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A complete farm management system based on animal identification using RFID technology

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ABSTRACT

In this paper, a platform for livestock management based on RFID-enabled mobile devices is described. The platform is the outcome of a research project named FARMA, and is based on the deployment of mobile computing, combined with RFID technology and wireless and mobile networking. The platform apart from using a data repository through which the RFID tag numbers are associated with animal data records, it introduces the use of rewritable tags, for the storage of information that can be used to identify the animal in case it gets lost, or even recognize some basic information about it (e.g. behavior against other animals) without the need of contacting the related database. An implementation in the context of the FARMA project is also given, together with the corresponding details, while the results of the evaluation that took place in the context of the project are discussed.

1. Introduction

The demand for animal identification and traceability is constantly increasing, driven by the need for quality control and welfare management in agricultural animals. Furthermore, the dramatic effects of infectious diseases in the environment (fauna) and the agricultural economy have highlighted the importance of well-organized monitoring platforms of animal capital. The outbreak of bovine spongiform encephalopathy (BSE), commonly known as mad cow disease (Johnson and Gibbs, 1998), is a characteristic example that reveals the necessity of such systems. Concerns about safety and quality, which have also increased during the last two decades, constitute yet another argument for the use of state of the art, electronic means of identification and traceability of agricultural animals (McKean, 2001; Saa et al., 2005). Technological evolution, on the other hand, has provided a comprehensive toolset, far surpassing traditional methods of traceability and identification. The wide adoption of RFID technologies and the progress made on standardization, has established the use of RFID technology for providing the technological framework, over which accurate and highly sophisticated management of animal capital can be performed.

Use of RFID technology in animal tracking has been a practice for the past years in countries around the world. RFID technology is used to track both domestic (livestock and pets) and wild animals, while there are efforts to standardize the methods and the specific RFID tag technology used (Ntafis et al., 2008). Several projects have been implemented worldwide, based on the use of RFID technology for tracking animals and monitoring the progress of a disease, such as the United States Department of Agriculture (USDA) project for tracking captive deer and elk in the U.S.A. based on the use of RFID tags in order to determine how deer and elk contract chronic wasting disease (National Animal Identification System (NAIS)). In the standardization field, we can reference the case of AIM Global (RFID technology News and Insights), which has developed a draft standard for RFID for food animals to address growing concerns about the threat of terrorist attacks and the recent outbreaks of both BSE and foot-and-mouth disease in different parts of the world. As the use of RFID technology is getting cheaper, the use of animal tagging is increasingly spreading. The U.S. Department of Agriculture has announced plans (USDA) for the universal tagging of livestock in the U.S. with RFID by the year 2009. In Europe, the EU conducted a large study from 1998 to 2001 called the IDEA (Identification Electronique des Animaux) project, concerning electronic identification of animals. The IDEA project (Ribó et al., 2001) was prepared by the Directorate General for Agriculture (DG Agri) with the technical coordination of the Joint Research

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Center (JRC) at Ispra. The evaluation of the results of this project will lead to recommendations for a system to trace animals from birth to slaughterhouse, including the appropriate technology to be applied in any generalized system for the livestock sector in the EU.

Moving on to an introduction to Radio Frequency Identification, it should be mentioned that RFID tags can be separated in different categories according to both use and technology criteria. There are three main types of tags used for animal identification: boluses, ear tags, and injectable glass tags, which are injected under the skin. Boluses are capsules, incorporating a radio frequency transponder, which are retained in one of the first two stomachs of the ruminants and it has been proven to be a safe choice for ruminant identification (Caja et al., 1999). They can be administered even to lambs after weaning at the fifth week and the retention rate can reach 100% (Garin et al., 2003). The injectable transponders on the other hand can be applied easily after birth (Caja et al., 2005), while the preferable locations differ in each animal species (Collin et al., 2000, 2002; Silva and Naas, 2006).

From a technological point of view, RFID tags can be grouped in two categories according to the carrier frequency band: LF (low frequency) tags function at 125–134.2 kHz, whereas HF (high frequency) tags function at 13.56 MHz. A series of reasons (Electro-com white paper) has dictated the selection of the LF 134.2 kHz frequency as the worldwide carrier frequency for animal identification. ISO 11784 and 11785 international standards regulate the radio frequency identification of animals in regards to code structure and technical concept and, among others, determine 134.2 kHz as the carrier frequency for animal identification.

Farmers, and especially diary ones, have been keeping animal records for over 100 years. Apparently, different means of identifications have already been used, such as branding, ear notches, paint marks (temporary identification), tattoos and ear tags (Wismans, 1999). Branding is a technique for marking individually livestock using either hot iron (traditional branding) or dry ice/liquid nitrogen (freeze branding). Ear notching has been used mainly to identify swine and it is referred to particular shaped notches, placed somewhere in the ears, while for tattooing, inked numbers are put permanently in the skin (most commonly in the ear) with a special tool.

