Design and Develop Cloud-based System for Meat Traceability

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Abstract. Meat traceability provides useful and essential information that consumers have to know, such as race, country of origin, breeding area and methods, way of processing etc. This paper presents the designing and developing of a traceability system, for a pilot meat market, which is based on the cutting-edge information and communication technologies to track the whole meat chain from farm to market. The front-end application is designed using a cross-platform approach and is based on web technologies. It is connected to a cloud server developed for the needs of the system. The application is accessible via desktop PCs and mobile devices that are connected to the cloud server. GS1 Databar labeling is used to track the life cycle from breeding to supermarket shelf. Based on this, an innovative traceability system for meat production is designed and presented.

Keywords: cloud computing; meat traceability; GS1 Databar.

1 Introduction

Traceability is a well-organized process to monitor and to keep a track of an entity along all stages of production and distribution (ISO standard 8402:1994, EC regulation 178/2002 -European Parliament, 2002). The need for traceability is present in all food domains because of food impact on human life, health and wellbeing. The safety and the quality of food particularly in agriculture and meat products are of critical importance. According to Regattieri (Regattieri et al., 2007) a traceability system consists of four distinguished components: *product identification*, *data*, *product routing* in the supply chain and *traceability* tools. Product identification is based on several techniques, such as bar codes, alphanumerical codes or/and RFID. The acquired data are transmitted over the network and stored. However, this procedure generates an enormous amount of data and new technologies and new traceability

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architectures with limitless storage capacity and the ability for parallel processing are needed (Bo and Wang, 2011).

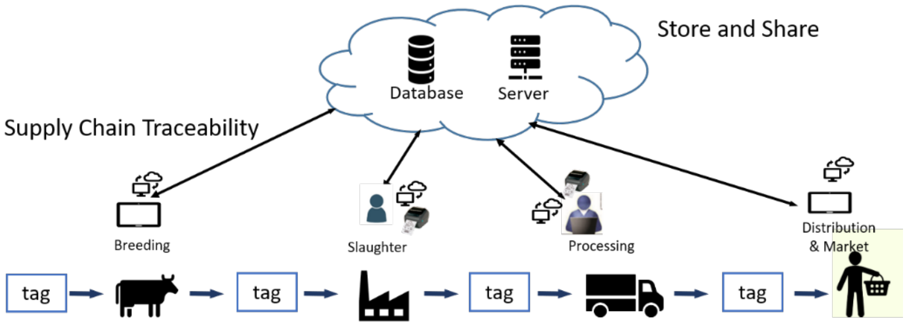

Fig. 1. Summarizing the cloud-based traceability architecture.

This paper aims to present a cattle/beef traceability system for a pilot Greek meat market, that tracks the whole chain of production and distribution of meat from farm to the final product sold on the shelf of the supermarket. The system encompasses mobile devices, desktops computers and cloud-based technology.

The data are stored in the cloud-based server and are transmitted to the users with the use of cloud computing technologies, giving them the option to access the data remotely. Cloud computing is a distributed system that shares resources with users. Thus, it can satisfy the requirements for massive storage resources (Shen et al., 2018), powerful data processing, low response time and accessible cost (Hu et al., 2017). Cloud computing supports real-time interactions, location of services within the internet, and strong computational and storage capabilities (Xu et al., 2015).

We implement an application appropriate for handling traceability data for desktop computers and mobile devices that are used by the users at each step of the traceability chain to capture vital information. It consists of a user-friendly interface application and it is used to capture and send the traceability data to the cloud server.

This paper is organized as follows: Section 2 describes the proposed system architecture and its main components. Section 3 presents the proposed methodology and applied techniques mainly based on web technologies. Conclusions and future work are presented in Section 4.

2 Proposed Traceability Architecture

2.1 System structure

In this work, we present the design and the development of an integrated traceability system for cattle/beef products to monitor and trace the whole process from "farm-to-fork" following users' requirements and EU's Food Law. Our approach is a generally applicable and adaptable traceability solution. A general system architecture is shown in Fig. 1. Based on the Regattieri model (Regattieri et al., 2007) traceability system consists of elements to *capture*, *store* and *process* data while keeping records for the path followed for a product in its life cycle.

At the bottom layer or the data capture layer, are mainly smartphones, mobile devices and alternatively desktop PCs to perform traceability tasks (e.g., store the data and capture the information). Selected information is gathered by the tag of GS1 Barcode. All collected data are directly sent to the above layer, the data store and the share layer, where the cloud is residing. Here, data are stored, processed and shared. Cloud-based traceability allows the identification of entities and tracking of their routes through the supply chain (El Madhoun and Guenane, 2014). Applying cloud computing to traceability data makes the traditional food traceability system "wise" and inherits to it their characteristics, for example, on-demand resource sharing, convenience, ubiquitous, low costs and interoperability (Qi and Tao, 2019). This facilitates the use of the traceability system by various users, expert and non-expert using a common device, the mobile device.

