energy consumption and packet loss. In (Perera et al., 2014) are examined and evaluated several IoT solutions which include context-aware technology perspectives, using a dedicated framework that allow data acquisition from various sensor networks, among them RFID networks. Let note also the study presented in (Lee et al., 2015) on the association of RFID tags with Cyber-Physical Systems (CPS) as a trend in transforming manufacturing industry to the next generation Industry 4.0.

The second area is less well represented in literature, especially due to the novelty of the topic. However, we can mention as representative few recent works which are considering context awareness as support for RFID - IoT integration and for the use of Web Services in this aim. (Boddhu et al., 2014) analyse the integration of Human-centric sensing paradigm in a generic architecture able to enhance situational awareness. (Celikkan and Kurtel, 2015) propose a context-awareness based software platform modelled as a layered architecture, having extensibility as main facility. Adding artificial intelligence techniques in the management of IoT systems is the aim of (Poniszewska and Kaczmarek, 2015). Another important theoretical issue is the developing of mathematical models for the virtualization of sensor node resources (Kantarci and Mouftah, 2015).

Finally, let mention that several European Research Projects addressed foundations for fostering the emerging Internet of Things. Among them IoT-A, the FP7 European Lighthouse Integrated Project, has addressed and created the architectural reference model together with the definition of an initial set of key building blocks (http://www.iot-a.eu/public).

3. TRENDS IN RFID AND IoT INTEGRATION

A big advantage of RFID is based on standardization that permit not only an easier communication but also interfaces with other possible protocols. EPC standards defines specifications for hardware, software, and data and provides services based on the Electronic Product Code (EPC), a globally unique serial identifier for RFID tags. The EPC global Architecture Framework (Traub et al., 2007) is a collection of interrelated standards, for the exchange of data and physical objects between companies. The standardisation made possible to implement all the necessary steps to identify, authenticate and validate the data from the tag. The most important challenge is related to develop full interoperability of interconnected devices possible, providing them with a high degree of smartness. This would make the functionality and information provided by IoT devices easily accessible for 3rd party application developers and would therefore open a completely new business sector in the same way as smart phones opened the market for mobile apps.

(Atzori et al., 2010) present IoT paradigm as a result of the convergence of different visions. In Fig. 1, the main concepts, technologies and standards are highlighted and classified with reference to the IoT visions they contribute to characterize best. Normally, we have placed RFID in the "Things" oriented vision. From such an illustration, it clearly appears that the IoT paradigm shall be the result of the convergence of the three main visions addressed above.

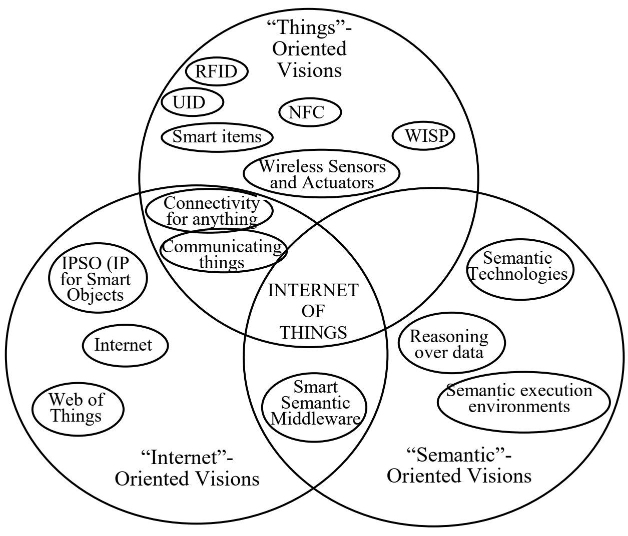

Fig. 1. IoT paradigm as a result of the convergence of different visions (after Atzori et al., 2010).

In order to realize IoT visions appears a need to enable high level interoperability between heterogeneous IoT devices. In this aim we consider the division into two levels of interoperability methods: *connectivity* and *semantic* (Kiljander, 2014).

The connectivity level interoperability covers basically the traditional Open System Interconnection (OSI) model layers from the physical to the transport layer. When devices are interoperable at the connectivity level they are able to transmit data with each other. The devices are not, however, able to understand the meaning of data.

The semantic level interoperability covers the technologies needed for enabling the meaning of information to be shared by communicating parties.

In traditional communication systems the semantic level interoperability has been solved by human users who communicate with each other by using devices.

By the contrary, in IoT devices become users and they therefore need to communicate directly with each other and interpret the meaning of information in run-time.

For this reason, we consider that the best solution is to adopt the design framework proposed by the IEC 61499 standard.

The IEC 61499 architecture was conceived in anticipation of the demand for distributed automation, and has evolved from the IEC61131-3 standard, widely used for PLCs programming and interconnection, as a most appropriate approach for the interconnection of devices equipped with interfaces to the environment, such as sensor networks, communication networks or processes.

The basic design element of the IEC 61499 architecture is the function block (FB). FBs can be used for describing decentralized control logic and properties of devices, such as their interfaces, as illustrated in fig. 2.