In an endeavor to compare and contrast RFID-based and conventional livestock tracking methods, a respectable number of advantages of the former can be mentioned. RFID tag data capacity is large enough that each individual tag has a unique code. The uniqueness of RFID tags means that an animal may be tracked as it moves from location to location, from the very first moment of its birth until the time of its slaughter. RFID technology can therefore provide reliable and efficient tracking, while, at the same time, permitting to monitor not only which farmer it belongs to or which animals are its parents, as is the case in the majority of the traditional tracking methods, but also many more parameters that could be of importance. This is extremely important and useful for ensuring food quality and safety and for tracing the source of a potential abnormality in cases of ill animals (alive or slaughtered). Furthermore, RFID tags are easy to apply and ensure successful reading of information and lack of stress to livestock. In particular, they provide easier use, under field conditions, since there is no need to have visual contact of the tag. On the other hand, one could pinpoint as drawbacks of electronic means of identification the higher cost in comparison with the less expensive conventional methods. However, through mixed strategies, that are combining conventional and electronic tags, a significant reduction in cost is achievable (Saa et al., 2005). Moreover, the – small but not inexistent – risk of a tag remaining in the food products (injectable tags) and the inability to protect from possible fraud (ear tags) (Stanford et al., 2001) are referred to as possible disadvantages of the RFID-based tracking methods in the international bibliography. Nevertheless, these negative aspects by no means outweigh the benefits introduced by use of RFID technology in animal identification.

The promising potential of RFID-based tracking methods for livestock identification has brought about the interest of industry and research alike. Up to the present work reporting on the use of RFID technology in livestock management appears in the existing bibliography (Trevharten and Michael, 2008; Ng et al., 2005; Eradus and Jansen, 1999; Bass et al., 2008; Bowling et al., 2008; Caja et al., 2005; Collin et al., 2002). The majority of this work focuses on the benefits and possibilities of using RFID technology to track animals or describes general frameworks for using RFID for livestock identification, while the according regulation is often referred to and commented, yet no definition of a complete and specific framework for collecting, storing and managing livestock information in farm environments is given. In work appearing very recently (Shanahana et al., 2009; Barbari et al., 2008) more complete approaches are provided.

In this context, this paper presents the developments and the results of a research project on animal monitoring based on the use of RFID technology: the FARMA project (FARMA Project Final Report, 2008). In the context of the project, a pilot platform aiming to provide an integrated framework for the identification and monitoring of agricultural animals has been designed and implemented. The benefit of deploying such a platform is significant for the agricultural and stockbreeding areas: animal diseases can be easily detected and reported, thus easily controlled and prevented, and efficient response, even to the very early stages of outbreaks, is possible. Through the use of the platform, a systematic identification of animals is performed, while support of identification of livestock vaccinated or tested under official disease control or eradication, is possible. Last but not least, through the use of such a platform, subsidies based on the number of animals or their genetic background can be allocated properly. This paper – as will become obvious in the following sections – gives a detailed description of an actual specific and complete system that has been implemented and tested in real world scenarios, in small scale of course, but simultaneously addressing possible issues that could arise; therein lies the contribution of this work in the existing bibliography.

In order to fully exploit the technological advances in information and communication technologies, in the context of the FARMA project, the use of mobile computing, combined with RFID technology and wireless and mobile networking have been adopted. The driving force behind the design of the system was the integration of state of the art mobile devices with a comprehensive data information management system that allows for distributed storage and processing of animal and animal production related data. But apart from the practical goal, directly linked to the provision of a fully functional and possibly commercially exploitable result, the project has investigated the possibility of having animal related, renewable data on the animal (in the form of a rewritable RFID tag). In this way, mobility of data related to the animal (in the sense of an electronic ID and the corresponding identification information) was evaluated and the benefits this could introduce to an animal tracking scheme were identified.

The rest of the paper is organized as follows: in Section 2, the FARMA platform is presented, identifying the subsystems from which it consists of. Each subsystem is explained in details. In Section 3, a practical implementation of the platform is presented. The paper concludes with Section 4, where the results of the evaluation that took place in the context of the project are discussed and future directions towards the use of RFID enable devices in livestock management are given.

2. The FARMA platform

2.1. Data

Through the use of the FARMA platform a large amount of animal related data could be managed. First of all, holding and animals identification parameters can be stored. These parameters can supply all the necessary information about the identity of the holding, as well as the identity of every single animal. In addition, the platform can control animal movement parameters, divided into two categories: ingress and egress activities. Ingress is related to all new animals entering the farm, whereas egress activity characterizes all animals leaving the farm or dying.

Moreover, productive and reproductive data can be stored. The former concern milk, wool and meat production whereas the latter refer to all the information needed to evaluate the reproductive performances of the animals. In addition, data concerning ethology and nutrition are recorded. Finally, animal health parameters, such as controlling infectious diseases, vaccination program and medication can be stored, so as to provide valuable information to the owners and to the vets of the holdings.