The mobile device is a key component in architecture as it provides users with internet access, barcode scanning capabilities, and positioning technologies (Daurer et al., 2013). Using a mobile device, the system operators make the identification process more quickly, the information acquisition simplest and data transmission faster.

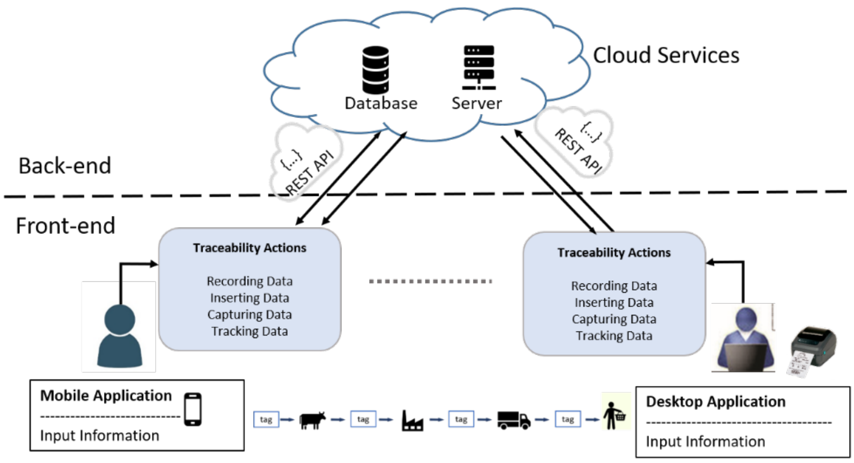

Fig. 2. Summarizing the software architecture of traceability system.

2.2 Functional description

Figure 2 illustrates the software's architecture and interface involved to provide transparency and secure end-to-end communication throughout the product's life cycle. It is ensured that the data flow between a back-end system and a front-end system. The back-end includes the server, the database, and the web facilities while the front-end focuses on the interaction with end-users. End-users or participants of the traceability system have distinct and different roles: farmer, factory employee, administrator and customers. The user interface is between users and the system to keep track or to respond for information and/or queries. Table 1 briefly describes the functional requirements of the traceability system.

Table 1. The workflow and the basic requirements of the traceability system.

Basic steps	Description	Methodology/ Technology
Identification	Unique ID numbers assigned to each animal	GS1 Databar
Information acquisition and transmission	Capture and transmit all the relative data accurately at the right time	Mobile device/ Desktop PC
Information tracking and tracing	Track the information about animal breed, health, feed and trace the whole process of supply chain in which the animal involved.	Recording
Data processing and manage	Data are stored, retrieved and processed in a cloud based database.	Cloud based technologies

The aforementioned solution operates in real-time, provides a low complexity, and high flexibility to the meat company. Using emerging information and communication technology, combined with traceability techniques, the solution provides the company with software implementation, that relies on the cloud, to support its computing needs.

The company's staff will use mobile devices and desktop computers at each location of the food chain in order to update the data of the product. All are synchronized in the cloud system. Every user is allowed only to insert and detect the desirable data according to his authority.

3 Software System Implementation

The software system development is based on a cloud platform and web technologies. According to components functionality, the system is structured on two main modules:

- *Front-end.* The front end consists of different parts: Desktop Application and Mobile Application able to be used by various users and both are developed with the cross-platform approach. Cross-platform applications are "written once and run anywhere". They are based on only one code base supporting multiple platforms while the native applications are developed specifically for a platform.

- *Back-end*: The back-end consists of the main *Server* and *Database*. The Server is using the REpresentational State Transfer (REST) architecture for communication with clients.

3.1 Front – end development

The most essential element of any traceability system is the provision and handling of captured data. In that implementation, data is getting gathered with Angular Reactive Forms. This type of form is being selected because it allows implementing more complex logic than the simple template-driven forms. The data is transferred through the REST API to the database. The forms are designed concerning the ease of use from the employee's side. Common design patterns have been implemented, so the transition from the mobile device (tablet) to desktop doesn't affect the usability. Furthermore, the interactive elements (e.g. buttons) for the tablet application, are big enough, assuming that the employees wear gloves throughout their shift.

