9

A Smart Tags Driven Service Platform for Enabling Ecosystems of Connected Objects

Kaisa Vehmas[1], Stylianos Georgoulas[2], Srdjan Krco[3], Liisa Hakola[1], Iker Larizgoitia Abad[4], Nenad Gligoric[3] and Ingmar Polenz[5]

[1]VTT Technical Research Centre of Finland Ltd, Finland
[2]University of Surrey, UK
[3]DunavNET, Serbia
[4]EVRYTHNG LTD, UK
[5]Durst Phototechnik Digital Technology GmbH, Austria

Abstract

Internet of Things (IoT) is about connecting objects, things and devices and combining them with a set of novel services. IoT market is unstoppably progressing, introducing a lot of changes across industries, both from the technological and business perspectives. Optimization of the whole value chain is providing many opportunities for improvements leveraging IoT technologies, in particular if information about the products is available and shareable.

TagItSmart project is creating an open, interoperable set of components that can be integrated into any cloud-based platform to address the challenges related to the lifecycle management of new innovative services. TagItSmart is a three years project (2016–2018), consisting of 15 consortium partners from Europe. The project is funded under the Horizon 2020 program.

A main target of the TagItSmart are everyday mass-market objects not normally considered as part of an IoT ecosystem. These new smarter objects will dynamically change their status in response to a variety of factors and

be seamlessly tracked during their lifecycle. This will change the way users-to-things interactions are viewed. Combining the power of functional inks with the pervasiveness of digital and electronic markers, a huge number of objects will be equipped with cheap sensing capabilities thus being able to capture new contextual information. Beside this, the ubiquitous presence of smartphones with their cameras and NFC readers will create the perfect bridge between everyday users and their objects. This will create a completely new flow of crowdsourced information that can be exploited by new services.

9.1 Introduction

Internet of Things (IoT) is about connecting objects, things and devices and combining them with a set of novel services. IoT market is unstoppably progressing, introducing a lot of changes across industries, both from the technological and business perspectives. The vision of the IoT did not change many from the beginning, but the reach that current technology brings to the table is still limited due to the certain limitations (i.e. technological limitation or for the practical reasons such as prices of the tags in some mass market scenarios) in different application of IoT.

Optimization of the whole value chain is providing many opportunities for improvements leveraging IoT technologies, in particular if information about the products is available and shareable. Many related industries are going to be affected by this, as packaging and insurance companies, among others, are requested to be more transparent to consumers, while consumers (78%) prefer brands that create unique and personalised content and are more interested in building a relationship with these companies [1].

Consumer packed goods (CPG) companies can prepare themselves for a range of possible futures by harnessing technology, reinventing brands, and exploring new business models [2]. The following five potential “undercurrents” that may impact the consumer product industry in 2020 are identified: 1) unfulfilled economic recovery for core consumer segments, 2) health, wellness and responsibility as the new basis of brand loyalty, 3) pervasive digitalization of the path to purchase, 4) proliferation of customization and personalization, and 5) continued resource shortages and commodity price volatility.

An important aspect to take into account is the need for a service economy around IoT [3]. The interconnection of products will promote ecosystems of new online services; therefore, new business models based on this network capital are gaining momentum. The new value chains will increasingly organize themselves as networks around consumers, offering a multiplicity of channels and interfaces across all value-add processes and business entities [4]. This makes consumer the one in charge, whose decisions affect the whole value-chain. Sharing information throughout the whole lifecycle of products and reactivity to context information are key in the short term.

TagItSmart project sets out to address the trends highlighted above by redefining the way we think of everyday mass-market objects not normally considered as part of an IoT ecosystem (Figure 9.1). These new smarter objects will dynamically change their status in response to a variety of factors and will be seamlessly tracked during their lifecycle. This will change the way users-to-things interactions are viewed. Combining the power of functional inks with the pervasiveness of digital (e.g. QR-codes, quick response codes) and electronic (e.g. NFC tags, near field communication) markers, a huge number of objects will be equipped with cheap sensing capabilities thus being able to capture new contextual information. Beside this, the ubiquitous presence of smartphones with their cameras and NFC readers will create the perfect bridge between everyday users and their objects. This will create a completely new flow of crowdsourced information, which extracted from the objects and enriched with user data, can be exploited by new services.

TagItSmart is creating an open, interoperable set of components that can be integrated into any cloud-based platform to address the challenges related to the lifecycle management of new innovative services capitalizing on objects "sensorization". To validate designed components and boost their adoption, a set of industrial use cases are used as a baseline for development, while additional stakeholders are being engaged through a co-creation Open Call approach.

TagItSmart is a three years project (2016–2018), funded under the part of Horizon 2020 program. The consortium consists of 15 partners coming from Austria, Finland, France, Italy, Netherlands, Romania, Serbia, Spain, Sweden, and United Kingdom. The coordinator of the project is DunavNET.

TagItSmart project aims to create a set of tools and enabling technologies with open interfaces that can be integrated into a platform of choice, enabling users across the value chain to fully exploit the power of mass-market connected products capable of sensing their own environment.