Finally, a minimum set of animal identification data that can be used in order to identify the animal and its behavior can be stored on the RFID tag on the animal, provided that rewriting of the tag is possible. In this way, if an animal is found, the information about its identity, the farm where it belongs and some useful data about his behavior towards humans, other animals or premises can be read, thus allowing for proper handling of the animal.

2.2. Platform architecture

The philosophy on which the design and implementation of the FARMA platform is based is graphically depicted in Fig. 1. The scope of the platform lies in the storage and management of information regarding various categories of animals (sheep, cattle, pigs, etc.), using various types of RFID tags (boluses, injectable glass tags, button tags/ear tags) to identify the animals. The entire platform involves various kinds of workstations, such as desktop computers

Fig. 1. The general philosophy of the platform.

(servers, databases), laptops, handheld mobile devices (PDAs, PocketPCs, smartphones, UMPCs), and comprises a number of different subsystems, which interact via multiple kinds of connectivity, i.e. wireless connection, mobile network technologies (2G, 2.5G, 3G), and wired link access.

Fig. 2 shows the three main subsystems that constitute the system:

- The central database.
- The local database.
- The mobile—RFID subsystem.

The central database contains general information about the existing farms, such as owner, address, contact information, kinds of

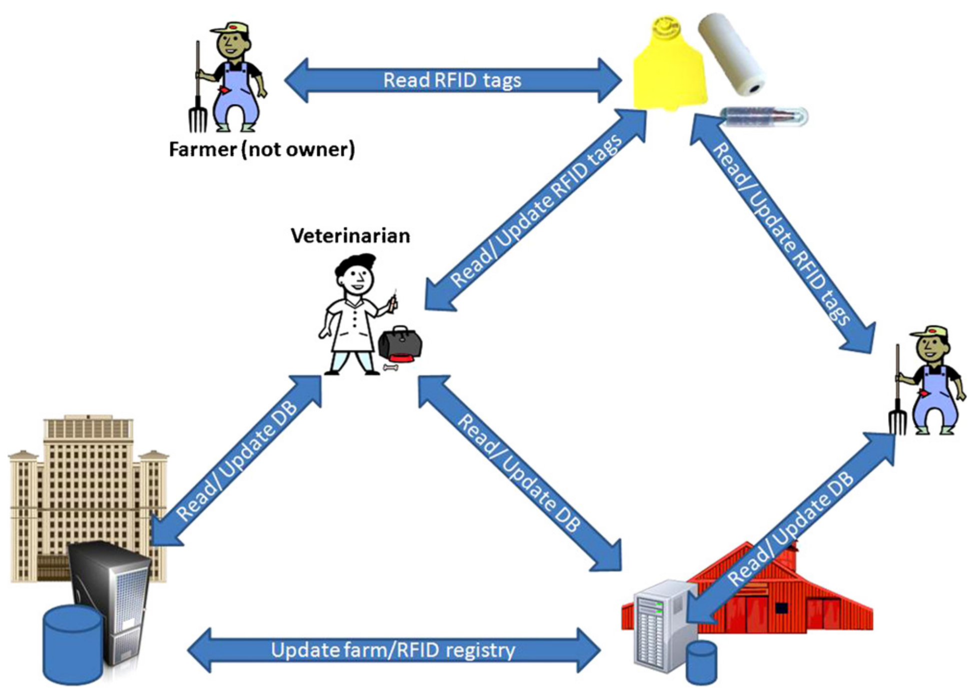

Fig. 2. Subsystems and actors of the platform.

animals bred, and range of RFID identification numbers rendered to each farm for the identification of its animals. The central database also contains general information about veterinarian visits to farms, along with a table of all the accredited veterinarians.

The local database is situated in every farm and stores specific and detailed information about the animals that are bred in that particular farm.

Finally, the mobile—RFID subsystem comprises a mobile device (usually a PDA or UMPC, but could also be a laptop) and a portable RFID reader/writer attached to the mobile device and reads (and in some cases writes) the content of the RFID tags placed on the animals for identification purposes.

Fig. 2 also depicts the "actors" of the system, i.e. veterinarians, farmers, and in exceptional cases (loss of animal) another farmer (not an owner) or third party, as well as their interaction with the subsystems.

In the next three subsections, the three subsystems of the FARMA platform are presented in detail.

2.3. Central database subsystem

The central database system is responsible for storing all information related to the management of animal tracking and monitoring at central level. Since the focus of the presented platform is given on the processes that can be applied at local (farm) level, this subsystem contains only the necessary information for keeping track of the assigned RFIDs, the available farm units and the corresponding registration information. Another reason that the central database system was not designed into details, was the fact that such a system will usually be under the control of state mechanisms, and the information included in the database should follow state or national regulations. For this, only the necessary information for linking to the local database system is described for the central database in the context of this paper, while expanding this information with more data on farms and animal capital does not affect the design of the platform.