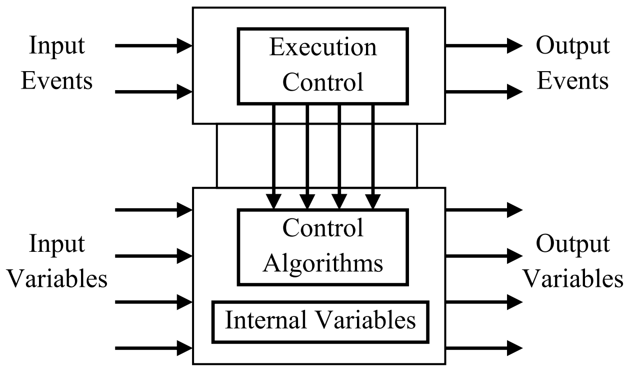

Fig. 2. Representation of a block function according to IEC 61499 standard.

To determine precisely the behaviour of a device interconnected in a distributed application, it is important to know the rules of function block execution, i.e. semantics (Vyatkin, 2010). The IEC 61499 standard defines the semantics for basic and composite function blocks and for their networks. FBs have defined interfaces of event and data inputs and outputs. Event inputs are used to activate the block. Behaviour of a basic function block is determined by a state machine, called Execution Control Chart (ECC). States of ECC can have associated actions, each consisting of invocation of an algorithm and emission of an output event (Dai et al., 2014). Function block instances can be connected one with another forming FB networks. The network's execution semantics is done by defining data flow between FB instances. FB networks are seen as a general model of both distributed and centralized control systems. In distributed systems FB instances included in a network can be regarded as independent processes. Communication between them is modelled by event and data passing. The IEC 61499 standard provides two generic models of communication: PUBLISH / SUBSCRIBE for one-way communication and CLIENT / SERVER for two-way communication. Application's FBs can be allocated to distributed devices, and communication FBs inserted whenever event or data connections cross borders of devices. For reading tags of an RFID device only unidirectional communication is necessary. Fig. 3 shows the block scheme of the distribution of an application across two IoT devices. The connections crossing the device boundaries are appended by communication function blocks.

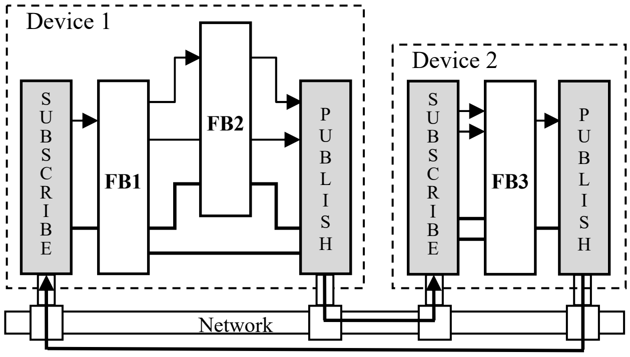

Fig. 3. Unidirectional connection of two IoT devices using block functions.

Let note also that the function block architecture of IEC 61499 can provide solutions for representing the logical relation between services at the system level, and, in particular, to offer a proper representation format reconfiguration of services during the system lifecycle.

Actually, we can demonstrate that the SOA (Software Oriented Architecture) and IEC 61499 are complementary:

1) in the SOA conception, functionalities are encapsulated in services which are communicating with others only by using message passing mechanism;
2) the representation of function block networks fits perfectly to the role of services description (and also of relations between them). So, function block types can be considered as service type definitions. Message passing between services is represented by connections between function blocks.

In the IEC 61499 standard there are two types of connections: event and data. Data inputs and outputs must be associated with event input and outputs in order to pass values in and out of function blocks. In the SOA view, each event connection is referred to as a message type. Data variables associated with this event are used as the input parameters of the message. Besides IoT, RFID integration by means of FBs can target also the access to Cloud. According to IEC 61499, FBs are designed as reusable components, distributed from the low level control and to the top high level control.

Adaptability to new demands is added by the inclusion of knowledge in the top layer. It is normal to consider the functions performed by FBs available as cloud services (Chenaru et al., 2015). Therefore, at the logical level, the functionality is encapsulated into basic elements called services, which may invoke other services in order to perform a task.

To conclude, let remind that implementing functionalities like adaptation and autonomous behaviour with the guarantee of trust, privacy and security is another important goal.

Fig. 4 illustrates a Strategic Research Roadmap with the functions and components interconnected to accomplish Internet of Things concept. The RFID technology offers the most comprehending capacity of mapping on IoT architecture.

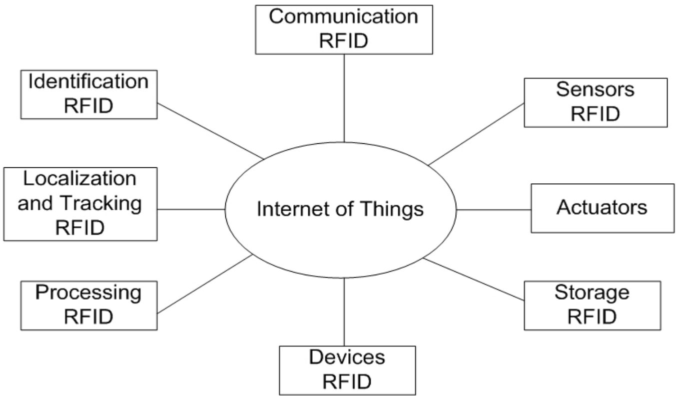

Fig. 4. Strategic Research Roadmap - IoT mapping RFID technology.

4. LIFE CYCLE MANAGEMENT IN LOGISTICS

Life cycle management in logistics is practically based on the traceability of the system service in each business stage of logistics supply chain. Data preparation, collection, verification and identification complemented with a series of fusion algorithms of tracing mechanism compose an integrated application of traceability.