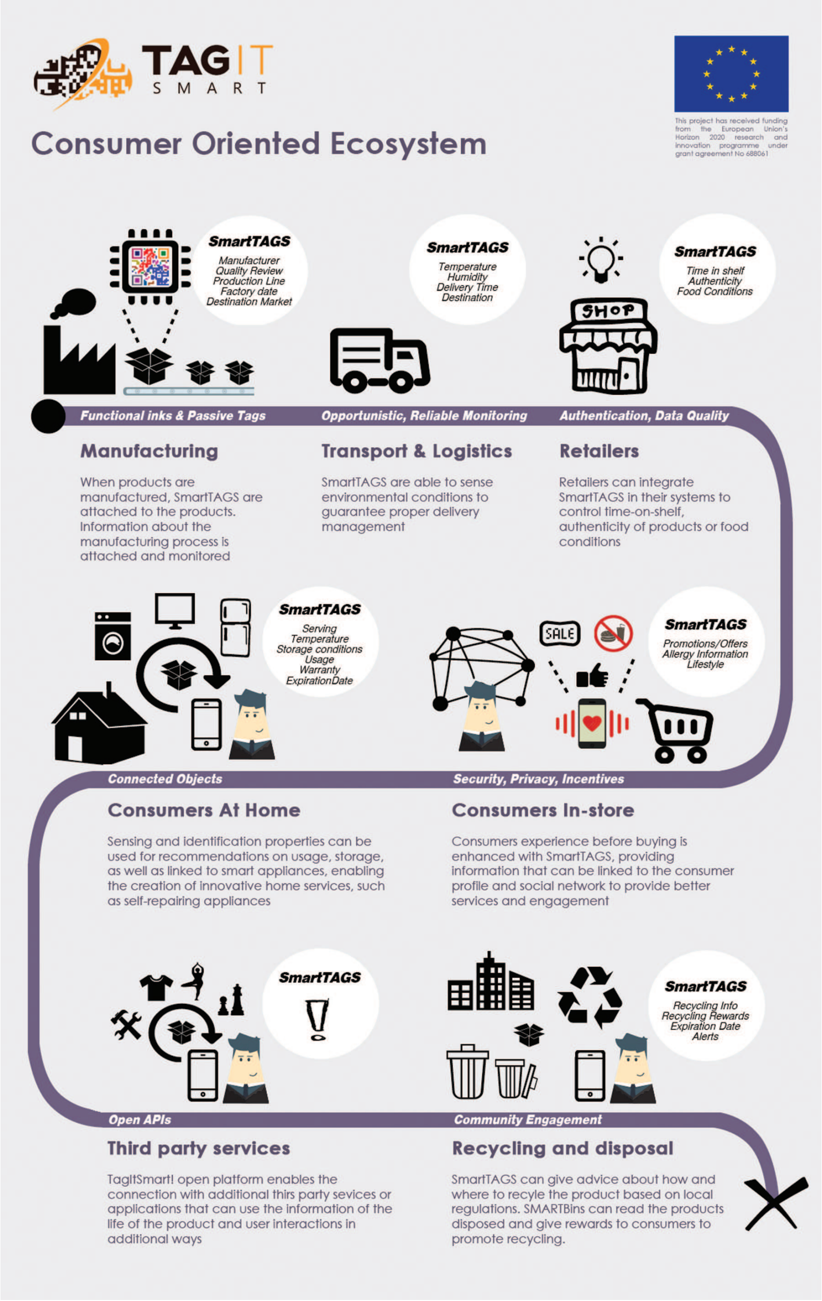

Figure 9.1 Basic concept of TagItSmart project.

9.2 Use Cases

The use cases for the TagItSmart project were created by combining expertise and real-life interests of consortium partners. In total five use cases were selected: 1) Digital product, 2) Lifecycle management, 3) Brand protection, 4) Dynamic pricing, and 5) Home services.

The digital product use case is a kind of umbrella use case including the whole value chain from manufacturer to transport, retail, consumer and recycling, see Figure 9.2. The other use cases concentrate more in details to one or two stages of the lifecycle of the product.

9.2.1 Digital Product, Digital Beer

Digital product use case extends a base use case for fast-moving consumer goods (FMCG) that want to become "smart" via SmartTag and TagItSmart. It combines novel solutions and enabling technologies and tools to create smart solutions for the whole value chain: manufacturer, transportation, retail, consumer and recycling. To implement the use case, a real FMCG has

Figure 9.2 The TagItSmart use cases under the Digital product umbrella.

Figure 9.3 The idea of Digital product use case.

been chosen. In this use case the beer and beer bottles are tracked from the manufacturer until recycling the bottle at the end of the value chain. From TagItSmart's digital product, digital beer needs at least functionalities for item-level control, life-cycle management, digital engagement and authenticity tracking. In addition, digital beer needs some basic sensing capabilities for monitoring conditions of the beer, see Figure 9.3.

The Digital product use case involves every part of the FMCG value chain and provides base functionalities for the TagItSmart project and other use cases. Making this use case live could affect every stakeholder in the chain and provide them new possibilities now and in the future.

By implementing this use case the manufacturers are able to control products that leave their factories throughout their lifecycle, e.g. where and how the products are transported and in which conditions, when they have been delivered to the retail stores and when sold to the consumers. This use case also creates a new channel for manufacturers to communicate with the consumer, so that they can enable easy access to related information on product and item-level which is not only static but depend on lifecycle and historical data of the item.

Especially consumer awareness has great potential when it comes to creating new business throughout the value chain; it makes it possible for product manufacturers to create products that address market needs better. Consumer awareness links to both two-way communication and item information, with two-way communication consumer can initiate conversion directly between him/her and the product manufacturer. This makes it possible to order customized products and removes overhead (and possible loss of information) when giving feedback of products consumed. However, it also works the other way; product manufacturer can reach customers with updated information about product and conditions it was manufactured, sources they use, etc.

In this use case, retail stores are not anymore midpoint warehouses but are more deeply engaged into the chain, giving them the opportunity to interact both with customers and product manufactures actively taking part in determining the next steps in product lifecycle.

Digital product use case also opens up possibilities for new use cases and new business. These solutions can be easily extracted to other fast-moving consumer goods. It also provides base functionalities for advanced use cases like home appliances, new recycling processes and customer-manufacturer engagement. These (and any other) use cases can use functionalities implemented by digital product use case as they are, extend them or replace them in order to support use case specific requirements.

9.2.2 Lifecycle Management

In Lifecycle management use case the aim is to implement a system/technology that allows the lifecycle management of every fast-moving consumer good (FMCG), or consumer packaged goods (CPG), that motivates and helps companies and citizens recycle their waste items, overcoming and solving current limitations and problems. The idea of this use case is described in Figure 9.4.

A key sustainability metric is the reduction in waste sent to landfill, but also the promotion of recycling. Items that are recyclable are often wrongly placed in a landfill bin, due to lack of awareness or engagement by the end user. This problem is compounded by the number of different regulations governing recycling at the local level and an inability to engage directly

Figure 9.4 The idea of Lifecycle management use case.

with end users at the point of product disposal. An opportunity exists for a system that can give end users geographically relevant information on the recyclability of an item at this point in time, either within the home, or at a range of other recycling outlets.