Following the above discussion, the central database is in fact a repository of all farms that are registered to the animal RFID tracking system, and therefore, it includes information about the identification of each farm such as type of animals, owner information, RFIDs associated with the farm, and (if available) corresponding veterinarian. Through this information, association of each animal to the corresponding farm and veterinary is possible, without the need for communication with the local database. Furthermore, communication with veterinarians regarding orders for treatment, submission of reports and collection of statistical information is possible.

To support the above, the central database needs to communicate with the local database, in order to assign RFID numbers, and to collect information about changes in the number of animals (births, deaths, transfers). Further collection of information such as data about diseases can be easily supported through the existing interfaces.

2.4. Local database subsystem

The local database system is based on an animal data management application. It includes information regarding the detailed data of a farm unit that relate to the management of livestock. Focus is given on the tracking of animals' welfare through their history data. In detail, the database stores and manages information about the farm units, the stockbreeders, the veterinarians and their visits to the farms. Fig. 3 shows a scheme of the local database. Access to the database is allowed for authorized users, through the use of username and password.

The main functions offered by the database are:

Management of data regarding the farm, such as name of owner, geographical position, number and type of animals, products being traded, etc.

Management of RFIDs assigned to the farm, based on the batch insertion of RFID codes included in an ASCII file received from the central database for animal RFID management. Apart from the insertion of RFIDs assigned to the farm by the central database, the farm database administrator should complete the information about the RFIDs by inserting date and record numbers, as well as activate the RFID codes, so that they are available to be assigned to animals.

Insertion of an animal record to the database, which is the result of the assignment of an RFID tag to the animal. There are three distinct cases here: birth of an animal (in the farm), purchase of an animal already associated with an RFID, and purchase of an animal not associated with an RFID (e.g. from abroad). Whenever data about a new animal are inserted in the database, a complete record including animal type, description, data of birth, date of purchase, ID of the farm from where it was purchased, old animal identification code, data about parents, etc., is formed.

Batch insertion of data regarding a group of animals, usually applied when animals already having an RFID (or even not), are registered in the farm database after a purchase from another farm. In this case, all data related to the originating farm and transport of the animals including date of transfer, number of animals, dates of transfer, name of transporter and identification of transporting equipment are recorded.

Tracking of breeding and parturition information. Here, the breeding and parturition related information is recorded in three different stages: breeding, gestation and parturition. In each of these three stages, the related information such as female and male animal codes, type of breeding (natural, artificial), breeding dates, breeding result, number of newborn animals, etc., is recorded.

Tracking of animal vaccination. Here, all information related to vaccination of animals is recorded. Information includes, apart from animal identification data, vaccine related information, dates of vaccination, and data about the veterinarian in charge of performing them.

Tracking of medication. Here all medical substances given to animals are recorded. Similarly to the vaccination tracking, apart from information about the animals, medication related information as well as information regarding the responsible veterinarian is included in the records.

Tracking of diseases. Here all animal diseases are recorded in an animal health record that includes name of disease, symptoms, related dates and treatment, as well as information about the veterinarian responsible for treating the animal.

Tracking of animals' diet. Here, information about animal nutrition including the type and amount of food is recorded, along with the corresponding time period.

General animal's log. This covers all general data about the animal such as type and quantity of product (e.g. milk), weight of animal per period, castrations, etc.

Removal of an animal from the farm records due to death or transfer to another farm. Here, the reason for removal and the related dates are recorded. In the case of death, the reason of death, and the data of the related veterinarian are recorded. If there is a default veterinarian for the farm, the corresponding data are recorded automatically. In the case of transport to another farm, the information recorded is the same as in the case of insertion of an animal from another farm.

In order to keep the central and the local (farm) databases data synchronized, periodic updates from the farm databases to the central database are performed. During these updates, information regarding the insertion of new animals to the farm and removal of animals (due to death or transfer to another farm) is exchanged.