RFID logistics management in the traceability system is a typical application of IoT. RFID logistics is based on ID tags allocation, identification, validations, recording, follow up on all the stages of the supply/distribution chain. Logistics traceability system can record process operation state, real capacity, transport condition, location and other traceability information and process operation state. In order to realize the intelligent recognition, positioning, tracking, monitoring and management in logistics processes, RFID technology is till now the best choice, so that the users can easily access logistics information management based on Internet. Fig. 5 presents the architecture block scheme of a traceability system.

Because RFID still remains the better method for Asset Management, we have developed the architecture of a RFID-based Asset Management System (RAMS) able to maintain the whole life-cycle of assets from their acquisition, transfer, maintenance, to retirement. The proposed system also allows displaying spatial information of assets on an electronic geographical map using WebGIS technology. In order to extend RAMS capabilities, the system was included in a larger structure able to support not only manufacturing processes, but also business applications. Therefore, we have created a framework which allows developing scenarios for life cycle management for various RFID applications integrated in IoT.

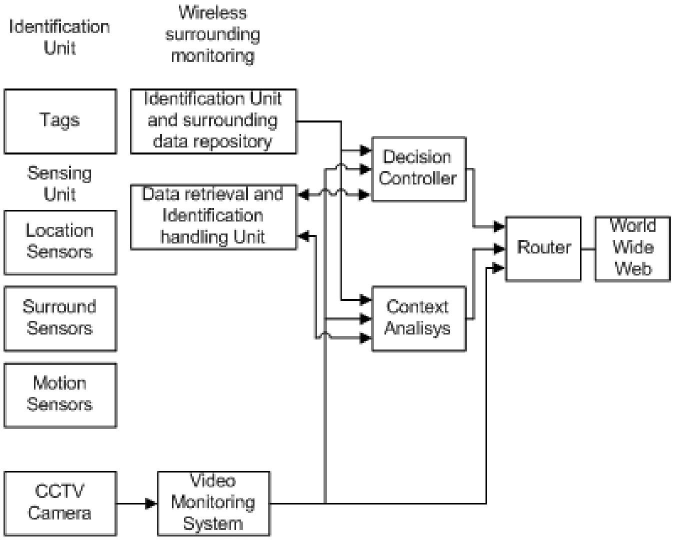

Fig. 5. The traceability application architecture.

The architecture of the framework is presented in fig. 6. The integrated architecture is based on modules such those depicted on fig. 5 allocated to each process of logistics flow.

At each process the data and information are collected and transmitted through Internet capabilities to application servers that can be interconnected such being possible to follow the pattern of each device/product on his logistic life cycle.

The whole supply chain of the application involves many factors related to the logistics business process, so the logistic traceability system is an integrated application with wireless surrounding monitoring units such as Geographical Information System (GIS) or Global Positioning System (GPS). It includes several internal sensing units for location and motion sensors and a CCTV monitoring system to complement identification functions with context analysis.

This approach raises another challenge: integrating contactless RFID networks and Context-Aware systems. To enable this kind of context-sensing and RFID activation and communication, we propose a three-tier architecture (Fig. 7) where context-information gathering, information processing and RFID are represented in different stages which work simultaneously.

The proposed architecture is based on the possibility of automatically exchanging information about the identity of an object by means of RFID radio transmission.

The first layer is the sensing and smart information storage unit, which acquires information about the IoT devices and the messages need to be sent by these devices.

The information is gathered by wireless sensor networks which act as location sensors and surround sensors. The storage also contains a means to identify IoT devices using IP addresses.