9.2.3 Brand Protection

According to the report on EU customs enforcement of intellectual property rights (IPR) of the European Commission from 2015 for year 2014 [5], which is: a) Report on EU customs enforcement of intellectual property rights – Results at the EU border 2013; Publications Office of the European Union, 2014, Luxembourg and b) Report on EU customs enforcement of intellectual property rights – Results at the EU border 2014; Publications Office of the European Union, 2015, Luxembourg, 35.5 million enforcements of IPR by case were detected at the customs of the borders of the European Union with a total domestic retail value of 617.1 million Euro. Roughly, 47 % of the cases were reported to be from textile products such as clothing, clothing accessories and shoes, which is even ahead of medicines and cigarettes.

Counterfeiting, specifically in textile products but also expandable to other goods, is caused by several factors including the simplicity of the production and refinement processes, the cheap way of production and the low structure complexity which widely opens the doors for illegal copying. Brand protection strategies based on the implementation of barcodes, tags or labels to the product till nowadays had only a moderate success rate, whereas sophisticated anti-counterfeit systems (e.g. active radio-frequency identification (RFID) tags, electronically secured packaging) are more limited to high-value products. In the brand protection use case the aim is to develop a security platform for goods which includes both the direct digital printing of a functional QR code on an article or the printing on labels or on packaging and the generation of suitable coding and decoding environment that are deployed at the production process that is simply implementable by the manufacturer directly on the product periphery or on the packaging.

More specifically the aim of this use case is the development of functional QR codes and their readout for the purpose of a security platform for originality proof to be implemented on labels and tags. The basic mechanism of the security platform is a light- or temperature-induced colorization or decolourization of inkjet-printed textures within the functional code, see Figure 9.5. The encoding is performed via the data matrix approach (see use case digital product).

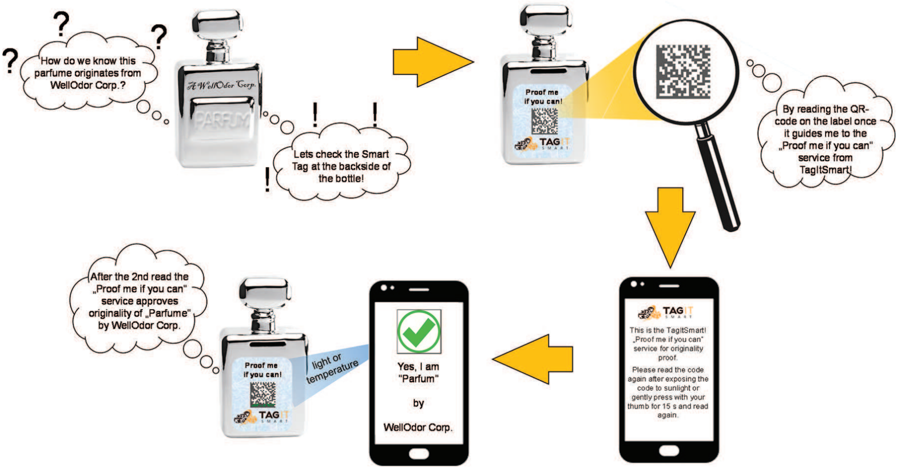

Figure 9.5 The idea of Brand protection use case.

9.2.4 Dynamic Pricing

The idea of the dynamic pricing use case is to deliver safe and fresh food, using packed meat as an example product that can benefit from conditions dependent pricing. Each package of meat is tagged with a SmartTag on the production line. The tag is capable of detecting temperatures higher than allowed for storing fresh meat. Once the temperature goes above the threshold for a certain period of time, the tag reacts and changes its content to indicate this event.

The SmartTags benefit several stakeholders in the value chain. Once the package arrives to a shop it can be scanned by the retailer. In that case, the packages that were stored in wrong temperature conditions will be removed. However, individual scanning of each package is not possible and the packages might end up on shelves. Once on the shelves, the consumers will be able to scan individual packages before buying. When consumers scan a package using a smartphone application they will obtain information about the meat: the origin, time of packaging, discount information and transport conditions. The obtained information is also forwarded to the meat supplier and potentially to other actors in the supply chain. At this point, it is possible to invoke condition dependent pricing mechanism depending on the relevant parameters like temperature in which the item was stored or time spent on the shelves.

Consumer takes the meat package to the cash register where it is scanned again. At this stage, the information is sent to the meat supplier and recorded in retailer's information system. In case the consumer had not scanned the item previously, the condition dependent pricing procedure is triggered in case the conditions for such procedure are met. After the checkout, the consumer goes to the car and puts the groceries in the trunk. When scanning is done at home, the SmartTag might indicate wrong temperature and the TagItSmart application would then suggest appropriate measures taking into account the time since the item was scanned at the checkout, i.e. the last control point. In addition to this, the consumer will also receive information about the recipes suitable for the type of purchased meat as well as instructions on how to dispose of packaging. The idea of dynamic pricing use case is presented in Figure 9.6.

Cold supply chains have been in use in various industries for a long time. The main characteristics of these systems is that the monitoring is done on a box or a pallet level while the items are in a truck, refrigerator etc. Modern supply chains solutions do not cater for monitoring at individual item level. Also, monitoring at critical points, when items are being handed over between different modes of transport or between two cold points (refrigerators) is lacking, thus preventing the stakeholders from having to have the complete picture and potentially exposing them to problems. Particularly critical is loading items to a transport vehicle and unloading at warehouse stores.

