A Sensor Based Management and Monitoring System for the Identification of Lambs Focusing on Milk Productivity Upturns

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Abstract. This paper presents a new system architecture and test bed application implementation called Sheep Manager. Sheep Manager system uses NFC technology for the identification of sheep inside a flock as well as sensors for the real-time measurements and recording of raw milk extraction per ewe. All recorded information are then stored into the cloud. Authors also propose an algorithm for sheep breed selection that uses feedback information from past successful breeds in order to increase milk productivity.

Keywords: sheep management system, breed selection algorithm, sensor based system, NFC technology.

1 Introduction

The demand for animal traceability and identification follows a continuously increasing curve. Nowadays tools that provide identification capabilities in combination with animal attributes traceability that characterize each animal in a flock are a necessity. Such necessity for livestock identification on the sheep industry, may assist for the prevention of certain forms of transmissible spongiform encephalopathy or other disease forms, increase the quantity and quality of products such as milk, cheese or wheat and assure low cost but of a high standard nutritional food for the stock.

From the consumer's part, animal traceability is a very important aspect. Traceability nowadays does not cover only the ability to trace the product back to its producer or production date or present information regarding products' ingredients as a result of chemical analysis. On the contrary, attributes regarding sheep's nutritional

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habits, environmental growth conditions, herd grazing time, or other metrics regarding flock hygiene are also of importance and need to be traced.

From a technological point of view, RFID technology is set to be the key player for animal identification in livestock. RFID technology shows advantages over previous technologies such as barcodes or QR-codes. RFIDs do not require direct line of sight and are not easily tore or worn. RFID tags have longer reading range. There are tags that have writing capability (with the use of specific recording device up to 4KB in passive and 1MB in active tags). Furthermore, there are RFID sensor tags (active or semi-passive energy harvesting tags) that include sensors and may transfer measurements of temperature, humidity, vibration, luminosity etc. up to 100 meters away (Ruiz-Garcia and Lunadei , 2011), (Hammer et al., 2015).

Regarding feeding technologies and nutritional habits of ewes in the Mediterranean environment for the purpose of improving milk quantity and quality, sensors and sensor networks can play a very important role. Sensors may affect animals' nutritional habits and increase milk quantitative and qualitative characteristics. Sensors that monitor confined lactating ewes' environmental conditions may lead to the reduction of ewes' heat stress. Sensors that monitor and coordinate irrigation of grazing fields, especially in summer seasons also affect positively ewes' nutrition. Moreover, since feeding value of crop residues especially in summer is often low, a sensor based system that coordinates mixing of forage or other forms of nutritional additives in silos increases milk productivity and qualitative characteristics (Sitzia et al., 2015), (Gaja et al., 2005).

Finally, passive injectable RFID transponders are used instead of ear tag based ones or neck lace placed ones. Injectable identification transponders is a far better technique in terms of safe-placement and accuracy (Gaja et al., 2005), (Collin et al., 2002),but still receives susceptibility from producers and requires further research and validation (Collin et al., 2002). In extent, RF energy harvesting techniques are nowadays investigated for powering up passive injectable RFID transponders with incorporated RF power up sensors.

In this paper authors present an architecture and implementation of a sheep identification and sensor management system called Sheep Manager. Sheep Manager uses NFC close contact RFID technology for the identification of sheep and flow sensors installed in the milking machine for the recording of ewe milk production. Identification information of ewes' daily milk production as well as per ewe nutritional daily habits is recorded to an Information system set as the cloud. Sheep manager system comes with an android Sheep Client application and a breeding algorithm that selects the appropriate sheep to breed based on productivity trends and incest avoidance.

2 Cloud and NFC Technologies Used by the Architecture

RFID is the technology used for identifying items using radio waves. At a minimum, an RFID system includes a tag, a reader, and an antenna. The reader sends a request to the tag via the antenna, and the tag replies with its unique stored information. RFID tags are either active or passive and use either: 1. Low

Frequencies (LF) 125 -134 kHz, 2. High Frequencies (HF) 13.56MHz, 3. Ultra High Frequencies (UHF) 433, 856-960MHz and 4. Microwave Frequencies 2.4-3.1 GHz for request reply data transmission (Ruiz-Garcia and Lunadei, 2011), (Voulodimos et al., 2010), (Hammer et al., 2015). RFIDs can cover distances from 10cm to 300m for UHF and microwave frequencies and from 10cm to 1m for MF and LF frequencies (Ali et al., 2014), (Ruiz-Garcia and Lunadei, 2011).