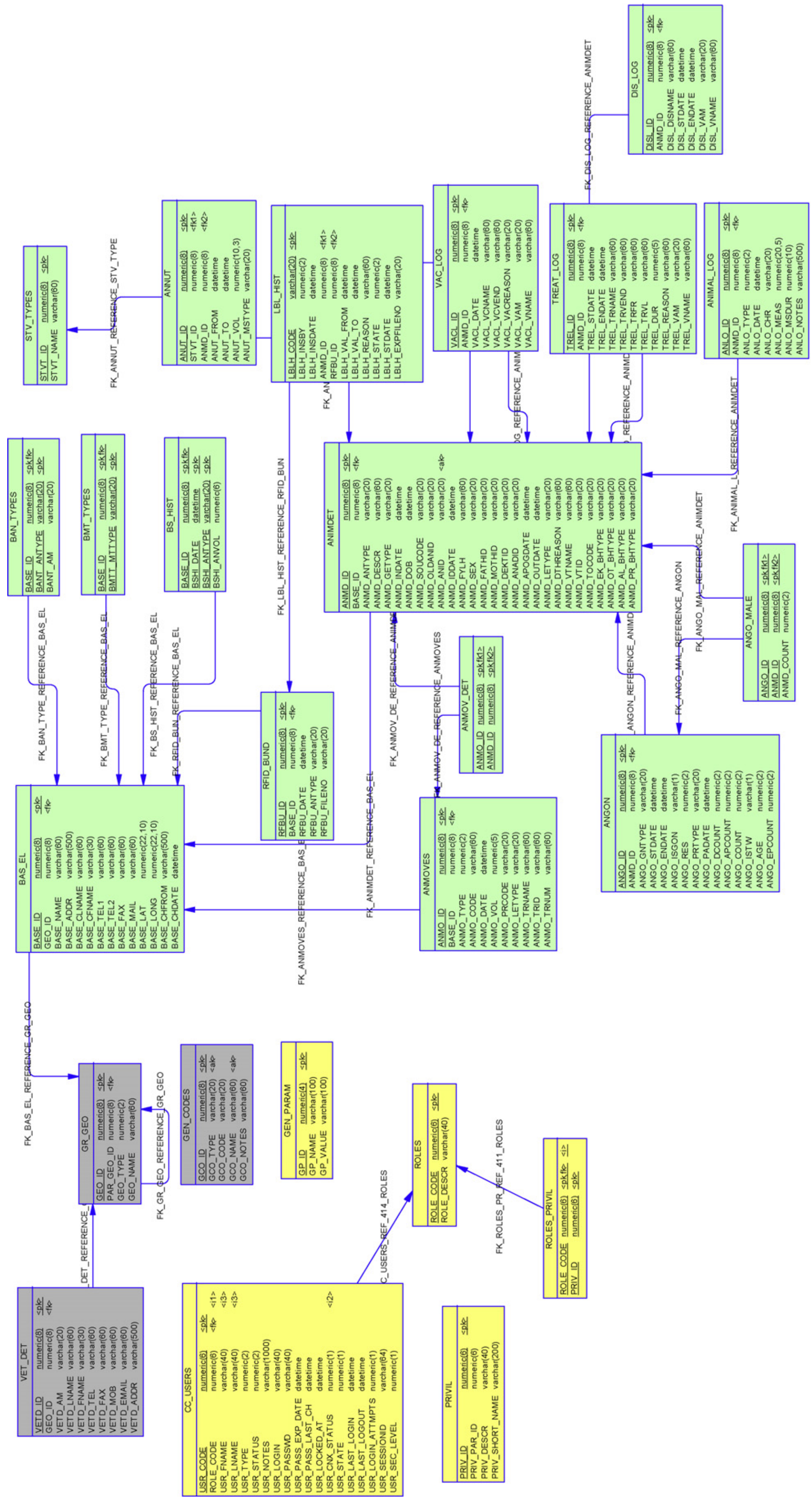

Fig. 3. Local database scheme.

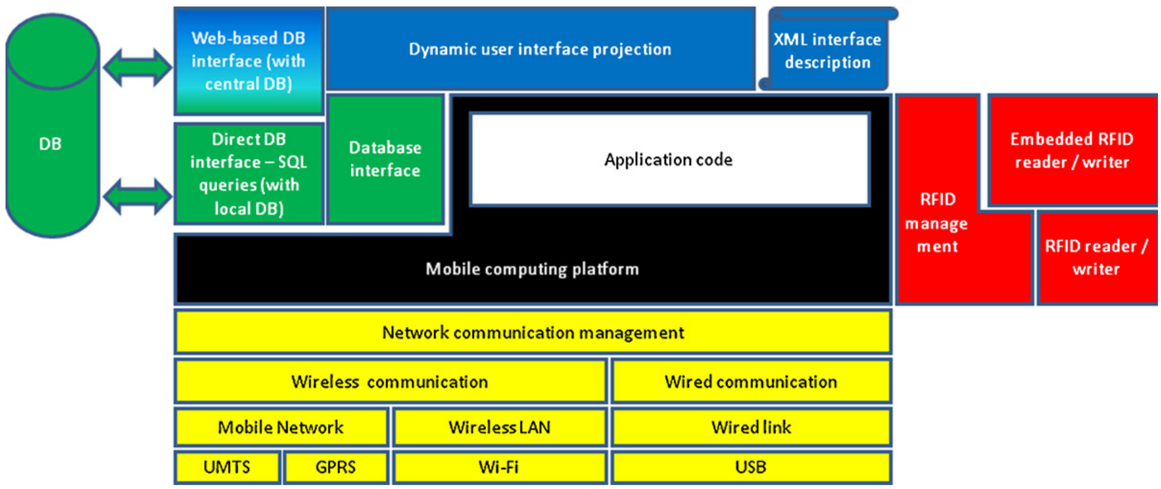

Fig. 4. Architecture of the mobile computing—RFID subsystem.

2.5. *Mobile computing—RFID subsystem*

The mobile computing—RFID subsystem comprises four "interfaces": User Interface, RFID Management, Database Interface, and Network Communication Management. Fig. 4 shows the architecture of the subsystem in a more analytical way.