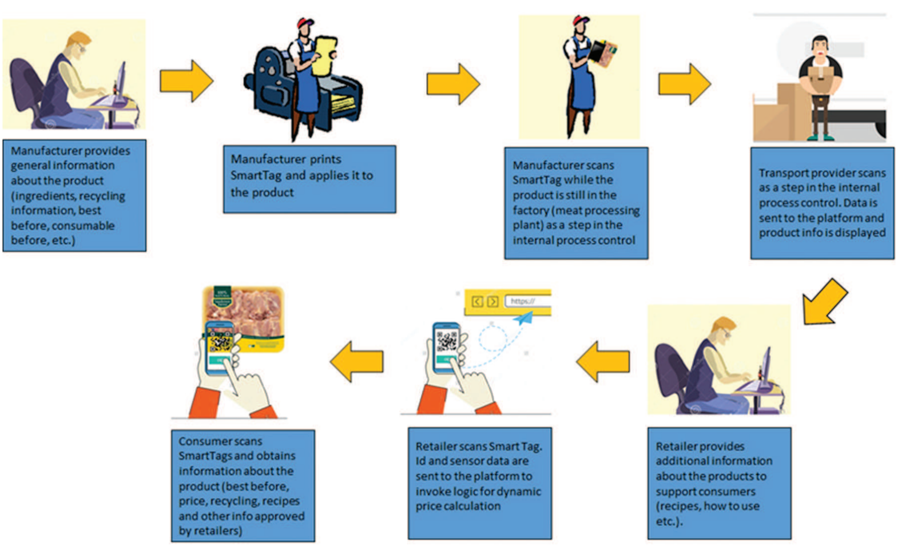

Figure 9.6 The idea of Dynamic pricing use case.

Integrated dynamic systems for monitoring products, the conditions of transport and storage, the relationship of its expiry date and price are not currently available. If a consumer is not a member of a loyalty programme, neither supplier nor retailer have the ability to interact with consumers in an easy manner and learn about the consumer habits. The goal of this use case is to enable monitoring of items at individual level, including at the loading/off-loading times. Further to this, the goal is to extend the monitoring of the item to its shelf time and further to consumer's house and eventually waste. Using this approach all stakeholders will be able to obtain information that can be used to improve work processes and increase quality of service.

9.2.5 Home Services

A good usage of the heating equipment (e.g. a boiler and an associated filtering station) is one means to provide comfort and a healthy living at home. This implies proper 1) maintenance, 2) repair, 3) replenishment, and 4) monitoring. This use case will test different services to the customer all along the life of the equipment at home. Some of the services will leverage access to information related to the product, its environment and its use; and some will provide specialized services (installation, maintenance, repair, etc.).

One example is boilers. The retailer has referenced different service providers according to their abilities and location. One SmartTag is attached on the boiler by the customer at home, by the manufacturer or by the retailer in-store and another SmartTag is attached inside the boiler by the manufacturer or by the retailer in-store. There are two more static SmartTags, one is attached on the boiler's burner and the second SmartTag is attached inside the filtering station upstream of the boiler, see Figure 9.7.

The environmental conditions at home are important to preserve the customer health and security, to control optimal conditions for the appliance operation (e.g. enough oxygen for proper combustion), and to detect malfunction of the appliance (e.g. carbon monoxide produced by the boiler) and optimize working conditions. Motivation for Home services use case is also that home equipment requires regular maintenance and many customers forget to proceed with this action; thus causing malfunction, shortening the life of the appliance, losing warranty, and losing insurance protection. From the retailer point-of-view warranty can only be set off in case of proper use

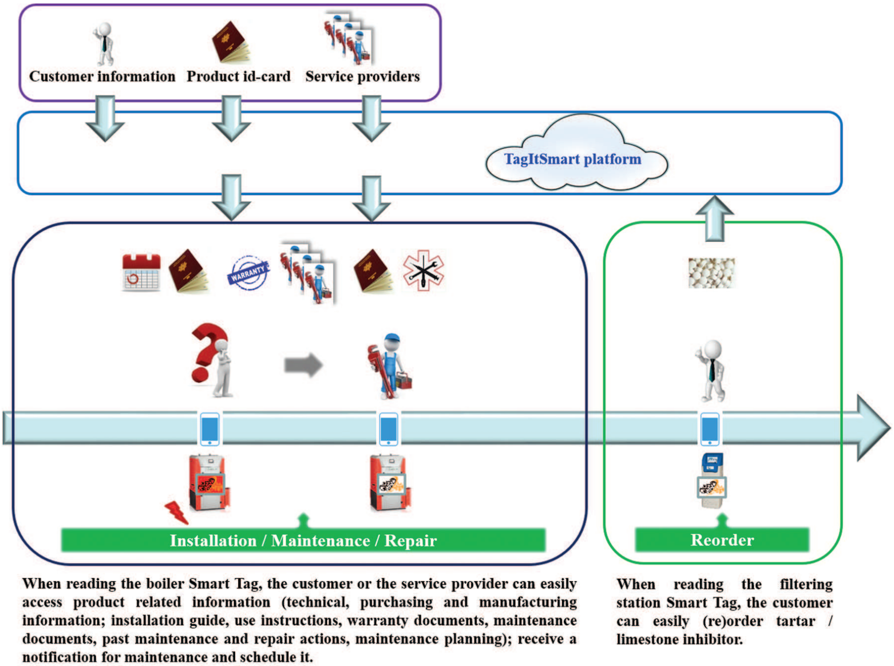

Figure 9.7 The idea of Home services use case.

and on time, maintenance of the equipment and the retailer is rarely able to verify this point. Quality and durability of the appliance are leveraged by good maintenance practices and enhance customer satisfaction. However, the retailer is rarely involved in this post-purchase process. Optimal use of equipment also enhances customer satisfaction.

9.3 Architecture

TagItSmart architecture was created based on the work done in previous projects like SocIoTal [6], available IoT system architecture reference models like IoT-A [7] and IoT platforms like FIWARE [8], Microsoft Azure [9] and EVRYTHNG [10]. Figure 9.8 presents a comprehensive view of TagItSmart architecture.