2.1 NFC Identification Technology Used

NFC is a close contact RFID technology that operates at 13.56 MHz. It uses ISO/IEC 14443 standard for contact-less smart cards operating in close proximity (~10cm) with a reader antenna, an extension of High Frequency (HF) RFID standards. NFC therefore shares many similar physical properties with RFID such as one way communication and the ability to communicate without a direct or clear line of sight.

There are however four key differences between RFIDs and NFC technologies (Ali et al. , 2014): 1. NFC is capable of two way communication and can therefore be used for more complex interactions such as card read-write operations performed from the same device and peer-to-peer (P2P) sharing, 2. NFC devices are limited to communication at close proximity, 3. Only a single NFC tag can be scanned at one time of interaction while RFID enforces simultaneous scanning and 4. NFC transponders are now included in a majority of mobile phones and this is perhaps the most important difference between NFC and RFID. Table 1 presents the major differences of both technologies.

Table 1. Comparison of NFC and RFID technologies.

Characteristic	RFID technology-passive	NFC technology
Operating Frequency:	LF/HF/UHF	HF:13.56MHz
Communication:	One way (One device for read another for write)	Two way-(RW operations simultaneously)
Standards:	ISO 14443, 15693, 18000	ISO 14443
Scan Tags Simultaneously:	Yes	No. – Faster scanning time
Incorporated into mobile phone:	No	Yes for contactless transactions

Concluding, based on NFC characteristics, it is obvious that NFC technology can perform similar to RFID (with the exception of close contact) and provide vast portability, easy to program and easy to use capabilities.

2.2 Collection of Livestock Data

Collection of livestock sensor data or NFC identification is performed by a simple HTTP POST operation of a session upload protocol following the Representational State Transfer (REST) architecture (Richardson and Ruby, 2007). That is, clients send HTTP requests to an open service to the Information system application server and the application service stores the request data to the database using prepared SQL statements (transactions). The format that the data are being transmitted follows the (REST) architecture for session protocols (Richardson and Ruby, 2007).

REST session protocols are a simple way to organize interactions between independent systems. REST allows you to interact with minimal overhead with mobile phone clients and other websites. REST uses JSON (JavaScript Object notation) and POST/GET HTTP requests for data transmission. In theory, REST is not tied to the web and can be used wherever HTTP protocol is used.

The alternatives of REST are complex implementations. That is, conventions on top of HTTP with the form of a XML-based language notation. The most illustrious example is SOAP. SOAP provides session level complexity with protocol conversion mechanisms (XML encode- XML parse, service requirements and processing capabilities), and thus not using HTTP to its fullest power. Because REST has been inspired by HTTP and plays to its strengths, it is the best and simplest way to transmit HTTP data in terms of `variable=value`.

3 Proposed System Architecture

Authors propose a system called Sheep Manager for the identification and recording of sheep productivity and characteristics. The proposed system uses NFC tags and NFC capable mobile phones for the performance of read-write operations on tags. Authors also propose a breeding selection mechanism that is included in the system. All system information along with nutritional data and sheep attitude characteristics are send into the *cloud*. That is, an application server equipped with a MySQL database that records productivity and animal profile information.

3.1 The Sheep Manager System

The sheep manager system architecture is presented at Fig. 1 and includes the following structural parts:

S1: The Application server where the owner of each stockyard authenticates himself with the Information system application service in order to gain access to its private database, where recording of information regarding his herd takes place.

S2: The main sheep yard of a closed establishment, where sheep milk gets extracted with the use of an electrical milking machine (Fig. 1 rectangular dashed line area), with coral or pen extensions where ewes wait for their milking process. This area is equipped with Internet connectivity via appropriate DSL router and Wi-Fi coverage (Wi-Fi access point-ADSL router). In the same area resides the modified milking machine and sheep owner's mobile phone with the Sheep Manager NFC client application. All sheep are equipped with their own NFC tags, previously initialized with a unique id and places behind their ear.