The implementation provides an *authorization form*, which allows the users of the system (e.g., farmer, administrator, employee) to interact with the system in a real-time environment. Any employee with access to the system has some unique credentials that have been created by the administrator. Figure 3 shows the home page of the application. When a user enters the credentials -if are valid- the system checks its role and according to his role, gains access for specific tasks (e.g. access particular forms). The user-farmer, at the farm level, has access only at the farm level forms, the user-employee has access at the factory level and the administrator (super user) has access to both levels. Figures 4-6 shows users' forms.

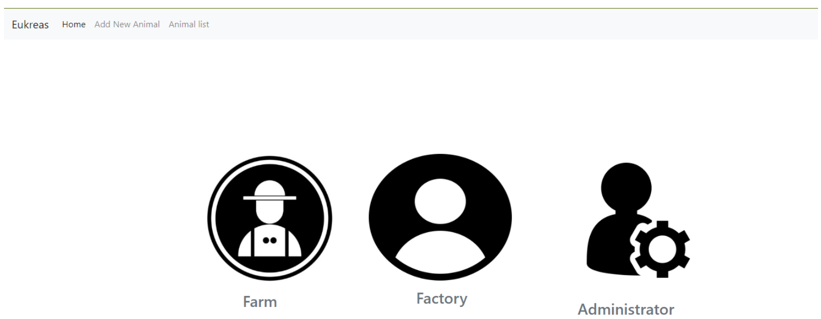

Fig. 3. The home page of desktop application.

