From Farm to Fork: Traceability based on RFID
A Proposal for Complete Traceability in the Wine Sector

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Abstract: This paper highlights the objectives and activities of the European project "RFID from Farm to Fork", which is focused on the food industry traceability. The final goal is to extend the traceability information to the final consumer, so these persons could feel the confidence on the food origin like our grandparents did when they lived in a less globalised World. The activities of the project in a winery at Ribeiro denomination of origin (Spain) at both vineyards (by means of wireless sensor networks) and the wine production process (by RFID technology) are also presented along the paper, in order to show some of the project outcomes.

1 INTRODUCTION

European Regulation CE178 (Regulation EC 178/2002, 2002) stated that the capacity of tracing and tracking a food along every stages of production, transformation, and distribution is a key question in the food sector. And it is important both in terms of quality and safety, and in terms of technology.

Thinking on quality and safety, the objective is to recover the confidence of the consumers in the products they purchase. That confidence on the food products has evolved during last times, as the way we acquire the food has changed a lot as our societies advance and move their activity and industrial sectors balance. Some years ago (and in several countries not so many years ago), consumers were very confidents on the origin of the food they eat: people bought the food directly to the producer, who belonged to a family known for generations; or the number of intermediaries was very reduced, and they were met by the buyers or neighbours, as well as the distance covered by the product from its origin (Cuiñas et al, 2011b). That time, people bough wine bottles (or perhaps barrels) directly to the winery, which was very confident. Perhaps the buyers had previously sawn the farmers taking care of the vineyards, or carrying the grapes, or washing the barrels and bottles. Probably, the parents and grandparents of these consumers had been clients of the parents or grandparents of the winery holders! Or, in the case they bought the wine in a shop, they most likely met the seller for long ago, and also the seller met the wine producer. And the same occurred with meat, cheese, fish, and all the food they consumed.

Besides, the transportation steps in the production chain were short, or even there were no transportation, as the local products dominated the shops and markets. Possible problems related to transport and delivery conditions (temperature, conservation, etc.) had no space in the consumers mind some years ago.

Currently, this situation has radically changed, as our shopping habits are not the same of some years ago. Nowadays, the small confident shop, or the traditional market, is mainly reserved for special days, for people looking for delicatessen groceries, or for elderly that feel better maintaining their traditional lifestyle. Most of the people generally buy their food products in super or hypermarkets, where the i.e. cheese is presented in clean and aseptic plastic boxes, and labelled providing some information. But we have lost the contact to the farmer that took care of the cow or the sheep! So, we receive a lot of information, but we do not have confidence in the origin and in the process suffered by the piece of cheese or meet, or the wine bottle, we are buying. Something similar occurs with other products.

Within this context of confidence loss, the price of the product could be a determinant factor to decide the acquisition of a product among the

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variety the supermarket offers us. This situation gives an advantage to goods produced by large companies, which could assure the quality along the production chain, but also to those produced in countries with lower salary costs or with less strict sanitary laws, where they could manufacture at lower costs.

Knowing the situation related to control the quality and safety of the goods we buy for eating, the high quality products developed by small companies seem to be in disadvantages against these products with less quality but also less price. And this situation is becoming worse in an economic crisis context. The chance for small and medium enterprises (SME) in developed countries is the incorporation of new technologies to focus their activities to the production of added value products: in terms of quality, in terms of origin guarantee, in terms of deep information, or combining all of them. An SME could not compete against non developed country companies in price, but they could in quality and origin control. Besides, these SME are in disadvantage against large companies in terms of assuring complete traceability.

The proposal of the European project "RFID from Farm to Fork" (RFID-F2F) is focused on SMEs and on a production sector: the food industry in Europe. We have important salary costs, which could be a problem to fight against producers from other countries, but we also have strong experience in origin guarantee systems as well as on sanitary control of the food, which is assumed to be an advantage in demonstrating the quality of the product. The goal is to give this information to the consumers… and, then, the consumers could select this higher quality product! Large companies could assure the traceability from the farm to the consumer, as they control all the stages of the business chain: farming, processing, transportation and delivering. SME are only present in one or two of these elements of the chain, so they need an external umbrella to hold the traceability links among the different agents.

2 THE "RFID-F2F" PROJECT

The project "RFID from Farm to Fork" is a CIP-Pilot action involved within the 7th Frame Work of the European Commission. The consortium is led by the University of Wolverhampton (United Kingdom), being the other members universities from Spain (Vigo and Politécnica de Cartagena), Slovenia (Ljubljana) and Italy (Salento), companies (Treviso Tecnologia, Santer Reply, IDxS BVBA), or institutions (EuroFIR, Institute of Food Research). So, the represented European countries are five: United Kingdom, Spain, Italy, Slovenia and Belgium.