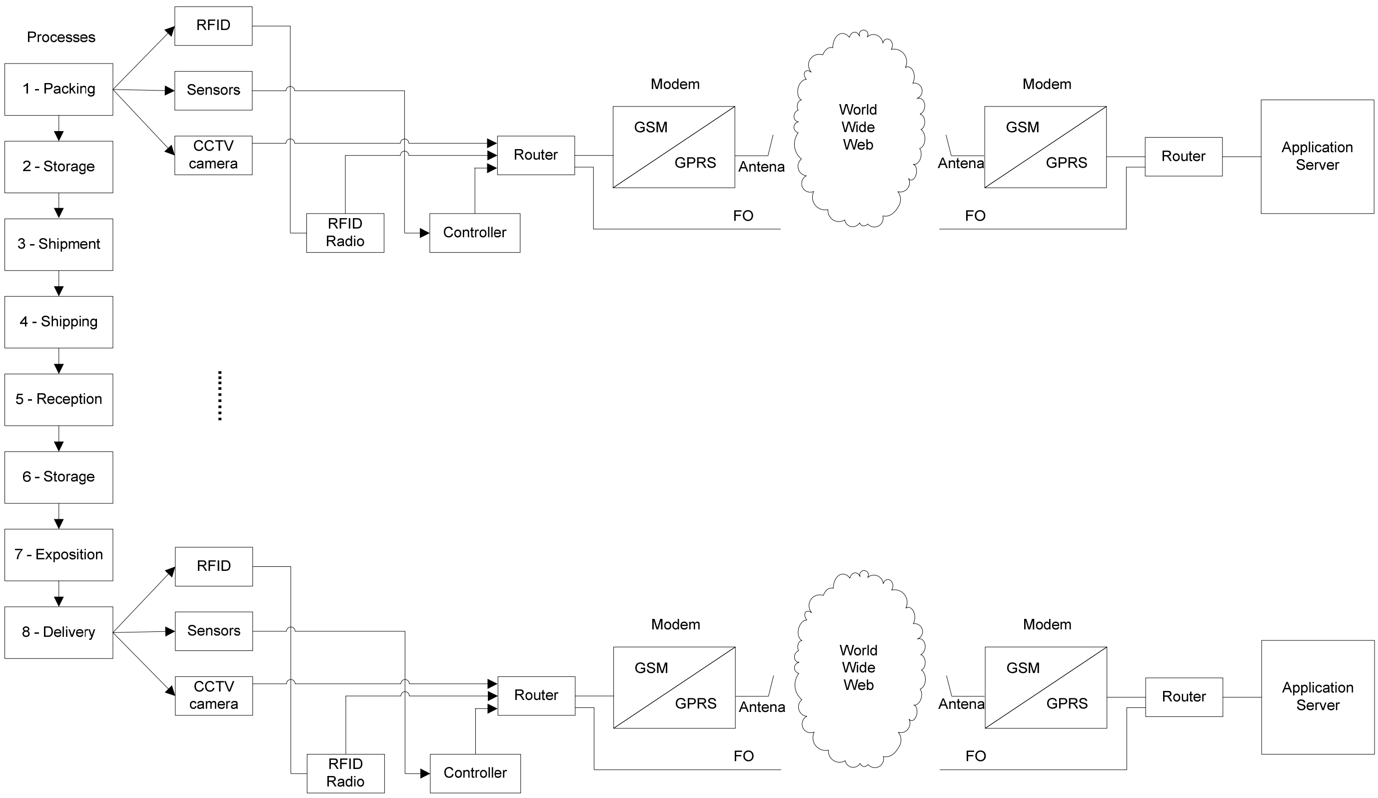

Fig. 6. Framework for developing lifecycle management based on IOT and RFID.

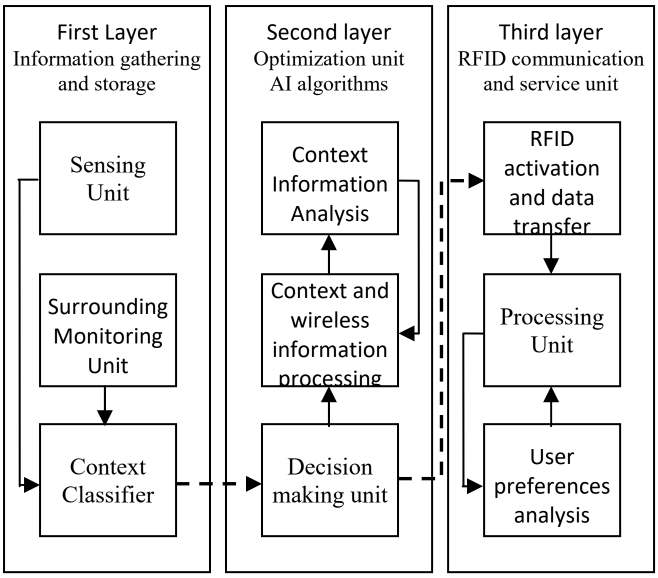

Fig. 7. Three-tier architecture to integrate RFID and context-aware systems.

The second (intermediate) layer is an optimization layer where artificial intelligence (AI) algorithms can be embedded in the intelligent devices in order to allow the intelligent IoT devices to respond to the context information in an optimum manner.

The third layer supports RFID activation and data transfer processing unit, used for identification, authentication and tracking.

The proposed architecture simplifies the future of RFID (for example in the evolved form of Near Field Communication (NFC) devices) and context-aware based automated transactions at various places, as the architecture is capable of learning and reasoning. NFC is rooted in RFID technology (known as RFID) which allows compatible hardware to both supply power to and communicate with an otherwise unpowered and passive electronic tag using radio waves. The proposed method serves to improve the efficiency of wireless and pervasive computing systems, offering an economical strategy where the RFID/NFC devices can learn their user surroundings by means of AI algorithms.

5. EXAMPLE OF RFID USE IN LOGISTICS

The success of the RFID in logistics is proved by numerous examples of companies that have implemented this technology along their supply chain. An interesting case is that of Decathlon, a company that already chose to use this system in all for the 262 stores in France and is planning to deploy it in the other locations it manages across the world (www.decathlon.fr).

The main advantage obtained with this technology is the availability of the products in the store, as the RFID allows a better adjustment of the store's supply of merchandise. Also, this system allows a quicker access out for the clients, reasonable prices as costs with storage, transport and thefts are lower, and higher security. The product is followed on the supply chain until it reaches the client, and also back to the store, in case the client wants to bring it back. The exchange is possible without the ticket, only by using the RFID tag. The system enables products to arrive in store ready to be put on the shelves, the employees no longer being bound to manually check deliveries or apply labels to merchandise before they reach the store (us.checkpointsystems.com).

As Decathlon manages all the supply chain, the introduction of this system brings benefits all along. All the warehouses are provided with tools being able to read the tags, like tunnels on the conveyors, poles that can read a whole pallet, readers at the entry to the sorting machine. This system follows any product from the manufacturing all to the client's hands. The flow control is thus quicker, simpler and more efficient.