The sheep owner has the ability to:

- Write a new tag with a new ID and add it to a newborn ship.
- Update information regarding sheep's gender, mother ID, father ID, mood or characteristics or nutritional habits and upload such information to the tag (sheep's profile information) and therefore to the application server.
- Perform an ID read and collect sheep's profile information by placing his phone in close proximity to the sheep's ear.
- Perform a breed search between an ewe and a ram by placing his phone in close proximity of both sheep ears and ask the application server to check if such breeding is permissible.
- Capture and upload data of milk extracted per sheep in liters (lt) with the use of two sensors located into the milking machine.

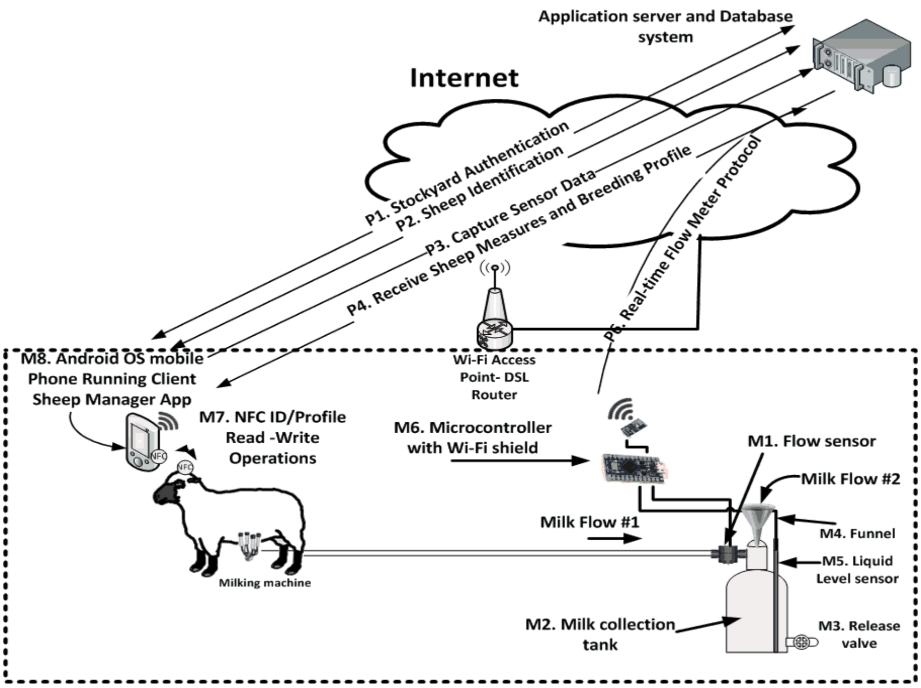

Fig. 1. Sheep Manager system high-level architecture. Figure shows the ewes' permanent closed yard where the milk is extracted and information between sensors and Application server is exchanged via the Sheep-Manager Application

The modified milking machine includes two sensors (see Fig. 1, Milk Flow #1 and #2): A flow sensor M1, located at the milking machine hose and a liquid level sensor M5, located inside the milk collection bottle of the machine. Both sensors are controlled by a microcontroller equipped with a Wi-Fi shield, in order to connect via the access point to the application server and upload its measurements. Measurements upload from microcontroller to the application server, are performed upon request from the Sheep Manager client application (mobile phone of the sheep owner) upon request and the collected data of milk quantity (in liters) is stored and accumulated to the daily record of the sheep that was last identified by the owner's mobile phone. That is, daily total milk quantity sums are stored automatically by the application server at the end of each day and statistical means of productivity are updated.

The use of two sensors instead of one in the milking machine for the calculation of milk extraction per sheep is for calibration purposes of the flow sensor M1, since milk's density and viscosity changes from sheep to sheep area to area and time of year and milking pumps of machines have different flow rates and technical specifications (flow sensor is a cheap sensor to use but requires frequent calibration).

In case of multiple milking machines, one flow sensor can be installed to only one machine for other machines to calibrate. Finally, if the milking machine's pump is out of order and the milking process needs to be performed by hand, the measurement of produced milk is not lost. The milkman can pour the milk with the use of a funnel from the top of the collection bottle and measure its quantity without the use of the flow sensor.