The action itself looks for the extension of radio frequency identification (RFID) technologies (Europe's Information Society web page, 2011) along the complete food supply chain: from the farms where cows, fishes, sheep, grapes, etc. grow; to the final consumer at supermarkets, including all the intermediate stages: transport, manufacturing processes, storage. The main objective is the use of only one technology to perform a complete traceability, recording data at each stage.

The final consumers could obtain different data about the whole process experienced by the product they are buying, just by moving the object (labelled with a RFID tag) in the vicinity of a RFID reader, which can be installed in the supermarket. An alternative could be products provided by QR codes or NFC tags that could be read from an application at each personal smart phone.

The individual identification of a product allows the software to obtain a complete traceability report from a central database, and to bring the consumer this information. Thus, the buyer could know what happens with i.e. the wine at each instant of its production, and also the conservation and transportation conditions from the winery to the shop, although each production stage would be conducted by different agents.

Besides, each of the producers along the supply chain could use the identification by radio frequency to control its production and storage, and to know some previous information of its ingredient matters.

The project involves both the design of the complete system and its tests at different stages of the chain: fishing companies, wine producers, food transporters, and final users, in order to define the actual interest of the system, its performance, and its advantages and disadvantages (Swedberg, 2011). After the tests or pilot experience, the consortium will have valued information on the possibilities of implementing RFID technologies for tracing and tracking food products, as well as a deep evaluation from the companies. This information would be transferred to the European companies, and indirectly to the whole society as a return of investment of the project efforts.

The project will show the ability of RFID technologies to make a return on investment for SMEs in the food industry, as well as to provide large information to the consumers (RFID-F2F web page, 2011). The opportunities for such a return on investment arise from the increment of productivity due to authentication, quality control, wastage reduction, and energy optimization. Until now, these advantages have been demonstrated in large organizations, which have control over most or all of the value chain and are in a position to make an end-to-end investment. Vice versa, the "farm to fork" traceability system has not yet been adopted by independent SMEs, which only participate in one stage of the value chain. By linking RFID and sensor network technologies with an Europe wide database as EuroFIR (EuroFIR web page), which can store the exact history of any food product, SMEs will be given the opportunity to optimize their own business process to maximize return. In addition, a pan-union resource will be created allowing producers to demonstrate the quality and freshness of their product, which will have the effect of increasing consumer confidence as well as producer margins (Cuiñas et al., 2011a)

It is known that the use of RFID in the food chain has been previously tested, and it could obviously provide a competitive advantage to the involved companies (Gandino et al., 2007) (Pérez-Aloe et al, 2007) (Fenu and Garau, 2009). However, the radio propagation in presence of liquids presents important differences compared to other more friendly environments (Dobkin and Weigard, 2005). Wine bottles, as an example, suffer from this disadvantage, which needs to be evaluated previously to incorporate this technology to the wine industry.

3 THE RIBEIRO WINE PILOT

Denomination of origin is the name used in Spain to define appellation regions: areas where a specific product is controlled, taking care of the geographical origin of the matters, the variety of the plants or animals involved, the processes employed during the elaboration of the food product, and also aspects as bottling, labelling, storing and delivering. Among various Spanish wine denominations of origin, "Ribeiro" is a controlled wine producing region located in Galicia, the North Western area of Spain. In a pilot company, both WSN and RFID systems have been deployed at the vineyards and winery, respectively.

The selected environment to deploy the WSN is a vineyard located in a mountain side from Ribadavia. This vineyard is property of the winery company.

The grapes involved in the production of Ribeiro wines have to come from a strictly delimited area. So, a requirement is to assure the location of the vineyards by means of precise methods. The control of different weather parameters is a must. The region is very rainy in winter, but it is also very warm in summer. The high humidity levels, in co-ordination with the sunny time, could lead to problems with plagues which are the main trouble during the growing of the grapes. The installation of a wireless sensor network (WSN) with adequate sensors help the farmers to develop tailor made strategies to keep the health of their plants.

During the wine manufacturing, at the winery, a fast and comfortable way to control all the movements of liquids among the different barrels, across filters, cleaners, and other machines is one of the claims of the winery managers. The proposal of a RFID based traceability system, operated by a handheld RFID reader appears to be a good solution for this task. Water resistant RFID tags will be glued to each machine and each barrel, and a three steps standard event will be defined to describe the movement of liquids from tank A (first step) to tank B (second step) across the machine M (third step). Some chemical data would be added manually to the database at different stages along the manufacturing of the wine.