2.5.1. *User interface*

The user interface part must satisfy two basic requirements: it must allow the input of all information that could be necessary for the complete updating of the local database, but it must also be simple and straightforward enough, so that users unfamiliar with technology and computers, like farmers, can interact with the application. The interface is based in forms, which are filled in by the user (veterinarian or farmer) with the appropriate data and then are sent back to the database, in order either to request the retrieval of information or to update the database. There are two versions of the main menu:

- the veterinarian menu;
- the farmer menu.

Depending on the profile/profession of the user (veterinarian or farmer), the appropriate menu is launched. Each menu includes all the possible actions that a veterinarian or a farmer may perform in the context of the platform. The creation of the forms is based on a dynamic user interface view. In particular, the content of all forms (tags, labels, textfields, etc.) corresponding to veterinarians' or farmers' actions is written down in an XML file. Thus, depending on the performed action, the appropriate form is launched, by using a code segment to parse the XML file. The functionality of the application can therefore be enriched in a simple manner.

The veterinarian menu, apart from allowing the view of the complete animal record, includes the following action categories:

- birth
- newborn animal tagging process
- examination of a female animal before fertilization
- examination of a male animal's reproductive ability
- vaccination
- providing medicines or hormones
- disease diagnosis
- disease outcome
- castration
- death of animal.

The farmer menu also permits viewing the complete animal record and includes the following action categories:

- birth
- newborn animal tagging process
- weaning
- milk production observation
- wool production observation
- animal weighing
- animal nutrition
- ethology observation
- leave from farm (sale, loss, theft).

2.5.2. *RFID management*

The RFID subsystem comprises two parts: the RFID reader and – possibly – writer and the RFID tag (or transponder). The RFID reader/writer is either embedded or attached to the mobile device (PDA, PocketPC), while the RFID tag is placed on the animal. As mentioned in the introduction, there are three main types of RFID tags in terms of shape and animal body parts where they are attached: ruminal boluses, ear tags, and injectable glass tags. In a technological regard, however, RFID tags could be separated into two different categories: rewritable and non-rewritable.

Non-rewritable tags only contain the animal identification number (animal ID). ISO 11784 standard determines the exact way, in which these IDs should be constructed and what information each segment represents (e.g. constructor of tag, country of animal breeding, etc.). Reading this ID results in the unique identification of each animal.

Rewritable tags, on the other hand, can be written upon. In the proposed platform, rewritable tags contain, apart from the ID, some additional basic information about the animal, which may be useful in case of animal loss. If therefore the animal is found by a third party (perhaps another farmer), reading the content of the RFID tag will supply some basic information, which could contribute to tracing the owner and to preventing problems from arising by the animal's temporary stay in a foreign environment. Since the available memory of the tag is limited, though, it is possible to store until merely 16 characters. This fact imposes not only careful selection of the kind of information that will be written in the tag, but also appropriate "encoding" of these data. The proposed segmentation and encoding for each character of the string in the tag is as follows:

The first six characters are further segmented into three groups of two characters each:

- Characters C01–C02 refer to the prefecture, where the farm belongs.
- Characters C03–C04 refer to the county (or sub-prefecture) of the prefecture.
- Characters C05–C06 identify the particular farm among the other farms of the county (sub-prefecture).

The six first characters therefore determine geographically the farm in which the animal is bred.

Characters C07–C10 represent the month and year of birth: MMYY.

Characters C11–C14 refer to the animal's ethology, i.e. the animal's attitude towards the environment. In particular:

- C11 describes the animal's behavior towards the breeders.
- C12 describes the animal's behavior towards the rest of the population.
- C13 describes the animal's behavior towards total strangers.
- C14 describes the animal's behavior towards the farm's premises.

Each one of these characters may take one of the following values:

0: normal behavior,
1: aggressiveness,
2: agitation,
3: indifference,
4: intense interest,
5: curiosity,
6: fear.

2.5.3. Database interface

The database interface can be separated in two different parts, each one corresponding to a type of database and group of relevant processes.

The first is the web-based interface with the central database. This interface is needed for the veterinarians' log-in and authorization processes in the central database. These processes should be implemented before updating the central database with the information about a vet's visit to a particular farm (e.g. "on March 15th, Dr X visited farm #012065 and performed animal vaccination"), or before the vet can retrieve information about his scheduled visits to farms and their locations.

The second and most frequently used database interface of the mobile subsystem is the interface with the local database. It is the interface that via SQL queries deals with the exchange of data between the local database and the mobile device about health condition, nutrition, ethology, etc., and on which the crucial updating process of the local database is based. Building this interface involves using software components for access to data and data services and more specifically to access and modify data stored in relational database systems. Details about these software components and their use are supplied in Section 3 of the paper, where an analytical description of the practical implementation of the entire platform is provided.