Based on this previous work, a list of identified required components for individual TagItSmart use cases were created. Then, they were combined into a common architecture, providing required functionality across all use cases. The following blocks were identified:

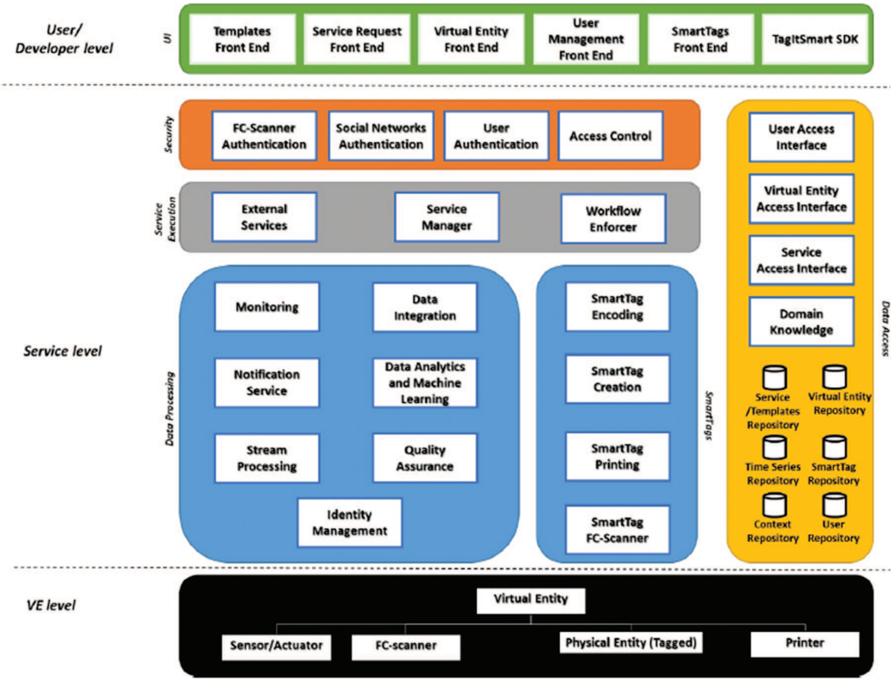

Figure 9.8 TagItSmart Platform functional architecture.

- **Service Management**: defines components needed to access, discover and execute services in the platform.
- **Virtual Entities**: defines components to work with virtual representations of the different objects defined in the use cases, from a CPG product to a sensor in a boiler.
- **SmartTags**: defines the components to manage the creation, scanning and management of SmartTags.
- **Security**: defines the components that will implement the authentication, authorisation, and any other security related aspects of the platform.
- **Domain Management**: defines components that are specific to a use case domain.
- **Utility Services**: defines utility components with services shared across use cases.
- **Application Development Tools**: defines the Software Development Kits (SDK) and tools needed to implement applications on top of the platform.

From the functional point of view, there will be a set of components at the **User/Developer level** providing the front end for the different components. Additionally, at this level, the TagItSmart SDK enables integration of specific TagItSmart features into different IoT platforms. At the **Service level,** we can find the following functional blocks:

- Security components dealing with aspects such as authentication, authorisation and access control to the rest of the components.
- Service Execution components include those that enable execution of services registered in the platform, as well as the service templates that will trigger dynamic creation of workflows.
- Data Processing components providing additional functionality to handle and work with the data generated in the platform.
- SmartTags components facilitating integration, creation and scanning of SmartTags.
- Data Access components provide the correspondent registries, semantic models and repositories on which TagItSmart will operate.

At the **Virtual Entity** level, the actual representations of the objects that are part of the platform provide access to their data and defined actions based on the semantic models. Each component is intended to define an integration strategy, mainly by the definition of an Open API. During the technical development in the correspondent work packages a reference implementation will be provided for the core innovative components (i.e. all the components directly related to the SmartTags and services), while others will be taken/integrated from already existing platforms.

9.4 Pilots and Trials

Validation of TagItSmart components is being performed in laboratory and controlled live environment, with the final validation planned to be done in live environment under real usage conditions. The goal of the trials is to validate requirements against individual components and services, while the focus of the pilot will be on the complete framework, the ease of use, end users' feedback, ease of use from the developers' point of view, integration with other systems, etc.

TagItSmart framework consists of a number of components required to enable the complete workflow of all envisioned use cases. However, not all individual components will be included in the validation during trials and pilots. Instead, the main focus of the trials will be on validation of the core components specific to TagItSmart, i.e., components involved in SmartTag scanning driven process, from the design and printing of the tags, to processing of data obtained from the tags together with the contextual information and finally delivering corresponding services.

The aim of the pilots will be on validation of functionality and performance of the system as a whole, not on the individual components. Further to the trial and pilots run by the project partners, additional validation will be done by the new partners joining the project through the open calls.

Operational trials for the different use cases have so far focused on different aspects. Some use cases have focused more on functional ink related issues (Brand protection), some on scanning of codes (Digital product), some on software component development (Life-cycle management), and some on preparations for pilot trials (Dynamic pricing and Home services). In the rest of this section we will present some sample results coming from the testing that has taken place already in the TagItSmart project. As the key enabler for the whole TagItSmart project are the SmartTags themselves, special effort has been given in the process of creating and scanning SmartTags in a way that sensing information can be reliably added to them and also reliably extracted from them.

9.4.1 SmartTag Creation

The main steps in the SmartTag creation process are the encoding of SmartTags to allow sensor information to be represented and the printing of the SmartTags themselves.

9.4.1.1 SmartTag Encoding

In TagItSmart project, Data Matrix [12] codes and QR codes have been used in the use cases. In the case of Data Matrix codes, in Digital product use case, different approaches how to integrate sensor information into existing 2D codes have been prototyped. Idea was to find the best combination of: 1) limitation of printing procedure and functional inks, 2) reading capability of mobile application, and 3) the cost of a solution. The best alternative so far has been to use a 2D code with a bar of functional ink overlaying part of the code, see an example in Figure 9.9. In addition, a square with functional ink was tested.

Encoding process itself is very easy when a rectangular symbol is used: data matrix is encoded based on the existing standards and sensor rectangle is added on top of the data matrix. Also, it is possible to encode a tag in the

Figure 9.9 2D code with sensor area.

reverse order, i.e. first, the sensor rectangle is encoded and then data matrix is layered on top of it. As these are most simple cases (and work in various printing systems), more complex encoding might be used for example in digital printing; in this case placing algorithm is used after the data matrix has been encoded. This algorithm replaces white cells at two last rows of the barcode with sensor ink. Information of the used sensor will be stored into (according to our TagItSmart architecture) the virtual entity counterpart of the product following the workflow shown in the figure below.