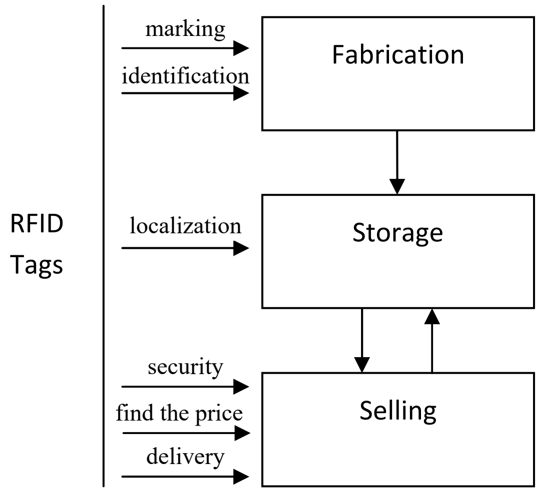

Fig. 8. Decathlon's supply chain in RFID mode.

The inventory is also simpler by using special rackets in the store, which can save different types of information like model, size, color, availability. The inventory operations can be carried out 5 times faster this way.

6. MANAGING RSNs ACCESS IN IOT

As it can be seen from the previous sections, we wanted to find a common solution for integration in IoT RFID devices and Wireless Sensor Networks. Therefore, we can consider that integration of RFIDs and WSNs in RFID-Sensor Networks (RSNs) will enhance their joint capabilities. An RSN node may draw its energy from the electromagnetic field of the reader, which reduces the power consumption and so extends significantly its lifetime. In addition, RFID tagging enables WSNs to track objects that otherwise are difficult to discover and locate. WSNs, on the other hand, add intelligence to RFIDs by providing detailed information on external parameters, offering rich context information. In addition to the ability to inter-communicate over multi-hops regardless of the reader's range of interrogation. For all these mutual advantages, RSNs represent an atractive solution for a multitude of scalable and cost-effective data gathering applications. Then, the integration of RFIDs and WSNs as IoT devices will enable the association of information with identifiable objects, not necessarily connected to the Internet, which usually belong to different domains and use specific communication protocols. In the following we present a solution for RSN management.

First, let define an RFID Sensors Network by the pair of sets: $RSN = \{R, T\}$, where R is the set of RFID sensors to manage inside the network and T is the set of RFID tags covered in a specific time interval t_i. The notation is similar to that used by Abad et al. (2012). According to this definition, an RFID reader which introduces tags inside the tag set (T) belongs to the input sensors set and an RFID reader deletes tags from the tag set (T) belongs to the output sensors set.

There are several operations to manage inside the RSN, which work in heterogeneous environments, including multiple readers. These operations are performed by the RFID middleware which can perform at least three activities:

1) Filtering RFID data in order to avoid redundant or erroneous information, and so allowing optimization of resources;

2) Interfacing and processing tag reads in heterogeneous deployments (multi-tagging and multi-readers systems);

3) Ensuring flexibility of integrating RFID system to support self-identification in different applications.

The functions performed by RFID middleware in relation with a RSN node include several features:

- operations to start-up and configure a RSN node inside a network
- configuration and parameterization of RFID devices:
- a specific function to avoid errors or false allocations related to physical parameterization and communication options
- statistics and reporting information on the deployment of RFID sensors
- procedures for providing additional such as input/output semantic function or parallel reading
- procedures for real-time monitoring of devices in live operation
- procedures for diagnosis of devices in live operation
- procedures for managing redundancy sets
- procedures for managing filter sets

As for the modern SCADA software architecture, a reader inside an RSN has two ways of acquiring the tag reads: polled or unpolled communication schemes. In our tests only the polled communication scheme was used, where the reader makes regular requests for data reads. The middleware manager can create n-tuples of acquired RFID tags and transform them in consolidated data, having three associated indexes (tag name, reader position and access time). This triple indexation allows to perform filtering and smoothing of physical reads and to avoid false or repetitive reads. The middleware must manage also the relations between different RSNs associated in extended RFID installations. We consider only two kinds of structures: RSN-Concentrator and RSN-Peer to Peer.

A concentrator receives data from different RSNs to consolidate data and generate the triple indexation. In terms of RSN definition a system is formally RSN-Concentrator if there is a set of m RSNs: $\{RSN_1, RSN_2, \ldots, RSN_m\}$ where $RSN_i = \{R_i, T\}, i=1,....m$ do not consolidate information, and every RSN_i manages the same tag set, T.

A RSN-Peer to Peer system allows to share data from two systems $RSN_1 = \{R_1, T_1\}$ and $RSN_2 = \{R_2, T_2\}$ if there are a reader set R' and a tag set T' such that R' is a common subset from R_1 and R_2 and T' is a common subset from T_1 and T_2.

Finally, let mention that the data exchanges depends of the different RSN topologies:

The *Point to Point topology* is the simplest configuration, where data is exchanged between middleware and reader stations. The acquisition middleware can be set up as master, and the RFID readers as slaves. It is possible for the middleware to communicate in full duplex mode (transmitting and receiving) with all the readers.

In the *Multipoint topology* data is exchanged between middleware and reader stations using a shared communication channel. Dedicated protocols should handle collisions between two different readers wanting to transmit at the same time.

The *Relay connection topology* uses RFID middleware to retransmit RFID acquired data to other RFID middlewares. A simple solution is to perform the *store and forward relay operation,* often encountered when one RFID reader retransmits messages to an RSN node.