2.5.4. Network communication management

Given that the applications offered by the platform require communication with the central and local databases of the system, it is of crucial importance to ensure seamless connectivity and to provide for the cases where network communication is temporarily not available. This requirement leads to the need for various connectivity alternatives, so that in each case the feasible or most appropriate configuration is chosen.

There are two main categories of connectivity:

- wireless connectivity
- wired connectivity.

In the majority of the use cases of the platform, wireless communication is needed. Two types of wireless technologies are supported: wireless LAN and mobile telephone networks.

The existence of a wireless LAN in the farm permits constant connectivity for a large number of simultaneous users. The connection speed can be very satisfactory, as it depends on the speed of the DSL line. The cost of this option is relatively low, but the need for maintenance and possible range issues in farms that cover a vast area constitute drawbacks.

Nevertheless, assuming that all farms are equipped with a wireless hotspot would not be a sensible and realistic hypothesis. Network communication could thus be alternatively achieved through the mobile telephony network. Each user (veterinarian/farmer) must have an appropriate connection with a mobile network operator. Both GPRS (2.5G) and UMTS (3G) technologies are supported. GPRS offers rather low connection speed (56–114 kbps), whereas UMTS allows connecting at until 3.6 Mbps, with the latter being a quite expensive service though. For both of these technologies, the dependence on the mobile network operator signal strength is obvious.

Despite the existence of different alternatives for wireless communication, the temporary lack of availability of all of these wireless alternatives (due to many possible reasons, e.g. weak mobile signal, problematic or non-existent Wi-Fi, etc.) during the deployment of a certain application by a farmer or veterinarian in the farm is always a possibility. For this, the system may function in "off line mode". In this way, any modifications destined for the local database, are temporarily stored in the mobile device, and at a later stage, when the user has network access, for example through a wired connection to his personal computer, he can update the database with the changes accruing from the previous application deployment.

3. A practical implementation

In this section, the details of a practical implementation of the proposed framework are provided. For reasons of support of large number of users, security, credibility, and expandability, a 3-tier architecture model was chosen for the central database subsystem. This architecture allows the separation into presentation tier, logic tier, and data tier, thus contributing to scalability, re-usability, access and data security and manageability. For the needs of the presentation tier, the ASP (Active Server Pages) model was used. ASP technology (ASP Technology Feature Overview) is an ideal environment for web application development. The ASP pages are executed by the web server, which in our case is Microsoft Internet Information Server, therefore constituting the application server of the architecture. Microsoft .NET Framework was used as the programming platform of the ASP pages. Microsoft .NET Framework contains extended libraries, which are required for the development of the web application. Microsoft SQL Server was used for the needs of the data tier, thus being the database server. Access to the central database is permitted only to registered and authorized users, whereas access in different parts of the central database depends on the category of the user (e.g. a veterinarian does not have permission to update data about the existing farms, but can only view related information). Search (among farms, veterinarians, farmers, etc.) can be performed using various criteria.

As far as the local database is concerned, the basic requirements consist mainly in the ease-of-use by persons not familiar with technology, since the local database subsystem is located in every farm. A rich user interface is therefore required. For this subsystem, the client–server architecture was followed, with the client application developed in Microsoft Windows environment and the server being a relational database system. Microsoft SQL Server was used again as the RDBMS, whereas the client application was developed using the PowerBuilder tool.

Regarding the mobile subsystem, the application is based on the Microsoft .NET Framework and written in C# programming language. The mobile devices (PDAs, PocketPCs) run Microsoft Windows Mobile 5 or 6 operating systems. For communication with the local database, the ADO.NET set was used. ADO.NET includes a number of programming interfaces, such as Connection, Command, DataReader, DataTable, DataView, etc., which act as a level of abstraction between the application and the database and allow data managing in a common way, regardless of the specific database implementation.

As for the RFID reader/writer devices, the following three alternatives were available:

- CF (compact flash) card
- SD (secure digital) card
- Embedded in a mobile device.

Each one of these solutions has both advantages and drawbacks. Since an SD card LF reader was still not available in the market at the time of the platform's implementation, only the other two solutions were adopted. Nevertheless, as soon as this type of RFID reader/writer is released, incorporating it to the platform will be a very simple process, since the platform is designed so that it can support many different configurations.

4. Field trials

The field trials took place in a small ruminants' farm of the county of Attica, where livestock comprises sheep and goats. In detail, concerning sheep, tags were applied at 3 ewes, 1 ram and 5 lambs. Taking into consideration the caprine population, 5 female goats, 2 male goats and 2 kids were tagged, respectively. It was decided to place the RFID tags in two different species, where both groups consisted of animals of different sex and age, so as to have a preliminary evaluation of the system's performance under actual, everyday conditions. The aim of the trial was the evaluation of the everyday use and effectiveness of these RFID tags, in the context of the entire system.

These field trials took place in the winter of 2007 and the experiment lasted 1 month. Since the RFID ear tags were selected, it was decided that summer should be avoided for their application, as it is not the period of choice even for the compatible ear tags, due to problems that may follow, such as auricle infections.