In the case of encoding QR codes, there are several issues associated with encoding tags that change with environmental conditions. These issues stem from the error correction mechanisms built into the QR code generation algorithms. The simplest approach to encoding a changing tag would be to simply design the two tags that are needed and then print the differences in disappearing or invisible inks that change under the same conditions. However, it is very difficult, and for some environmental conditions impossible, to change both inks under the same conditions. Therefore, the approach to encoding requires that only one type of ink (disappearing or invisible) be used. In the TagItSmart project, dual and mono coded tags have been developed. In dual coded tags, two tags are created. Each is designed in the normal way; one tag reads as the 'before' activation and the other reads as the 'after' activation. Before printing a carefully chosen set of dots on each tag are identified for printing with reactive inks. Both tags are printed side by side and the scanner will only read one of them. The mono tag approach is more complicated and restrictive. The design process must be allowed to choose some of the characters in the code.

It is also possible to encode SmartTags that are combinations of QR codes and images; this allows for embedding sensor information into SmartTags in cases a standalone use of a QR code would not allow for this (e.g. transitions between 2 different readable QR codes are not possible due to limitations in the way functional inks react).

9.4.1.2 Printing SmartTags

Different printing methods have been evaluated for their capability to print QR and Data Matrix codes with different functional inks on different paper based substrates. The concept for using functional inks in enhancing dynamic nature of 2D bar codes is that parts (e.g. some of the cells) of a 2D bar code are printed with a functional ink that reacts to the surrounding environment, e.g. temperature, humidity or light conditions. Changes in the environmental conditions cause the cells printed with a functional ink to disappear, to appear, or to change colour. This changes the physical layout of the 2D bar code thus also changing the information content (e.g. website address). Thereby the environmental conditions have an effect on the scanning process and resulting digital service. The services can also take into account the other user and context related data, such as user profile on the smartphone and GPS location of the smartphone. These context-aware features will further improve the value and quality of the services provided.

There is a range of colour-changing technologies, out of which the most popular and readily printable are thermochromic (changing colour with temperature) and photochromic (changing colour with sun or ultraviolet light, even camera flash light). Functional ink technologies are available at the moment mainly for analogue printing methods (flexography, screen printing, offset printing). For digital printing mostly, fluorescent inks are available. This is due to the large particle size of the colour-changing pigments, which present challenges in inkjet ink formulation. Functional inks can be used for printing 2D bar codes similar to regular printing inks, and detected by smartphones [11].

For printing functional inks both analog and digital printing methods are suitable. In analog printing (e.g. flexography, screen printing, offset) a physical master, a printing plate, is required for image reproduction thereby not making analog printing economically feasible for printing customized (individual) 2D bar codes. Analog printing is, however, capable of producing large batches in high speed with static printing layouts. Digital printing methods (e.g. inkjet, electrophotography), on the other hand, are suitable for printing customized, even personalized, 2D codes since the printing layout comes from a digital file without a physical master. There are inkjet printers available designed for printing variable data, such as Data Matrix and QR codes, for coding and marking applications. These printers are suitable for integration with other production and printing lines, and produce variable data on-the-fly. Manufacturers include Domino Printing (www.domino-printing.com) and Videojet (www.videojet.com). TagItSmart project partner Durst manufacturers label inkjet printers also suitable for printing variable data with 2D codes.

There are several different ink technologies available for analog printing methods, and those are readily usable with existing analog printing presses. For digital printing the availability is limited to only a few technologies, mainly UV or IR fluorescent inks.

There are, however, some limitations related also to functional inks for analog printing. The colours and colour changes available are limited. For example, with thermochromic inks the colour disappears when the temperature is higher than a specific limit. In some cases, it might be preferred to have an appearing ink instead of a disappearing one. Another issue is the difference between inks and indicators. For some cases, such as time-temperature monitoring (product at a particular temperature longer than a particular duration), there are only indicators available – not inks. Monitoring of time-dependent temperature changes is somewhat complicated and requires a logging capability that cannot be achieved with a single ink. This limits the usage scenarios since use of variable data is not possible due to the need to purchase ready indicators from the manufacturers.

To conclude, when selecting the functional performance of the SmartTag, it is important to understand the limitations and capabilities of the functional ink technologies and indicators, and select the functional performance based on their availability and properties. Also when variable data (e.g. individual 2D codes) are required for smart tag production, a proper selection of the printing methods is required due to the limited availability of the functional ink technologies for digital printing methods. In most cases hybrid solutions (combination of analog and digital printing methods) should work, where the 2D codes are printed with regular inks with digital printing, and the functional parts with analog printing or assembled from indicators.

Thermochromic inks

Thermochromic ink is a type of ink that changes colour with heat. This can make certain images appear (or disappear) as soon as the label or product

Figure 9.10 Data Matrix code with two functional inks. Code size is 3 cm x 3 cm. In the left picture both thermochromic inks can be seen (T < +31°C). In the middle picture black thermochromic ink has disappeared (+31°C < T < +47°C). In the right picture both black and red thermochromic inks have disappeared (T > +47°C).

goes above or below a certain temperature. These temperatures can vary from –10 to +65 °C. Temperature-sensitive inks come in two varieties: reversible and irreversible. With reversible thermochromic ink, the colour will revert when the temperature returns to its original level, whereas the colour remains constant after a change in temperature with irreversible thermochromic ink.

One example of a QR code that contains two flexography printed thermochromic inks is presented in Figure 9.10.

Photochromic inks

Photochromic materials change their colour when the intensity of incoming light changes. Most photochromics change from colourless to coloured upon exposure to UV light, and then fade back to colourless upon removal from the UV source. The normal wavelength of excitation is around 360 nanometres. Moreover, while sunlight works the best, a fluorescent black light, which emits near-UV light (320–400 nm), will usually work. Different dyes have different kinetics, meaning some will colour and fade quickly, while others will colour and then fade slowly. One example of an inkjet printed irreversible photochromic ink is presented in Figure 9.11.

NFC manufacturing

Printed Dopant Polysilicon Technology (PDPS) is used to produce the Printed Integrated Circuit (PIC) used in the NFC labels in TagItSmart project. The production has the following steps: PIC Production, wafer conversion (PIC bump and dice), dry inlay assembly and wet inlay conversion. The PICs are currently produced in a sheet-based process where 4 out of 8 layers are printed, see Figure 9.12.