The RFID middleware controls the access in an IoT framework, as an "*entity*" which can interact with both IoT domain and environment. This entity constitutes a "*thing*" in the Internet of Things, and is represented by two components: the hardware component named "*device*" and the software component named *resource*". The device attaches the entity to its environment in order to monitor it. The software component provides information on the entity and enables the control of the device. The resources exploitation is dependent on the hardware support, so a "*service*" is necessary to provide all functionalities for interacting with entities and related processes, by the means of a standardised interface. The services ensure the functionality of a device by accessing its resources. The relations between entities and services are named "*associations*". These associations could be static, e.g. in case the device is embedded into the entity; or could also be dynamic, e.g., if a device from the environment is monitoring a mobile entity.

Figure 9 illustrates the relations between the four elements of this IoT access model.

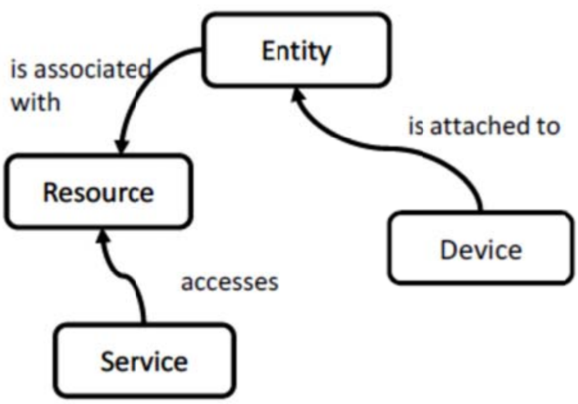

Fig. 9. Interactions of components in the IoT access model.

The services are described by their service profile. A service profile must contain information about the entity it is associated and on the link to the resource offering this service. A service which needs an input to be processed by a resource formulates this need by a "*property*". According to this property the service is linked to an entity. By their action services change properties of entities from an initial state (specified as precondition) to a desired state (specified as effect). IoT users have access to resources over the IoT through a suitable access interface which address a Web Service. The technical details that users need to access the service are specified by a mapping from domain specific entity attributes to properties observable by RSNs.

Real RFID middleware implementations employ RFID readers from several vendors and therefore mix sets of different equipment. It is recommended to define a specification that all vendors should implement so that there can be a single way of interacting with such a device. One existing specification for RFID UHF readers is the EPC global Reader Protocol (Traub et al. 2007). In respect with this specification, we have selected a minimal set of common instructions which allows introducing heterogeneous RSN nodes inside a homogeneous IoT framework. For example:

- The list of the configuration commands must include: - set identification data for a specific reader; - set data line type; - set the connection type for an RSN device; identify the user reader access; configuration of the message format to be used by the reader; specification of polling configuration.
- The list of commands for changing the operation mode is: start/stop autonomous reader functions; activate the trigger sending/reading functions; reset periodic timer sending/reading functions; establish a communication connection; order to autonomous function mode to pause working.

We consider that our proposal for RFID middleware offer a solid and efficient solution to include RSNs. The new topological readers network and the heterogeneous process application must be connected though RFID middleware solving all the established requirements. The advantage of the proposed access model is the easy management of topological RSNs and at the same time the fact that it meets the existing standard proposals, including the standards for control architecture design. This aspect (the compatibility with systems engineering standards) will be discussed in the next section of the paper.

7. V-MODEL EXTENDED

There are a lot of approaches developed for systems engineering and control architecture engineering. The most suitable seems to be the V-model that is now widely used in many industries. The V-model is a conceptual model designed as a standard application of systems engineering to produce a better understanding of the complexity associated with industrial systems development, focusing on the rigorous development of project management and lifecycle models. By using this model, it is possible:

- To define exactly the project area where this will be applied

- To envision the architectures classes to be used, including the integration of existing structures, modules, components opportunities
- To improve the framework with the implementation capabilities
- To optimize the planning and project development in order to respect the time schedule

(Singh, 2014) discusses the advantages of using the extended version with two-wings, the most used currently, for System Development Life Cycle modelling.

Our goal is to demonstrate that this extended V-model (see fig. 10) can be the best model to be applied for the development of IoT and RFID systems.

To represent this type of systems is most suitable because in the left wing is comprised the use of a families of architectures or an adequate framework and in the right wing is provided the capability of the system to evolve, by improvements or up-grades in the entire life-cycle till the retirement.

Therefore, the model can describe key activities such as identification of the architecture or parts of architecture suitable to be applied, check of the project consistency related to the propose architecture and identification of the necessary changes and solutions to be used.

This approach can destroy one of the best known myths of software development model, stating that the designer should use detailed analysis first before design is executed.

Our opinion is that the use of the extended two-wings V-model allows introducing a program design phase before the analysis. The reason is that the designer's skills in the program can to encompass a number of particular issues derived from operating procedures even at the risk of being initially wrong because these designs can be refined through iterations.

This finding is indispensable in the rapid development of a prototype as a proof of concept and the validation of the concepts prior to committing time and resources.