The management of the bottle stock by individually tagging the bottles appear to be more complicated: there were some reading problems around the bottles (Expósito and Cuiñas, 2011) and, which is no less important, the cost of each individual tag is still too large to be economical assumable by the winery.

4 WIRELESS SENSOR NETWORK AT THE VINEYARDS

4.1 Network Description

A system following the ZigBee standard has been installed during November 2010 last week, and it has been working continuously since that date. A coordinator node and six regular nodes compose the communication facilities of the WSN. Different sensors are connected to the regular nodes: soil moisture and temperature, soil water content, ambient temperature and humidity, leaf wetness, solar radiation, and one weather station. The nodes assure the communication of data among them and towards the coordinator node. Each node collects regularly the data from the sensors it has plugged in, and it also transmits these data towards the coordinator node. This coordinator connects to a gateway to extract the information from the WSN to a database installed at the winery or a management place. The deployment and performance of such a network has been widely described in (Gay-Fernández and Cuiñas, 2011).

Prior to the deployment, large tests were performed in controlled environments: both propagation measurement campaigns and laboratory experiments were carried out. The propagation campaigns were focused in defining attenuation models adapted for different environments (Gay-Fernández and Cuiñas, 2011) (Gay-Fernández et al., 2010). These studies allowed us to decide the distances between nodes, which resulted to be up to 250 meters, depending on the environmental conditions. The laboratory tests had the objective of measuring the node energy consumption. We observed that the nodes could work up to 4 months without solar energy. As the individual solar panels recharge the batteries during sunny (or even clear) days, the node life would not be conditioned by the energy supply.

4.2 Connectivity Aspects

The architecture of the global system is depicted at Figure 1, involving the own WSN and the link to systems placed out of the vineyards, where the data has to be stored and then analyzed. The connectivity at both stages has to be considered.

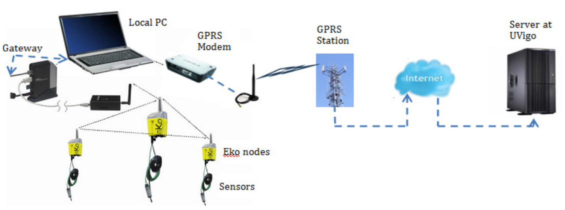

Figure 1: Global system architecture.

The connection among nodes is driven by the ZigBee protocol, based on a mesh topology: if one node fails, the network is automatically reconfigured, looking for new paths to reach the isolated nodes. During the operation of the WSN we detected some connectivity fails due to the growing foliage of the vineyard, but also due to the presence of trees cutting the line of sight of the radio links.

The connection from the coordinator node to the database could be more complicated, as external power supply could be needed. The adopted solution was the use of the GPRS network to extract the data from the coordinator to the database via the Internet, running tailor-made software on a local PC.

5 RFID DEPLOYMENT AT THE WINERY

During the elaboration of the wine from the harvested grapes, a lot of processes have to be applied within the winery. The objective of the RFID deployment at the winery is to register the different traceability events suffered by the product, in order to know what, where and when each event occurs.

5.1 Hardware Definition

The hardware definition includes the selection of the RFID tags and the RFID readers most adequate for being employed along the wine production chain, within the winery. The RFID activities begin at the vineyard, where the use of a hand held reader to read/write the tags at containers or trucks after the harvesting appears to be better option than fixer interrogator. Water resistant encapsulated tags would be needed at this and other stages, in order to survive the ambient conditions.

Figure 2: Tests on wine tanks.

At the winery, both hand held and fixed readers will be needed: the hand held reader to read the tags on grape containers, wine tanks and other equipment/machines along the wine processing; and the fixed readers will be mounted on conveyor belts, forklifts and arcs at storage doors.

Previously to the selection of hardware and tags, some tests have been performed, using tags glued on wine metallic tanks and on bottles. The objective of the test on metallic tanks was to determine the best tag orientation, as well as to define maximum reading distances. We used a hand held reader and different encapsulated tags for this experiment. Figure 2 depicts an instant of such campaign. The maximum reading distance was obtained with the tag glued vertically on the tank, as could be checked in Table 1. This is probably due to the curvature suffered by the tag when it is horizontally located.

Table 1: Reading ranges as a function of the orientation of the tag.