Figure 9.11 Printed tag with an inkjet printed photochromic ink (red QR code). The red QR code appears when exposed to UV or sunlight.

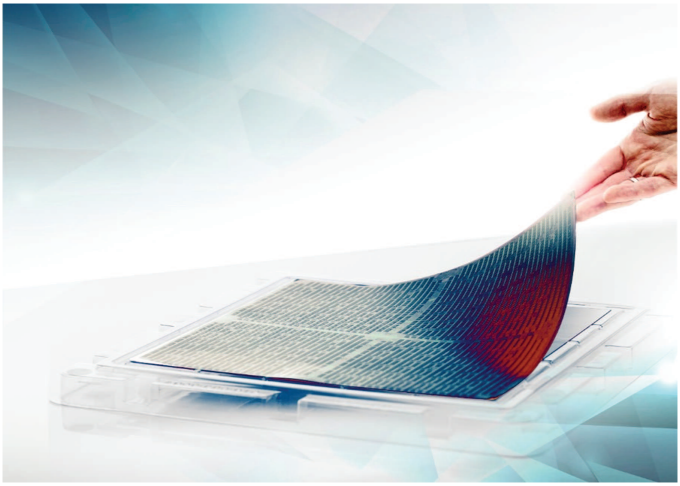

Figure 9.12 The PICs are produced on stainless steel sheets.

After the conversion to wet inlays, the remaining steps are to place the labels on the final product. This is typically done by a converter or by the customer.

9.4.2 SmartTag Scanning

As part of the SmartTag scanning process, enablers that allow authenticating an FC-Scanner user as well as decoding the content in SmartTags have been developed.

9.4.2.1 FC-Scanner Authentication

Since SmartTags may carry information that can reveal personal aspects about an individual and/or objects they own, authenticating a user before they are allowed to scan an object with a SmartTag attached to it is of big importance. As an example, one can imagine the case where a person is wearing a t-shirt with a SmartTag that allows retrieving the temperature of that person. An authorised person (e.g. a doctor) should be allowed to scan such a SmartTag; an unauthorised person who just happened to pick up the doctor's FC-Scanner device should be blocked from doing so.

To account for scenarios like the one above, an authentication module for FC-Scanner devices has been developed that based on mobility data of the owner, is able to "on the fly" authenticate a user automatically without requiring any intervention or direct input from the rightful owner, as the module learns to identify this rightful owner.

The TagItSmart platform can leverage the outcome of the authentication module to take remedial actions, such as "lock" the FC-Scanner device, ignore SmartTag scanning events coming from it and also notify the rightful user (through other devices registered under his ownership) about this. The architecture of the authentication system for TagItSmart is presented in Figure 9.13.

9.4.2.2 Decoding SmartTags

For all (Data Matrix, QR code, QR code together with image) types of SmartTags currently successfully encoded, the decoding mechanisms have also been developed. In the case of a SmartTag consisting of a QR code together with an image, a special TagItSmart decoding application had to be developed combining an off the shelf QR code decoder together with a custom made image recognition module. The decoding performance has been very promising with successful decoding of a SmartTag being able even for very small SmartTags (down to 2cm $\times$ 2cm in size and even lower), with high speed (lower than 2.5 seconds) and under low lighting conditions, as low as 35 lux. Figure 9.14 presents the SmartTags being successfully decoded when attached to real-life products.

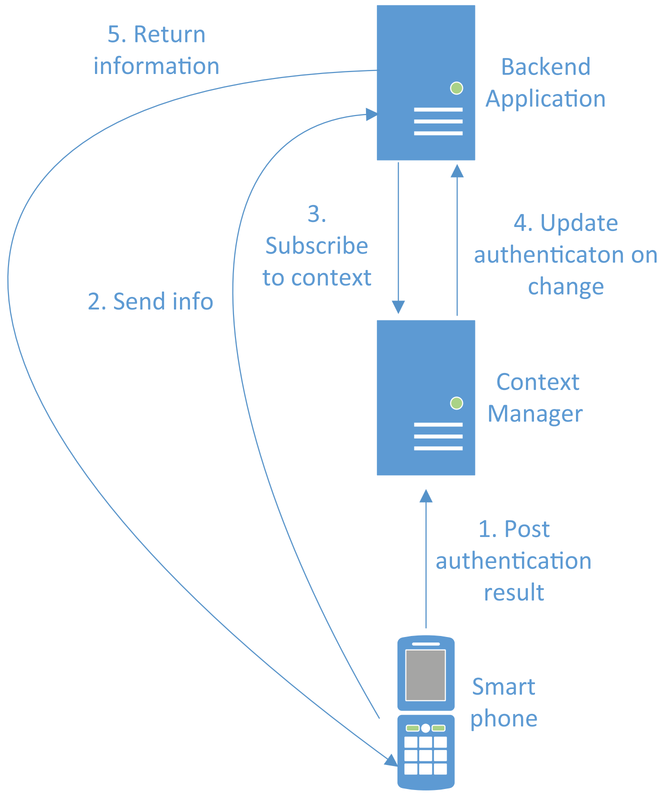

Figure 9.13 Architecture of the authentication system for TagItSmart.

In a similar manner, NFC based SmartTags produced by the project are capable of allowing for scanning reliability of higher than 99% with response time lower than 0.5 seconds, as long as the scanning distance matches the requirements of near field communications (lower than 2cm).

9.4.3 Service Offerings Leveraging the TagItSmart Platform

The various enablers developed in the TagItSmart project allow for many services to be offered leveraging the information that is extracted from SmartTags. This is still an ongoing process given the early phase of the project and the need to develop first the enablers that allow getting in and out of SmartTags the information that more advanced service offerings rely

Figure 9.14 Examples of SmartTags being successfully decoded when attached to real-life products.

upon. In the context of the Dynamic pricing use case, the service scenario of presenting different prices for the same product based on how close this is to its expiry date (as this is reflected by the attached SmartTag) has already been tested successfully, illustrating the successful interworking and integration of encoding, printing, decoding and decision making for this scenario (see Figure 9.15).