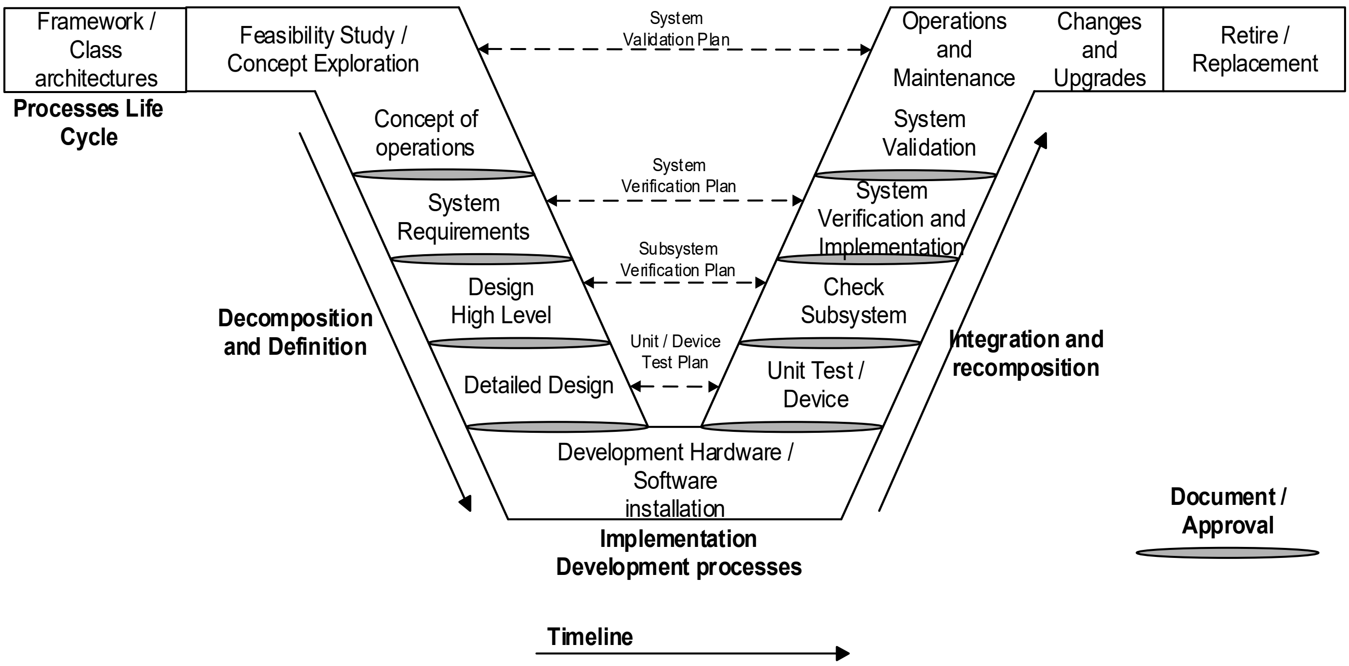

Fig. 10. V-model extended applied to IoT solutions.

8. CONCLUSIONS AND FUTURE WORK

The IoT development pushes the RFID technology to new frontiers, new applications and continuous development. In the same time the integration of RFID with sensors network, intelligent devices and appliances can help IoT concept to demonstrate the progress is done by.

The purpose of this paper was to propose a competitive architecture of a context aware system that allows the access of RFID tags (connected in RFID networks) to the IoT.

Starting from the evidence that such "things" have data which must be accessed by the means of web services which at their turn must process, learn and interpret this data, the following main contributions can be emphasized:

1. Ensuring semantic interoperability

We believe that in order to meet IoT objectives there is a need to enable high level interoperability between heterogeneous, such that the IoT devices functionality becomes easily accessible for application developers. To this end, we have presented a novel semantic level interoperability architecture where information and capabilities of devices are represented by using block functions. The core idea in this architecture is to enable even low capacity devices, like RFID tags and sensors, to interact with each other only by sharing semantic information via common communication blocks. From this point of view, because the main objective of the paper is the integration of RFID networks in the IoT is important to judiciously choose the placement of the semantic support in the IoT system information flow. We decided that the most natural places for the access methods is the middleware level.

2. Developing RFID middleware

RFID middleware is anticipated in the near future to one of the main research objectives of RFID applications. Actually, we have adapted the basic solution used in System and Data Acquisition (SCADA) systems into the areas of RFID acquisition. The solution for RFID networks management consists in promoting an abstraction layer used to hide heterogeneous devices inside a homogeneous acquisition network. When a new node is activated, the information about the node and the associated connection procedure is stored in a device registry placed in the middleware component. The registry is part of an intemediate layer where is stored also the semantic information. A higher layer such as the layer for information processing can connect to middleware and request the network information from a more powerful component.

3. Compatibility with IEC 61499 Standard

We mentioned that IEC 61499 was developed as a high performance solution which enables intelligent automation to be embedded into software components, to which function blocks (FBs) were assigned. These components are naturally designed as reusable components, distributed from the low level control and to the top high level control. For their inter-connection, we have developed the specific procedures for both unidirectional and bidirectional communication. Additionally, we mentioned that RFID integration by means of FBs can target also the access to Cloud. Our approach was to consider the functions performed by FBs available as cloud services. Each service can be encapsulated as a BF, and then can perform tasks, either by itself, or by invoking other services. In this way we enhanced the opportunity to use Cloud Computing facilities in different layers of the RFID Network – IoT - Cloud global software architecture.

4. Framework for developing lifecycle management

Several architectural approaches were used in the attempt to construct this framework. First, we proposed the conceptual architecture of a traceability system to be included in a larger application of an Asset Management System. The core of this second architecture was an RFID-based lifecycle management which includes not only RFIF networks but also various devices (sensor networks, surrounding sensing units, control devices), all interconnected within IoT. Finally, we have proposed a three-tier software architecture that allows embedding context aware systems with RFID and Near Field Communication devices. This approach is justified by the fact that with the development of wireless capable devices, more and more IoT objects are becoming context-aware, i.e. can perceive their surroundings and offer context information. Our solution allows investigating whether some methods and algorithms of artificial intelligence are suitable for use in the association of context-aware systems with intelligent IoT devices. Let note also that for the integration of the proposed structures in a global architecture we recommend the use of the extended two-wings V-model.