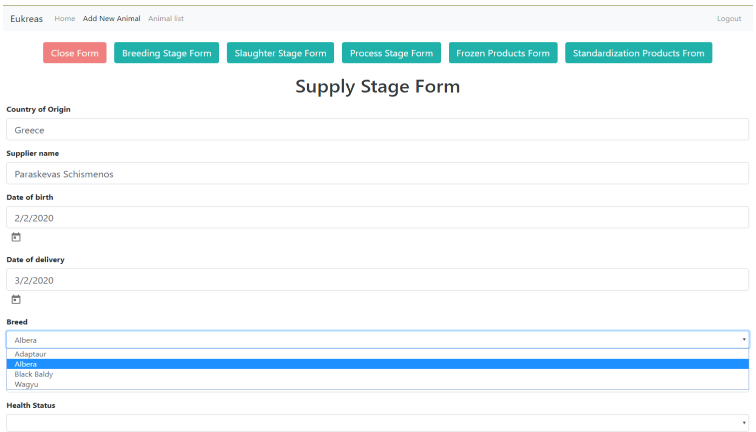

Fig. 4. Supply Stage Form for Desktop

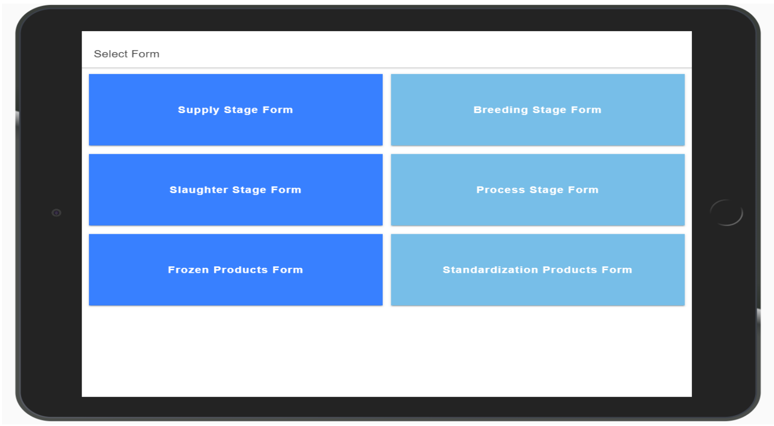

Fig. 5. Form Menu for Mobile Device

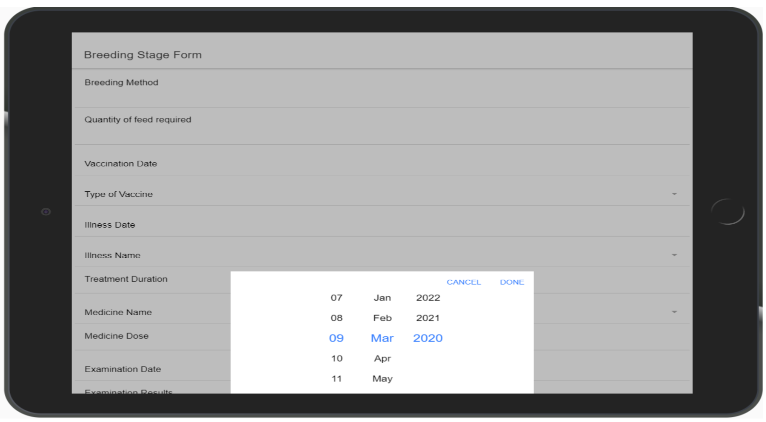

Fig. 6. Breeding Stage Form for Mobile Device

3.1.1 Identification

The most important information for any meat traceability system is the unique identification of the animal throughout its entire product history, the data collection at any products' processing and integrated information management (Yordanov & Angelova, 2006). Each animal or animal product carries its unique id. When the animal reaches the farm, the farmer retrieves all its birth data included in the passport, such as age, origin, and other information. That data is inserted into the traceability system and generates a new unique GS1 Databar, which is the id that will follow the specific animal and its products during the whole traceability process.

3.1.2 The tracking and transmission

The traceability of the animal is getting implemented, by scanning the GS1 Databar that animal has in all the stages of its life-cycle, so the super-user of the system can track and identify where the animal or its byproducts locate. He has access to various forms only to insert new information about the animal.

There are six different forms divided into two main categories as follows (see Fig. 7):

Farm Level: This is the first entry for the animal where the farmer generates a new GS1 Databar and creates a new record in the database with the animal's unique ID. Then, the farmer can add further details or proceed to the next record, by scanning a new animal. The data collection at the farm level is being split into two stages; the supply stage and the breeding stage.

*Supply stage***:** In this stage, the animals enter the farm and the farmer inserts into the system the initial information about the animal, such as country of origin, supplier's name, birthdate, delivery date, breed, weight and health certificates.

Breeding stage: After the animal has been registered in the system, the breeding period starts. This is the period where the farm raises the animals until taking them into the abattoir. Information such as the breeding duration, the food quantity consumed by the animal, the date and types of vaccinations and diseases occurred should be filled -after the advice of the veterinarian- with information about disease name, date, treatment duration, medicine dose and, finally, a health report should be submitted.

Processing Factory Level: After the breeding period, the animals are getting transferred into the factory for the carcass disassembly, cuts, processing, freezing, and standardization process. There are corresponding forms for all these stages.

Abattoir stage: In this stage, the employees scan the GS1 Databar of the carcass to identify it. Further data should be added, such as the weight, the age of the animal at the time of the slaughter, the slaughter date and the location of slaughter.

Process stage: After the abattoir stage, the product enters the process stage, where the information such as process date, meat temperature, type of processed meat, the weight of main meat parts and expiry date should be updated.

Freezing stage: The products are getting transferred in the freezer where the freeze date, the conditions of the freezer and the expiry date is getting added to carcass' information.

Standardization stage: The final stage -before the product reaches the store- is the standardization stage, where the details of the standardization process, standardization date and expiry date are added to the animal's record.

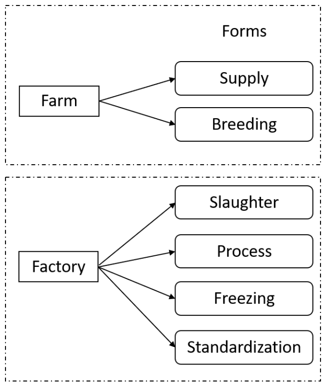

Fig. 7. Front-end: Structure of forms

Any product, as long as they enter the store, carries the barcode which holds the information that is gathered from the company throughout the whole process -from the farm to store. The customers can scan the barcode and have any information about the products that are about to consume.

3.1.3 The data storage

All collected information from forms are transmitted and stored to database of system as mentioned at the next section.

3.2 Back- end development

Server: The REST API server is running in a NodeJS environment using the ExpressJS framework to create several services to handle the incoming requests from the front-end. The services are responsible for the transmission of the data between the database and the front-end. The REST API is an architecture that is used for application integration and for provisioning web services that provide better performance, scalability and low coupling (Feng et al., 2009).

Database*:* The backend is using a NoSQL database to store traceability data. The NoSQL databases are better at handling big data compared to the traditional relational database management systems (RDBMS). Moreover, it has flexible data models, providing the ability to make minor changes to the data that are gathered faster and easier (Jose, B., & Abraham, S., 2017).

4 Conclusion

In this work, we present the architecture and the implementation procedure for designing and implementing a cloud-based traceability system for meat products. The developed architecture employs a cloud computing model, mobile devices, and modern technologies in order to provide a user-friendly and flexible traceability system. We focus on end-users and present how to integrate and interact with various traceability tools. The end-user of the system, in accordance with its role is able to monitor, manage, update information or just access the provided information. The established system provides more safety and quality in meat production and it enhances it with more information and knowledge.

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