Figure 9.15 Dynamic pricing scenario; different price calculated and displayed based on SmartTag information.

9.4.4 User Experience on Use Cases

Use cases, developed in TagItSmart project, have been evaluated with Finnish consumers by using Owela platform (Open Web Lab, http://owela.fi). Owela has been developed at VTT in 2007 for user centric qualitative studies and it supports active user involvement in the innovation process from the early ideas to piloting and actual use [12]. Owela can be utilized to involve users in all phases of a development process for an innovation.

Discussion in Owela was open during two weeks from January 2017. Totally, 45 Finnish consumers participated the discussion and gave 341 comments to the discussion. Fifty-three percent of the participants were female, and 47% of male. Age distribution varied between 17–79 years, the average age of the participants was 49 years. The use cases were presented to the participants as stories to understand the idea of the use case. After reading the stories, participants discussed about their interest towards the different concepts. Based on the results, it was clear that people in Finland are familiar with 2D codes. All the participants had seen them e.g. in the packages, advertisements and tickets. Three out of four had read 2D codes with their smartphones but only 17% said that they read the codes regularly.

Consumers found all of these concepts interesting. Seventy-nine percent of the participants evaluated it to be interesting to read the codes from local producers' products and to create an interactive relationship with them. To utilize the codes in fast moving consumer goods, like meat packages, was in the interest of 55% of the participants. Finnish consumers did not see so much potential in using the codes in cheap products and they were not concerned about the origin and safety of the products. That was also the case in the authenticity of the products, but still consumers saw a lot of potential in this case. Eighty-five percent of the participants evaluated the authenticity of the products interesting.

In addition, we got lots of information about the advantages of the TagItSmart concepts, and also about consumers' concerns related to them. First, even if consumers are used to seeing and using 2D codes, they have often been disappointed with the content they can receive by reading the codes. They expect something more – high quality content that offers them additional value. In addition, consumers were also interested in the possibility of interactivity. There were most potential in using codes in unique and/or personalized products, ensuring food safety of the authenticity of the products and also in creating interactive connection with producers.

Consumers were suspicious about if it is too easy to counterfeit the codes, recycling of the tags and also privacy issues related to the novel IoT services.

It is essential that the consumers can trust the service and service provider. It is important to take into account when TagItSmart solutions will be brought to the market, how the services are communicated so that consumers understand the difference between traditional codes and functional ones, and also to realise the added value and ensure the trust.

9.5 Conclusion

The activities performed in TagItSmart project so far, prove that there is a great business potential for connected FMCG products, across a number of domains. All industrial partners in the consortium have identified use cases of interest and are now proceeding to validate them in the pilots. Further to this, based on interaction with various stakeholders as well as External Industry Advisory Board, the proposed use cases were validated as being of interest to a wider number of organizations. On the consumer side, even if they are used to seeing and using 2D codes, they have often been disappointed with the content they can receive by reading the codes. They expect something more – high quality content that offers them additional value. In addition, consumers were also interested in the possibility of interactivity and these are the features TagItSmart can and is planning to offer.

Technology is available to produce novel services for consumers and stakeholders by utilising functional inks and combining them with digital solutions. A number of challenges related to printing codes using functional ink and even logistics of printing on-site or transporting codes sensitive to temperature or other environmental parameters to the labelling facility, have to be addressed before large scale uptake becomes possible.

The process of coming up with solutions that will enter the market is iterative, and potential users are involved in different phases. It is important to take into account how the services are communicated so that consumers understand the difference between traditional codes and functional ones, and also to realise the added value.

Acknowledgements

This work was supported by EU; the TagItSmart project (Grant Agreement No 688061) is part of Horizon 2020 program. In the project, we have altogether 15 partners from Serbia, Finland, United Kingdom, France, Sweden, Romania, Netherlands, Italia, Austria and Spain. We want to thank all the partners for their co-operation during the project.

References

[1] Consumer Goods Forum, 'Rethinking the Value Chain: new realities in collaborative business', 14 December 2015. [Online]. Available: https://www.uk.capgemini.com/resources/rethinking-the-value-chain-new-realities-in-collaborative-business.

[2] P. Conroy, K. Porter, R. Nanda, B. Renner, A. Narula, 'Consumer product trends: Navigating 2020', 25 June 2015. [Online]. Available: http://dupress.com/articles/consumer-product-trends-2020/.

[3] C. Links, 'Consumers want Smart Systems Not Smart Things', GreenPeak, 8 January 2016. [Online]. Available: http://www.sensorsmag.com/networking-communications/consumers-want-smart-systems-not-smart-things-20558.

[4] Consumer Goods Forum, 'Rethinking the Value Chain: new realities in collaborative business', 14 December 2015. [Online]. Available: https://www.uk.capgemini.com/resources/rethinking-the-value-chain-new-realities-in-collaborative-business.

[5] SeeDiscover, 'Behind The Numbers: Growth In The Internet Of Things', 23 October 2015. [Online]. Available: http://www.seediscover.com/behind-the-numbers-growth-in-the-internet-of-things/.

[6] SocIoTal, 'Creating a socially aware and citizen-centric Internet of Things!', [Online]. Available: http://sociotal.eu/.

[7] IoT-A, 'Internet of Things – Architecture IoT-A Deliverable D1.5 – Final architectural reference model for IoT v3.0', [Online]. Available: https://www.researchgate.net/publication/272814818_Internet_of_Things_-_Architecture_IoT-A_Deliverable_D15_-_Final_architectural_reference_model_for_the_IoT_v30.

[8] Fiware. [Online]. Available: https://www.fiware.org/.

[9] Microsoft Azure. [Online]. Available: https://azure.microsoft.com/en-us/?v=17.14.

[10] EVRYTHNG. [Online]. Available: https://www.evrythng.com/.

[11] L. Hakola, H. Linna, 'Detection of printed codes with a camera phone', Conference proceedings. 32nd International Research Conference Iarigai, 2005, Porvoo.

[12] P. Friedrich, P., 'Web-based co-design: Social media tools to enhance user-centred design and innovation processes', Espoo 2013. VTT Science 34. 185 + 108 p.