Our contribution to development of the framework for developing lifecycle management based on IoT and RFID can be object of further researches. As main objectives, we mention:

- improvement of framework capabilities to allow searching the large scale data of the instances of the models in the IoT domain, in order to facilitate the inference of dynamic associations.

- achievement of the required level of synchronisation for modelling specifications of the elements and modules involved in the design.

- using this framework and V- model approach to implement an integrated system for control panels life cycle in waste water management.

REFERENCES

Abad, I., Cerrada, C., Cerrada, J. A., Heradio, R. and Valero, E. (2012). Managing RFID sensors networks with a general purpose RFID middleware, *Sensors,* Volume 12, Issue 6, pp. 7719-7737

Al-Turjman, F., Al-Fagih, A., Alsalih, W. and Hassanei, H. (2013). Reciprocal Public Sensing for Integrated RFID Sensor Networks, *9th IEEE International Wireless Communications and Mobile Computing Conference*, pp. 746-751

Atzori, L., Iera, A., and Morabito,G. (2010). The Internet of Things: A survey, *Elsevier Computer Networks*, 54, pp. 2787–2805

Boddhu, S., Flagg, R., Grzebala, P., Bodduluri, R. and Williams, R. (2014) A Generic Sensor Fusion Architecture for enhancing Situational Awareness, *IEEE National Aerospace and Electronics Conference*, pp. 143-148

Celikkan, U., and Kurtel, K. (2015). A Platform for Context-Aware Application Development: PCAD, *Proc. of the Federated Conference on Computer Science and Information Systems*, pp. 1481-1488.

Checkpoint systems (2016). Decathlon further extends its RFID source tagging program for millions of products in all its stores around the world, http://us.checkpointsystems.com/news-events/news-item/decathlon-futher-extends-its-rfid-source-tagging-program-for-millions-of-products-in-all-its-stores-around-the-world/

Chenaru, O., Stanciu, A., Popescu, D., Sima, V., Florea, G, and Dobrescu, R. (2015). Open cloud solution for integrating advanced process control in plant operation, *23th Mediterranean Conference on Control and Automation (MED*), pp. 973 – 978

Dai, W., Christensen, J., Vyatkin, V, and Dubinin, V. (2014). Function Block Implementation of Service Oriented Architecture: Case Study. *12th IEEE International Conference on Industrial Informatics*, pp. 112-117

Decathlon (n.d.). L'innovation au service de la relation, Retrieved 23 January 2017 from http://media.decathlon.fr/communique-presse/innovation-services/landing/landing.html,

Elmstrøm, S., Jensen, H. and Jacobsen, R. H. (2013). Access Control with RFID in the Internet of Things, *27th*

International Conference on Advanced Information Networking and Applications Workshops, pp. 554-559

Finkenzeller, K. (2003) RFID Handbook: Fundamentals and Applications in Contactless Smart Cards and Identification, 2nd ed. John Wiley & Sons

Fera, M., Iannone, R., Mancini, V., Schiraldi, M. and Scotti, P. (2013) Economic Evaluation of RFID Technology in the Production Environment, *International Journal of Engineering Business Management*, vol.5, 39, pp. 1-13

Kantarci, B. and Mouftah, H. T. (2015) Sensing Services in Cloud-Centric Internet of Things: A Survey, taxonomy and challenges, *IEEE Int. Conf. on Communications, Workshop on Cloud Computing Systems, Networks and Applications*, pp. 1865-1870.

Katiyar, K., Gupta, H, and Gupta, A, (2014). Integrating contactless Near Field Communication and context-aware systems: Improved Internet-of-Things and cyber physical systems, *5th International Conference-Confluence The Next Generation Information Technology Summit*, pp. 365-372

Kiljander, J. et al. (2014) Semantic Interoperability Architecture for Pervasive Computing and Internet of Things, *IEEE Access*, Vol. 2, pp. 856-873

Lee, J., Bagheri, B. and Kao, H. (2015). A cyber-physical systems architecture for industry 4.0-based manufacturing systems, *Manufacturing Letters*, vol. 3, no. 1, pp. 18- 23.

Lin, X. (2013). Unified Traceability Information System of Logistics Pallet Based on the Internet Of Things, *Advanced Materials Research,* Vols. 765-767, pp. 1181-1185

Pardal, M. and Marques, J. A. (2011). Cost model for RFID-based traceability information systems. *IEEE International Conference on RFID-Technologies and Applications*, pp. 486-493

Perera, C., Liu, C. H. Jayawardena, S. and Chen, M. (2014) A Survey on Internet of Things from Industrial Market Perspective, *IEEE Access*, Vol. 2, pp.1660-1679

Poniszewska, A. and Kaczmarek, D. (2015) Selected methods of artificial intelligence for Internet of Things conception, *Proc. of the Federated Conference on Computer Science and Information Systems*, ACSIS, Vol. 5, pp. 1343-1348.

Traub, K. et al. (2007) The EPCglobal Architecture Framework 1.2, *GS1 Study*.

Singh, R. (2014). An Empirical Study of Impact of Software Development Model on Software Delivery, *International Journal of Emerging Technologies in Computational and Applied Sciences*, pp.124-127

Vyatkin, V. (2010). The IEC 61499 standard and its semantics, *IEEE Industrial Electronics Magazine*, 3(4), pp. 40 – 48