During the experimental period, serious problems were not detected. Animals responded well to the tags' application and no effect on the animals' welfare was observed. Moreover, animal's health status was not affected by the devices and common problems that usually follow ear tag application were avoided.

Over the period of 1 month, data from the farm were collected and stored. The owner of the holding was able to follow every step of the field trials, being able to understand the procedure. This system was especially intriguing for the owner, as it was easily understood that it can replace handwritten records, with electronic ones, able to maintain a larger amount of valuable information for the animals. Furthermore it was realized that the RFID reader/writer devices were easy to cope with and in some cases facilitated the acquisition of the data, compared to the compatible ear tags. Moreover, during the field trial a vet was present, configuring welfare and health status of the animals. The veterinarian was kept informed with every step of the system's implication and was able to comprehend easily details about data's recording, showing a fairly positive reaction.

5. Evaluation and future work

The platform described in this paper, based on the corresponding implementation of Section 3, has been evaluated in the context of field trials. The rationale behind the evaluation was the assessing of different methods of RFID tagging in relation to the use of mobile devices and the performance of mobile devices in (rural) environments.

As regards the use of the different types of tags, the selection of the ear tags seems to be the most appropriate since it can be used in all types of animals (sheep, goat, cattle), in contrast to the boluses, that are best suited for cattle. Furthermore, since there is the need for low consumption of the reader/writer device, the use of ear tags is again better than that of boluses, since the reading/writing distance is significantly smaller, while the tag is visible. The use of injectable glass tags, though it has the same advantages as the ear tag, is best suited for pets.

As regards the use of communication technologies, through the evaluation tests of the project, different scenarios have been tested in order to test the conditions for network access availability in rural areas. In details, access through Wireless LAN technology and IP connections over mobile networks (i.e. GPRS) was tested. The availability of a wireless LAN can be only assumed in areas near the farm, and provided that the farm already has the required infrastructure. This can only be assumed for organized farms, while still the overhead of management of this networking infrastructure is intimidating for many farmers. Therefore, as regards the use of on line connectivity to the local database, the deployment of IP over mobile networks is the most probable solution. The tests performed over such connections have resulted to encouraging results, since connectivity was high, while the data volume exchanged with the server was not high. This was due to the use of direct database access through SQL queries, which had to transfer only a small amount of data for each animal. However, the issue of cost and possible unavailability of mobile network coverage in some areas has indicated that an alternative solution should be followed. This has been through the provision of a mechanism for bulk downloading and uploading of information to the local database. This data exchange could be performed even by direct wire connection (e.g. through USB interface) of the mobile device to a terminal or the database server. Use of files that are synchronized through standard applications such as Microsoft ActiveSync has produced good results. Therefore it may be considered as the solution for rural environments, where wireless connection is not supported by any means.

Furthermore, the lack of support for solutions that are compatible with standard mobile devices has been a problem. The available solutions for enhancing the capabilities of mobile devices with RFID reading capabilities are not meeting the need for both sophisticated devices supporting both wireless and mobile access, together with the need for a low power, versatile connection interface such as SD. On the contrary, available solutions include custom, factory made equipment that though it can support the needs of the specific platform, is based on equipment that is impossible to be used for other purposed such as voice communication. This is expected to change as RFID technology penetration increases.

Finally, though the ISO 11784 and 11785 international standards have been agreed as regards the regulation of radio frequency identification of animals, there are still only a few reading and writing devices that are compliant to the standards, while most of them are based on factory built compact devices.

In conclusion, this paper proposes a very specific, detailed – yet simple to implement – system, which tracks animals from their birth until their slaughter, monitoring every single parameter or element that could be of interest: nutrition, health history, behavior, milk/wool production, specific whereabouts, potentially non-ordinary situations such as theft, loss, etc. One of the core advantages of the proposed system lies in its scalability: distributing the data in one or few central database and many local databases permits the elimination of redundant or duplicate data and guarantees speed, security, reliability and efficiency of the proposed system. An additional feature of the system that adds to its novelty is the encoded information stored on the rewritable RFID tag: in cases of an animal being lost, essential information (more than the owner's address and contact information, e.g. ethology/behavior or other) can be directly retrieved on the spot by an RFID reader.

It seems that it is still too early to determine if such solutions will finally prevail or competing technologies, such as near field communication which have already started to find their way into mobile devices, will jump into the game. In any case, the platform that has been presented in this paper can be deployed, even if different identification technologies are used, since the database and the mobile device platforms will remain the same, with the substitution of the corresponding medium access layer.

Finally, the enhancement of the platform with location tracing information through the use of GPS modules (already inherently available in some mobile devices) can provide the platform with extended capability for animal tracing and the support for advanced use case scenarios: muster roll of animals in a farm, or enhanced vaccination scenarios with direct reporting about the time, place and vaccinations from the veterinarian with direct communication with a central database system are among these. The research group that has implemented the platform is investigating these scenarios in a future enhancement.

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