Furthermore, all milk quantity measurements are performed in a differential real-time manner: That is, *time 0,* is the time where an ewe is NFC identified. The milk in the bottle at that time is considered as milk of 0 liters for that animal. When the milking process of that animal is finished and another animal enters the milking area and identifies itself with the NFC tag, then this is considered as *time 1* for the previously identified sheep. The (*time 1– time 0)* milk quantity is considered to be the extracted milk quantity in liters of the previous sheep, as uploaded to the application server.

Authors' proposed system architecture is close to the FARMA platform proposed at (Voulodimos et al., 2010). The main differences between FARMA and authors' implementation follow:

1. Our architecture utilizes NFC instead of RFID technology for the sheep identification process. In fact our solution is portable to any Android mobile phone NFC capable, while FARMA solution requires an RDIF reader-writer embedded into a mobile device usually a small notebook or PC.
2. Our architecture uses sensors to transmit data (milk quantity extracted per sheep and may include other sensors) and focuses only to sheep industry.
3. Our architecture uses different implementation technologies. While FARMA utilizes C# for its client application and protocol and SQL database server and IIS-ASP for its Application services, our implementation uses Android Java for the client, a REST HTTP mechanism instead of an XML data transmission mechanism for data collection and PHP-MySQL-Apache for the database and Information system application services.

3.2 Proposed Breeding Algorithm

Authors proposed breeding algorithm uses two independent processes:

Process 1: The **pure breed selection algorithm**, where a check for breed is performed up to the depth of k generations set be the milk owner (default value of k is set empirically to 7 generations). If there is a common ancestor between an ewe and a ram for a depth of k then the breeding process is denied as a degenerated one and appropriate alert message is displayed into the Sheep client application. If no common ancestors found then process 2 takes place.

Process 2: In this process the average yearly milk production by that ewe is compared to that of the herd. That is, a percentage threshold set by the farm owner of the milk quantity of the ewe that produced the maximum average yearly quantities in the herd. If milk quantities of that ewe are bellow threshold then a warning message is displayed to the Sheep client application for actions to be taken (The breed can be performed).

With mID being the potential ewe ID and fID being the potential ram ID in the Information system's database, the **pure breed selection algorithm** operates as follows:

```
Pure_breed_selection_algorithm (mID, fID)
        P = [mID, fID]
        P = sort(P)
        prevP = P
        gen = 0
        common = 0
        while (gen<= k) and (common == 0)
                tempP = ∅
                foreachitem in prevP
                        [item_mID, item_fID] = search(item, database)
                        tempP = tempP∪[item_mID, item_fID]
                end
                tempP = sort(tempP)
                P = merge(P, tempP)
                gen = gen + 1
                prevP = tempP
                if check(P) common = gen
        end
        return common
end
```

where:

- sort is a sorting function (quick sort).
- search is a search function for an item ID in the database (binary search) and returns the item's mother and father IDs (item_mID and item_fID).
- merge is a function merging two sorted arrays.

- check is a function that checks for common ancestor existence. Since P is a sorted array with IDs, a common ancestor will appear as two consecutive same IDs. Thus, check function returns 1 if there are at least two consecutive positions in the P array with the same value, and 0 otherwise.

The algorithm returns the first generation with a common ancestor or 0 (if there is no common ancestor in the last k generations).

4 Testbed Sheep Manager Client Application Implementation

The Sheep Manager Client application is an Android application can be installed into the sheep producer's Android OS mobile phone (Godas and Kontogiannis, 2014). The application authenticates the farm owner into the information system and the system's database where the farm owner records information regarding its livestock. The application's main window and sub-activities are illustrated in the following Fig. 2:

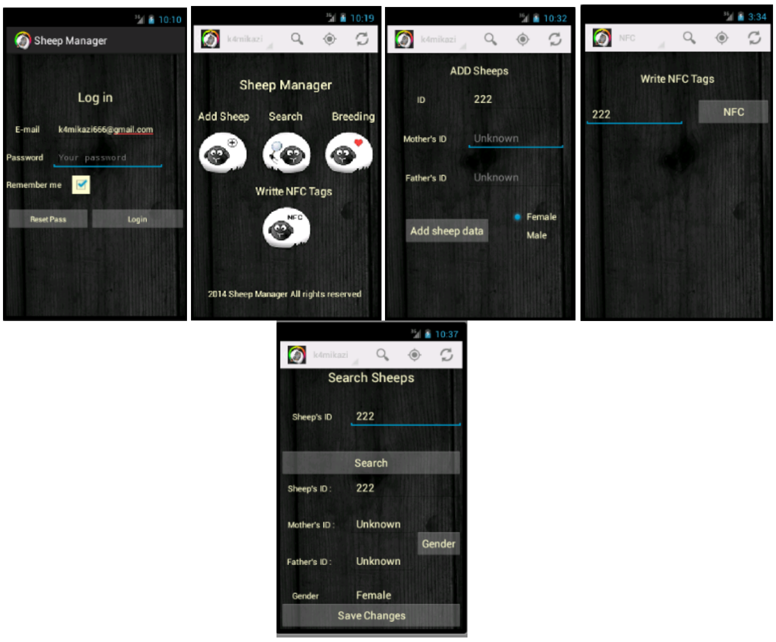

Fig. 2. Sheep Client application Main window and Dialogs-activities: A1. Farmer Application Authentication Window, A2. Main Window, A3. Add sheep Activity then write NFC tag activity and A4. Search sheep activity by hand or by NFC tag touch.

The Sheep Manager application has the following capabilities:

A1. Authenticate to the Sheep Client Application server. The farm owner authenticates himself to the Sheep Manager system service with a username and password via HTTPS protocol in order to acquire access to his flock database.

A2. Sheep Client application Main Activity. This form shows the available application options of adding a sheep to the flock database and searching for a specific sheep. Delete and update operations have not been implemented and can be performed only by the Sheep Manager application and database server administrator.

A3. Add NFC tag and overwrite identification activity. In this activity the farm owner fills out an ID for the NFC tag to be placed to a newly born sheep. He also fills out the sheep's gender as well as its mother's and father's ids. Then by clicking Add sheep data button a Timer instantiates that gives time to the sheep owner to place his phone in touch proximity near the sheep's ear. When the characteristic NFC found sound occurs a new activity called write NFC tag is instantiated and by pressing write the tag is overwritten.

A4. The search Activity has dual operation. That is, read NFC tag ID automatically by placing the mobile phone in close contact to the NFC tag. Then sheep's ID is revealed and searching information regarding the selected sheep from the Information system's database (Mother ID, Father Id and gender) by clicking search button.

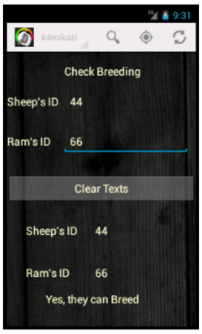

Fig. 3. Sheep Manager application check breed activity form with breed check algorithm

Finally, in the preliminary Sheep Manager application a breed activity form (see Fig. 3) is included, where the breeding search algorithm was incorporated. This preliminary version of breeding algorithm has the ability to search for ewe's sheep ID in comparison to a ram's ID in depth of *k* generation and check whether they can breed or not. Generation search parameter *k* can be set by the sheep owner and by default is initialized to the empirically set by sheep breeders value of seven generations-level search.

The breed selection is set to true only if both sheep ancestors have never breed before in depth of seven generations. This is because from our preliminary studies regarding breeding and milk production seven generations distance between ram and ewe was mentioned by farm owners as a good start point for sheep race breeding in order to avoid incest that affects milk quality.

5 Conclusions

In this paper authors propose a Sheep manager system that uses NFC technology for sheep identification and breed selection purposes, accompanied by suitable proposed breeding algorithm. Sheep management system is also capable for monitoring ewes daily milk productivity, sheep nutritional habits and sheep race-breed and character characteristics for traceability purposes.

Authors implemented their proposed system NFC sheep identification and selection part. This preliminary implementation includes a client application installed into the sheep owner mobile phone in order to perform read-write NFC operations and perform breed requests. Also authors propose a breeding algorithm that is also implemented to the proposed system for the purpose of sheep breeding check and validate.

Authors set as future work the final implementation or their system into a live herd where both milk sensor data as well as nutritional information per sheep shall be recorded automatically to the Sheep manager application service.

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