Orientation related to the vertical	Reading range
0º/90º non-metal surface	162 cm / 160 cm
0º on metal surface	**81 cm**
30º on metal surface	78 cm
60º on metal surface	73 cm
90º on metal surface	53 cm
120º on metal surface	53 cm
150º on metal surface	73 cm

The second test has been made within an anechoic chamber. It consisted on measuring the readability pattern around different bottles (four full bottles, and two empty used as reference) tagged with up to seven RFID tag models. The complete measurement system was controlled by means of tailor-made MATLAB scripts. A description of the measurements around white wine bottles could be read in (Expósito and Cuiñas, 2011).

These previous tests indicates that the received power after reading a RFID tag on a bottle full of wine is less than 25% of the same magnitude on an empty bottle. Besides, the reading pattern around the bottle is modified in its shape, as well as the reading arc width appears to be reduced.

5.2 Software

The business process was the basis for an event definition, which allows the programming of the RFID application for tracking systems. The way to attack such task was to define some standard events and then to adapt all the event definition to this catalogue of standards. Many processes along wine production chain follow a simple scheme: they consists on moving a volume of wine (or must) from the tank/barrel A to the B passing through some equipment as filters, chutes, decanters,... So, a standard event could be easily defined.

Most of the data generated along wine pilot supply chain are going to be collected by using a handheld reader, as it is more comfortable to be used along the winery, at different operation areas. So, a hand held application has been programmed with separate forms depending on the step of the production process to be performed. Figure 3 shows the initial display of such application.

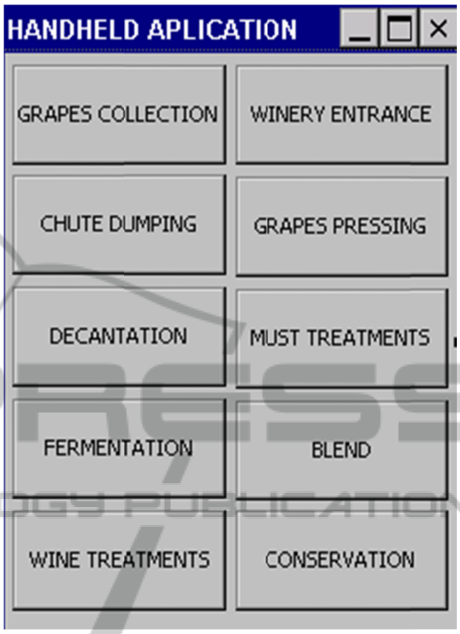

Figure 3: Display of the hand held reader application.

After the reading of origin and destination tanks, and intermediate action, the RFID reader generates an EPCIS compliant XML file containing the collected data. Extra information for internal management operation could also be added (e.g. chemical analysis data).

Final consumers would have the possibility of selecting goods among a large catalogue at their current groceries shops or supermarkets, as could be observed at the demonstrative project video at: http://www.youtube.com/watch?v=lmvHohm3SYA.

Some products could be labelled with NFC tags (the RFID version for low frequencies) or QR codes. The consumers would use their smart phones to detect the NFC signals or to interpret the QR code. The information at such tags would connect the phone to the RFID-F2F web server. The code sent to this portal is used to ask the database at each agent along the business chain for its traceability information, which is elaborated and presented as a web page. Thus, final consumers obtain complete information on the different stages of the production of the wine bottle they have on their hands.

6 CONCLUSIONS

The European project "RFID from Farm to Fork" activities and objectives have been presented along this paper, as an application of RFID technologies to provide traceability along the complete food chain, from producers to final consumers.

A pilot experience developed in a winery at Ribeiro area, in Spain, has been also presented, in order to show a specific installation. Previously to this development, various tests have been carried out in both WSN and RFID technologies, and their results have been also commented.

Related to WSN deployment, propagation models were defined from the results of large measurement campaigns. They were useful to define the distances between nodes in the network, and to install the complete system.

The readability of RFID tags on metallic tanks and on full wine bottles has also analyzed, and the results were valid to determine the better allocation of tags on such elements. The read distance when the tag is glued on a metallic tank is reduced in more than 50% compared to non metallic. And this reduction also depends on the orientation the tag is installed.

Related to the readability patterns around wine bottles, the effect of the wine is very significant in terms of received power and in terms of the shape of the pattern. When the bottle is empty, the RFID tag could be read all around, at enough power levels. When the bottle is full of wine, the received power from the tag is reduced significantly, whereas there are various directions at which it is not possible to read the tag: the shape of the readability patterns change.

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